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Environmental understanding of agro-based industrial systems and sustainable development

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Abstract: Today agro-based industrial zero emissions systems (AIZES) enjoy significant adoption in many countries around the world and widespread attention from the research community. However, it seems that additional awareness through environmental education of zero emissions system is still necessary in society as much as on waste management, recycling, reuse and modification as well as the vision behind AIZES. In this paper, an overview and closer description of the concepts for finding 'zero emission' are given. Further on, the relation of zero emission systems and sustainable development will be discussed. The paper will also point out the principles of 'zero emissions' emerging in a AIZES. The vision, benefits, challenges, opportunities as well as concept of waste prevention through utilisation of all wastes as process inputs will be reviewed in the paper's sections. Also, what we have learned from case study will be displayed to illustrate the application of the aggregated material in a widespread processing industry.

Keywords: zero emissions system; waste; sustainable development; SD.

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1 Introduction

Much work has been done to categorise approaches of waste management towards the aim of 'no waste' in the production (Kalhammer et al., 2007; Baas, 2007). When considering industrial production processes that serve important social or industrial needs, some work focuses on their synthesis via environmentally friendly synthetic pathways or processes. Other work focuses on developing replacements for the processes capable of achieving the desired performance without negative human or ecological impacts. The concept of zero emission systems has arisen from these ideas in the '90s. It is comprised of the difference that is sharing the common goal of designing new production processes as well as products with safer and less harmful impact in their lifetime. Through this concept the notion of integrated waste management applied to reduce waste at its source, before it even enters the waste stream and has spread. It implies that waste materials generated must be recovered for reuse and recycling. It also envisages all industrial outputs from the process being used as process input materials or converted into value added inputs for other processes, to maximise resource consumptions and to increase eco-efficiency. By employing this production process is reorganised into a closed loop. This industrial metabolism emulates the metabolism of the sustainable cycles found in nature – 'grow-use-waste-reuse'. Basically, waste can be fully matched with the input requirements of any other processes. A perfectly integrated process management produces 'zero emissions', it is an innovative system of sustainable industry development, where reduction, minimisation and utilisation of waste are simultaneously realised.

2 Understanding of zero emissions agro-based industrial systems

2.1 What is AIZES?

Normally the term emissions is associated with vehicles and other combustion based machinery for transport (over land, sea, air, rail) and for other uses (agricultural, mobile power generation, motor, etc.) which contribute heavily to global warming and pollution. There is a definition regarding 'emissions' in the area of vehicle and mobile machinery defined by Michael P. Walsh that 'zero emission refers to an engine, motor or other energy source which emits no waste products pollutes the environment or disrupts the climate' (Kalhammer et al., 2007). It implies that a zero-emissions vehicle produces no emissions or pollution when it is stationary or operating. Emissions of concern in this case include particulates, hydrocarbons, carbon monoxide and various oxides of nitrogen. Although not considered an emission by this definition, carbon dioxide is one of the most important greenhouse gas implicated in global warming scenario.

In the subject of agro-based industrial production processes, there is no formal definition of a zero emission agro-based industrial system, even more than 15 years after the concept of zero emissions was initiated in 1991 by Gunter Pauli. This means that ideally a definition of zero emissions agro-based industrial system seems to be necessary to point out in this paper.

A leading remark regarding 'emissions' themselves was for instance made by Mickael Planasch in the Conference on Environmental Management in 2006:

> "Emissions that pass the defined system boundary in a zero emissions system must neither interfere with ecological nor social requirements."

To define what a zero emissions agro-based industrial system is, we start with a definition of 'zero'. 'Zero' in this case means 'no'. Emissions, in this case, approach to waste in the form of solid waste (municipal, agricultural, hazardous waste), liquid waste (wastewater) and gasses. It also implies 'zero' requires the concentration of every compound in emissions to be below its detection sensitivity limit. So, the meaning of zero emissions is expressed regarding 'no solid waste, no wastewater, no gases to contribute greenhouse gasses, no energy losses'. But in addition waste should be used as input materials in a closed-loop of the production (Figures 1 and 2). In this way, emissions are considered as an unexpected part of the production processes. Emissions can be defined by the formula:

$$\text{Emissions} = \text{Mass in} - \text{Mass out} \tag{1}$$

$$\text{or } \mathrm{E} = \mathrm{M} - \mathrm{P} \tag{2}$$

where E = emissions, M = mass in the process or process input, P = mass out from processes or product of process.

In the equation (2) we can see in the production process mass of inputs and mass of outputs are principally similar. It implies that total input in each sector equals to total output, at that time the formula between input and output is:

$$M_j = \sum_{i=1}^{n} m_{ij} + P_j. \tag{3}$$

The coefficient of direct consumption represents the production quantity of sector *i* which is used in the producing process of another product in sector *j*. Generally, we denote it with m_{ij}. The formula is written:

$$a_{jj} = m_{jj} / M_j. \tag{4}$$

Direct consumption coefficient matrix consists of all direct consumption coefficients, which is noted as:

$$A = (a_{jj})_{mxn}. \tag{5}$$

This factor can be employed in a Leontief matrix. The Leontief inverse coefficient matrix reflects the full demand to produce one unit of the final product, which is also known as full demand coefficient matrix, that is:

$$\bar{B} = (I - A)^{-1} \tag{6}$$

where A is called the technical coefficient matrix, I is the n by n identity matrix, and $(I - A)^{-1}$ is referred to as the Leotief inverse matrix if it exists. The relation between input and output from the perspective of total output is shown as equations (2–3). After defining vector Y which presents the full demand of each sector, we can get vector M which presents the total output of each sector by the following formula:

$$\mathrm{AM} + \mathrm{Y} = \mathrm{M}. \tag{7}$$

The matrix is defined by:

$$\begin{aligned} (1-a_{11})X_1 - a_{12}X_2 - \ldots - a_{1n}X_n &= Y_1 \\ -a_{21}X_1 + (1-a_{22})X_2 - \ldots - a_{2n}X_n &= Y_2 \\ -a_{n1}X_1 - a_{n2}X_2 - \ldots - + (1-a_{mn})X_n &= Y_n \end{aligned} \tag{8}$$

In matrix form, the above equation becomes:

$$(I - A)M = Y \tag{9}$$

or

$$M = (I - A)^{-1}Y \tag{10}$$

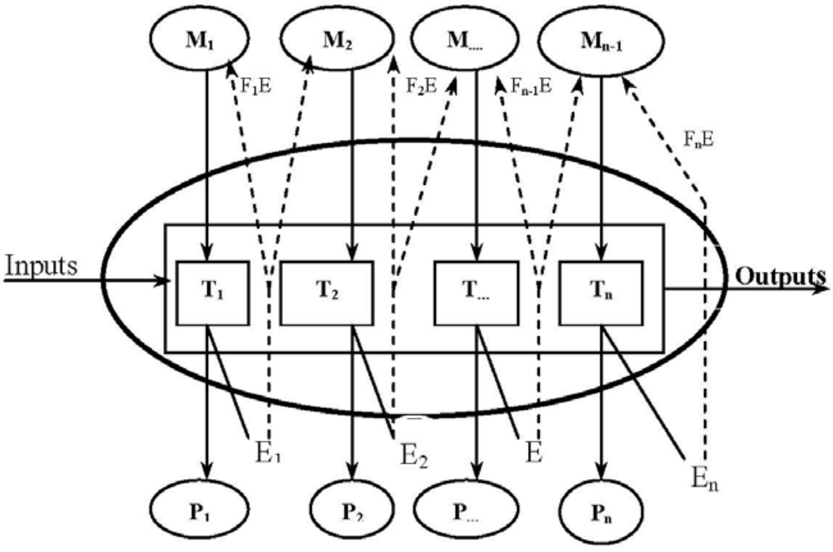
then

$$E = (I - A)^{-1}Y - P \tag{11}$$

When M, mass entering the process, is changed, E as emissions will be changed. If the change of 'Mass in' is big, the emissions will get big as well. Input-output is based on two fundamental assumptions in which the multi input and multi output relation is linear, and the technical coefficient is fixed during the underlying time-period for the data available. If a production approaches zero emissions, E will no longer exist in the production, it is moving into a new process (Figure 1). It illustrates that if emissions will be matched as an input material in the new processes to produce other products, (2–5) can be written as:

$$E_n = E_{n-1} + (I - A)^{-1}Y_n - P_n \tag{12}$$

Figure 1 Material flow in a process approaching AIZES

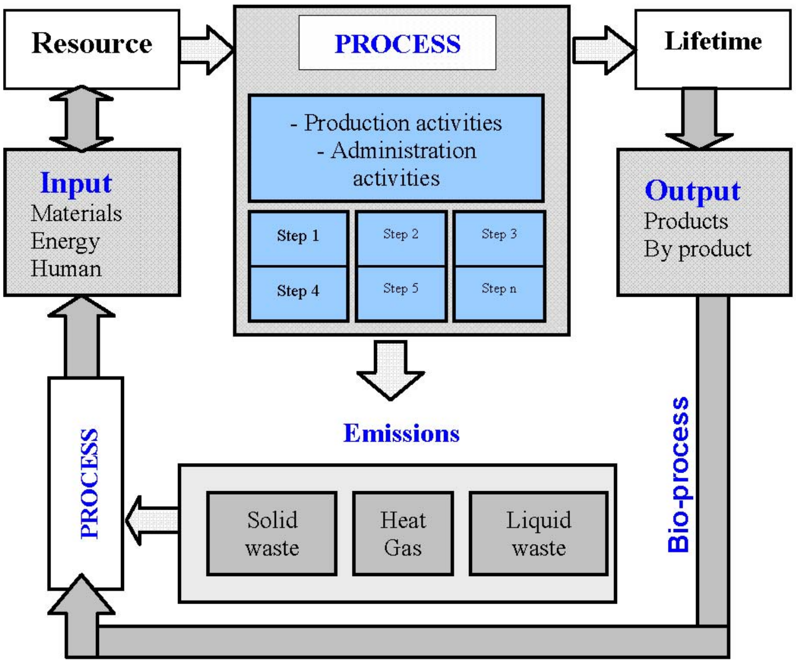


When the input-output analysis is used in assessing the environmental impact of manufacturing processes, the traditional input/output analysis needs to be modified.

We can make a definition of a zero emission agro-based industrial system that:

> "A zero emissions agro-based industrial system is a system in which industry and agriculture corporate to produce the products serving important social or industrial needs but no longer generate harmful emissions to human and the environment".

Figure 2 Production considered for approaching zero emissions systems (see online version for colours)



2.2 A vision of AIZES

From a system viewpoint, the sun provides the energy for the earth, which drives the photosynthesis processes. This processes order atoms and molecules to higher value such as forest and food products. Dead matter is processed by microbes in the soil to become food for the next cycle. It means natural cycles function without producing waste (McDonough and Braungart, 2002). Waste existed in the production process will serve as a resource for other processes. This can be expressed similarly by the equation 'waste or emissions = food'. A AIZES approach is employed when returning residual products as inputs to further processes in industrial closed loop systems. This may involve redesigning both products and processes in order to eliminate hazardous properties that make either of them unusable and unmanageable. Also, all of the input production factors are completely used up. The factors are either utilised in the final products or become high value added raw materials for industries. As the final goal is to have the total input volume equal the total production volume, the ultimate objective is for industries to generate no waste products whatsoever. As well, it contributes to energy conservation through using the waste heat generated during recycling processes to provide heating and hot water, and by producing solid fuel and other energy from the compression and combustion of refuse. Under this concept AIZES also represents an increase in eco-efficiency and elimination of waste as well.

From a theoretical perspective, the elimination of waste in the concept of AIZES displays the ultimate solution to pollution problems that threaten ecosystems at global, national and local levels.

The defined zero emissions agro-based industrial system boundaries can enclose a private company, a cluster of companies or a region certainly. From a holistic point of view, zero emissions technique is not a stand-alone technique. It must be implemented in context of existing environmental techniques and technologies; for instance, cleaner production, eco-efficiency, pollution prevention, upsizing, industrial ecology, design for the environment, green chemistry and integrated bio-systems; and combine the strengths of all waste management methods. This can be found through materials and energy that have to be sourced to a much greater extent from renewable resources or a shift from products to services. This will adapt to the beneficial economic and environmentally traits in ecosystem clusters which advocate the use of waste and convert it into additional products through value added processes. In addition every substance in the production has a detection sensitivity limit which it can not be controlled, although the implementation of zero emission techniques to production processes requires the creation of safe products to limit environmental negative impacts to a minimum.

For business, AIZES can mean greater competitiveness and represents a continuation of its inevitable drive towards efficiency. From a perspective of industrial progress we may conceive that the first productivity of labour and capital in the industrial revolution and today's major shift come the productivity of raw materials – to be producing more from less. Zero emissions can therefore be understood as a new standard of efficiency and integration. Shortly 'zero emissions' is a completely new approach to a sustainable and resource efficient economic development.

AIZES also promotes a shift in society as a whole. It is widely recognised that the production and consumption are tightly intertwined activities. Thus, to truly achieve AIZES it is necessary to consider the larger societal system within which industrial activities take place. Achieving zero emissions at a societal level includes addressing such issues as urban and regional planning, consumption patterns, energy conservation, upstream industrial clustering, reuse and recycling of products and the interactions of these activities with the local industrial production base. Also, AIZES envisages all industrial inputs being used in final products or converted into value-added inputs for other industries or processes. In this way, industries are reorganised into clusters such that industry's wastes or by products are fully matched with the input requirements of another industry, and the integrated whole produces no waste of any kind. This technique should be based on the well-established economic analysis tool known as input/output method. By this way, AIZES strategies consider the entire life-cycle of products, processes and systems in the context of a comprehensive system of interactions with nature and search for efficiencies at all stages. It also offers a chance that waste can be prevented through the designs based on the full life cycle of the product. Instead, waste should, like any residues of processes, be thought of as potential inputs for starting new processes. The opportunities for reduced costs and reduced negative environmental impacts will be possible. Under this way, AIZES strategy does not only lead into a look for efficiencies in the use of materials, energy and human resources, but also achieves a sustainable future, extreme efficiency in the use of all resources and meet the needs of human. Additionally, the strength of AIZES concept is it moves and clusters waste together, and then uses process outputs as inputs. In the process, AIZES offers a bridge between the specific innovations occurring in cleaner production and the attainment of an industrial system supplying human needs within the constraint of global and local carrying capacity. The limited aspect of the application of AIZES is that zero output from a process except for desired products is not possible according to laws of nature.

2.3 Why did we start zero emissions systems?

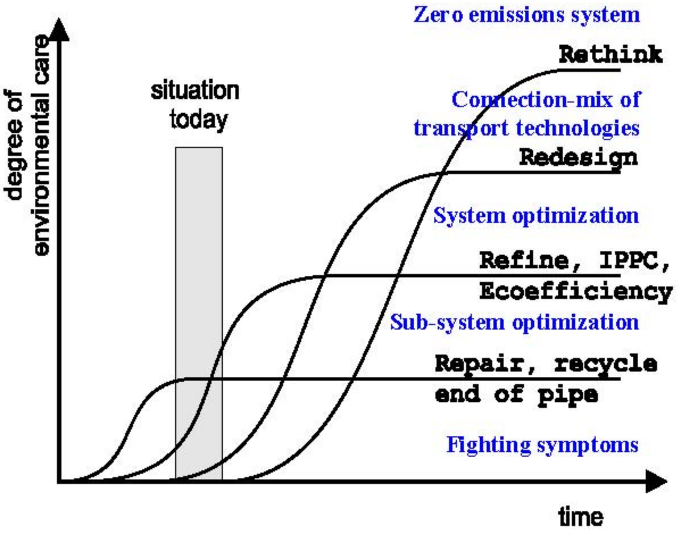
Our worldwide manufacturing, processing industry, distribution and even disposal systems have evolved with impact from laws and common practices over more than 100 years, encouraging the rapid conversion of natural resources into finished products. In the past, a country's land appeared so vast it could absorb any amount of environmental pollution while giving up its wealth endlessly. Today everyone knows this was an illusion; we cannot do this anymore. Suitable waste disposal sites are becoming difficult to find as urban areas expand and industrialisation progresses. This problem is aggravated for countries with an increasing population density. Furthermore environmental pollution has recently been intensified because of the increasing economic and industrial progress in most of the developing countries. Reasons to let us think about the idea of zero emissions systems are because of decrease of resources, increasing greenhouse gases concerning the problems of global warming, reducing the environmental pollution by waste (solid, liquid) and hazardous chemical compounds, using energy and materials efficiently and balance efficiently between production costs and benefits.

We can propose that emissions from the production are inefficient usage of raw materials, energy and capital; harmful to the environment; and result in costs for the treatment of waste generated in the production processes. In recent years, environmental pollution does not only stop at the borders of one country, but also could impact on the environment globally, since the ecosystems of our world are interlinked and connected globally through the climate.

We know that even though our ancestors' dedication to industrial development has spurred tremendous production and technological achievements, continuing this approach to production life cycles can not sustain a healthy, satisfying quality of life for the world's vastly increasing population as we progress in the 21st century. Zero emissions techniques and technologies have emerged as the solutions to minimise environmental pollution and offer a satisfactory progress in the management of our waste. Previous approaches to pollution such as end-of-pipe treatment, waste prevention technologies, pollution prevention techniques and cleaner production technologies, could not solve the problems cited at their original source. More especially, nowadays, the grand challenge facing government, industry and academia, in the relationship of our technological society to the environment, the concept of zero emissions is reinventing the use of materials. The concept has arisen with the notion of responding to the scarcity of resources and human needs, inspired from natural systems, where in the complex interaction of different species no resource is wasted in nature – whatever substance is waste for one species is of value to a different species, similarly in our industrial productions, we should use all waste as process inputs for other processes.

In addition moving our production and the society as a whole in the direction of sustainability must be based on an understanding of the functional principles of the eco-system, meaning for instance the dependency of the different species upon each other, the balance of the ecosphere as a whole and the interaction of our society with it. If a process can operate without waste or emissions, it can be built anywhere in even an ecologically sensitive environment, not to be affected by environmental restrictive regulation and issues and operate at maximum efficiencies. At the side of a private company, possibility to apply zero emissions techniques promises alternative fossil fuel as well as CO_2-free emissions. On the other hand a AIZES is feasible. We are, on the other hand, seeking for possibilities to reduce the emissions as well as to approach the aim of sustainable development (SD), why not a zero emission system?

Figure 3 Mobility towards environmental improvements (see online version for colours)



2.4 Challenge, option and opportunity of AIZES

Most definitions include both objective and subjective elements, AIZES is as well. We believe that this explains the widespread incompleteness and ambiguity that characterise most definitions of alternative industrial systems. An approach that we have found usefully is to define such industrial systems according to their proximity along a spectrum to a set of preferred goals. When the idea of a zero emissions system emerged in 1991, there were some ideas regarding 'zero emissions' to argue it is simply unrealistic because it can be found that no matter how good we get at recycling and reducing our waste, there will always be something left over for which there is no reasonable way of dealing with except disposal. Also, critics argue that a zero emissions industrial system is impossible How expensive it is? So should we set a goal that is more achievable? Certainly, a lot of expectations as well as arguments are placed on zero emissions system. By setting a goal of zero emissions, we have made a decision as a community that waste is not acceptable. Waste must be rejected in a zero emissions system due to its reuse as well as recycling. Additionally, catching technology and society changes will find us new ways of doing things that will get us closer and closer to the goal. Moreover, recycling and resource recovery may create up to 20 times as many jobs compared to landfilling the waste, and the costs for treatment waste are automatically reduced in the production of course. Lastly, with the rationale to research on AIZES done, the opportunity to reach the goal is possible and can be innovative depending on its application.

What is the option? As a community, we look at all the options and decide on the best way to manage our emissions now and in the future. A zero emissions system is one option that is attracting more and more attention related to its advantages, but it is only the best option for a system in which industry and agriculture corporate. From practical viewpoint, business on waste by reuse and recycle is possible in AIZES models. However, adopting a goal of AIZES is setting a realistic goal for waste reduction and giving ourselves a reasonable amount of time to do it. This is a common and sensible approach. It can be included optimal nourishment, optimal individual and social development and sustainability. Nonetheless, the facts that many firms in developing countries have limited technological and organisational capabilities that may cause them to choose end-of-pipe solutions once the environmental challenges appear. This tendency may be reinforced by the biases in the regulations, technology providers, etc., in favour of end-of-pipe technologies. But since developing countries economies, in particular many countries in Asian countries, are widely based on agriculture, significant potential for the implementation of AIZES is given.

2.5 What does a AIZES review basically cover?

A AIZES review can expose hidden weaknesses to be dealt with so that company' business should improve and is better prepared for the future. The period of a review can vary depending upon the size, capacity and complexity of the business. Ideally, the action plan arising from the review should be integrated with the company's strategy, production plans as well as operating plans. Hence the purpose of undertaking such an exercise is to examine a company's operations, inputs and outputs and waste management to identify opportunities for financial and environmental gain through zero emissions prioritised according to their feasibility. The following aspects are central to an AIZES review:

- *Company background*: The information required is company description: its history, size (employees and turnover), working hours, scope of operations and production processes, ownership, products and services, location, competition and industry structure, growth and strategic priorities, improvement history, etc.
- *Production processes, method and technologies*: These show major items which include process control; factory layout and production flows; machinery and equipment; process technologies; materials usage and handling; inward and outward packaging; and significant sanitary conditions (hygiene).
- *Materials input*: Amount, types and toxicity and hazardous characteristics of materials (materials, energy and water) used in the production are considered for economical and environmental beneficial improvements. Besides, waste generated from the production is also considered because of the use of waste as process inputs.
- *Outputs*: The finished products, waste streams, emissions (gasses), by products, rejects, packaging, etc. must be identified and analyzed towards potential process optimisation as well as use and recycle of sources of waste and raw materials.
- *Waste management:* Management of waste involves the official management of waste, technical management of waste (waste treatment), waste handling and water and sewer discharge. A AIZES review usually covers the implementation of waste limit, minimisation and 'zero' generation. All of this considers the levels and costs of reuse, recycling as well as treatment. The suitable waste management method should be found.

- *Housekeeping:* Is a method in consideration of material and waste storage and usage, labelling, inventory, maintenance, scheduling and spill containment. It can be a key element to reduce the waste generated in the production.
- *Environmental permits and compliance:* Compliance issues require attention in production and business. Review of internal reports and past problems should be shown in business progress. The environmental permits or licenses for company's business actually depend on the countries. However this seems being a really not important objective in some countries, particularly in the poor or developing countries, although principally environmental permits or compliance must be allowed.
- *Opportunities for improvement* display all factors considered for product or service redesign, process redesign, raw materials choice, monitoring and control, manufacturing methods, waste creation, process technologies, processing, minimisation and elimination, alternative energy sources, operational procedures, staff training and pollution control. The determination of these factors can be surprised for benign environmental and economic improvements from AIZES.
- *Evaluation of alternatives* is listed in the opportunities to improve profitability and eco-efficiency.
- *Market demands* with environmental management and regulation before.

3 The principles of AIZES

Like the other methods, AIZES should have the principles which approach to a more environmentally benign fashion where industrial clusters imitate nature, eliminate waste and pollution and are more productive than conventional models.

Again, there is no formal principle of AIZES, even the concept of zero emissions initiated more than 15 years ago. We present seven principles of AIZES distilled from a diverse set of practices and emerging research. These can be viewed as imperatives or directives that address alternative input materials, processes improvement, waste management, producing and reusing of renewable energy and materials and production process control. Certainly the application of these principles is flexible and depends on the situation.

3.1 Prevention waste

The first principle of AIZES suggested is 'prevention waste'. This principle shows it is better to prevent waste than to treat or clean up waste after it is formed because environmental pollution prevention by waste is always better than waste treatment. This is due to spending time for waste treatment as well as costs for treatment. In an industrial production process, waste prevention is definitely considered as the first principle in management of material flow. Many researches have shown that regardless of the scale, using benign and safe materials in the production is always going to be beneficial and costs of disposal of solid waste and hazardous materials usually exceed reuse costs per volume. At manufacturing scale, the costs to remain within legal emission levels and the associated costs to monitor and document these levels become quite high, therefore realisation of the first principle: ‘prevention waste’ makes ‘environmentally sensitive sound production industry’.

3.2 Less harmful materials and synthesis

The second principle of AIZES suggested is less harmful materials and synthesis. This principle proposes wherever practicable, synthetic methodologies should be designed to use and generate substances or materials that possess less harmful, hazardous and toxic properties. In addition, the materials, chemicals or compounds should be digestible to avoid creating the persistent pollutions, compounds and materials. Especially, manufacturing and engineering procedures need to ensure the contamination from these processes do not appear in the final product. The products of the production or manufacturing in AIZES are products which should be made by bio-synthesis. Increasing output (products) and decreasing input (raw materials) are encouraged in this principle. Reengineering production processes to minimise waste create the new products or use innovative raw materials which are less toxic and more recyclable should be reached.

3.3 Energy efficiency

Energy requirements recognised for their environmental and economic impacts should be minimised. Normally, physical or chemical reactivity is obviously governed by the laws of thermodynamics, mass and kinetics. Every transformation requires an input of energy to overcome the activation energy of the transition state in the process. Energy inputs can amount to a substantial component of the overall environmental footprint of a transformation. New transformations must be designed to work within more readily accessible energy limits to assure energy efficiency. Or, pollution reduction has been achieved through using of clean technologies and avoiding usage of fossil fuel of course.

3.4 Reuse, recycle and renewable feedstock

Focuses of the fourth principle are reuse, recycle and renewable feedstock. These would ameliorate waste generated in the area which is waste-intensive. A major opportunity in AIZES to reduce the amount of waste generated into the environment is focusing on reuse and recycling. The negative impacts on the environment and the costs for waste treatment will be less; this is due to the application of the principle of reuse as well as recycling. Moreover, raw material should be renewable rather than depleting wherever technically and economically practicable. The chemical industry’s reliance on petroleum should be addressed. The timeline for depletion might be debatable. Nevertheless, long-term sustainable alternatives should be identified. Agricultural-based resources offer an alternative as the isolation and purification technologies improve such as bio-ethanol (bio-fuel), chemicals (lactic acid, amino acid, acid amine, etc.), bio-products (organic products) and degradable products which are extracted or produced from biomass through a natural fermentation process or reaction in bio-catalysts, bio-degradation, photo-synthesis and bio-digestions. Not only are the products made from renewable or agricultural-based resources, they are also capable of being completely recycled or even composted after use. Certainly this principle tends to drive down manufacturing costs and is the elimination of unnecessary intermediate products and finished harmful products.

3.5 Waste-based economy

The fifth principle suggested for AIZES is waste-based economy. This principle is based on a material and energy balance method which should be designed to maximise the incorporation of all materials and energy used in the process into the final product. Under this way, the process should be designed within the framework of making the product at whatever the cost. In addition waste must be used back for a new process to improve the profitability. At process level, output material of the transformation is an actual increase in non-incorporated materials into the final product therefore we must do an accurate calculation of using of waste in the new process. If, for instance an existing reaction provides a 70–80% yield together with the amount of by-products, usage of waste in a new process must be improved by a significantly higher yield and more environmentally responsible.

3.6 Design products to degrade after use

The finished products from a production process towards the aim of sustainability should be designed under a way that at the end of their function they do not persist in the environment. Particularly, their chemical compounds should be broken down into the innocuous degradation products – as a natural rule, the earth's natural environment is full of ecological cycles where the waste of one process becomes a feedstock of another. Before our needs require for durable and stable materials such as plastic materials, however these materials enter a non-degradable cycle. Nowadays, we are dealing with their negative characteristics, e.g., plastic materials in landfill. Most of plastic materials are non-degradable materials regardless if they are landfilled for more than 20 years; the non-degradable ability of plastic materials seems taking very long time. Therefore, we must better understand these cycles and incorporate them into the design of future materials. Design of finished products in AIZES should be focused on the production of materials which has the ability of being broken down innocuously after use. Hence, its accumulation will not longer be able to persist in the environment. The implications for the use of a genetically modified plant should certainly be considered for this.

3.7 Real time analysis for pollution prevention

The requirement of this principle is based on the aspect of real-time analysis. It implies that analytical techniques to prevent pollution must be developed in the real-time because of the relation of dynamic reaction and the inter-influences in the process. Certainly these applied analysis techniques will be different and depend on the type of enterprises such as small-sale, medium-scale or large-scale manufacturing processes. In particular analytical methodologies need to be further developed to allow for real time, in-process monitoring and control prior to the formation of waste and hazardous substances. Also there is a need to improve analytical techniques to consume less material and energy. Quantitative determinations of contaminants and pollutants in the environment are important aspects of analytical techniques certainly.

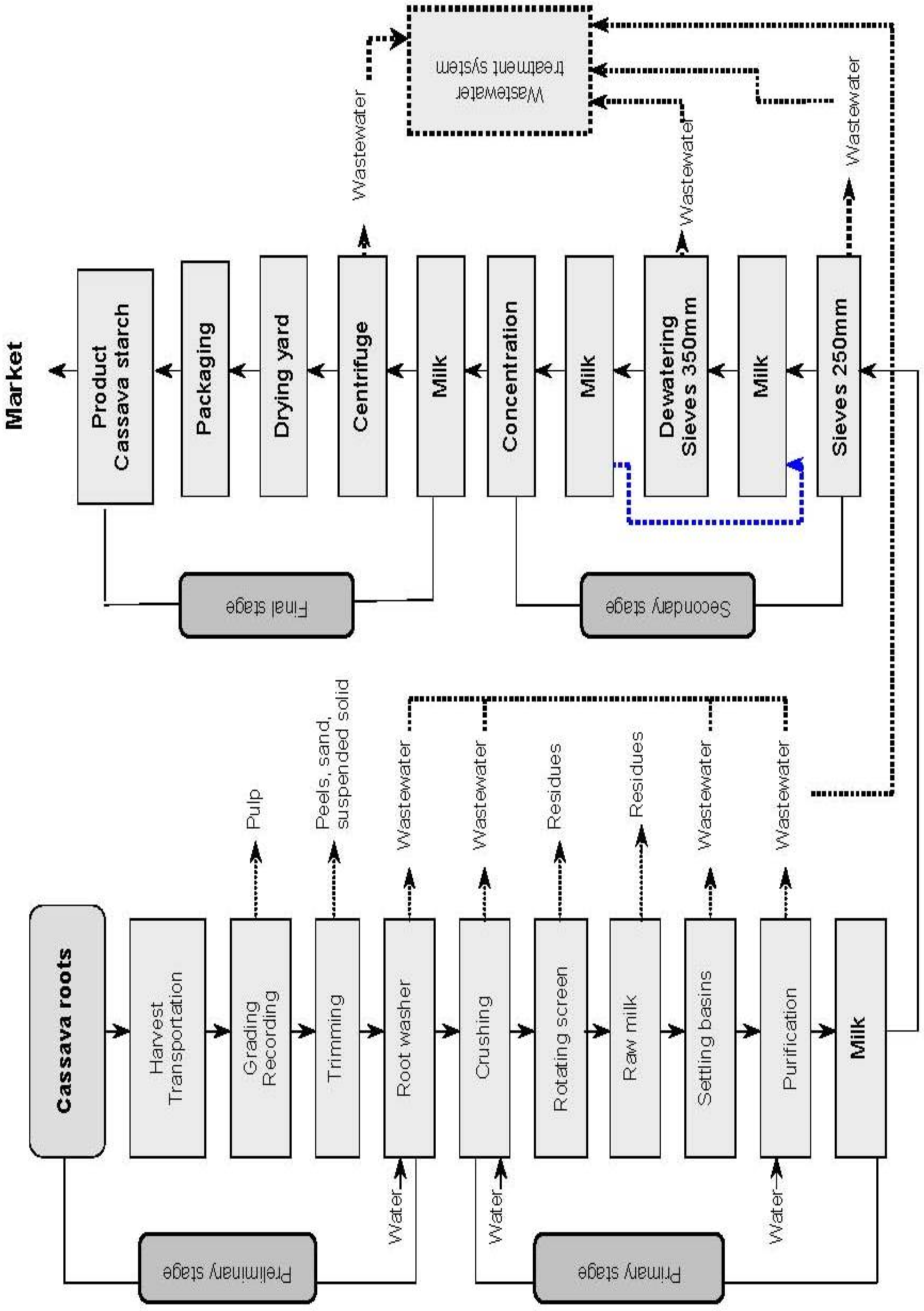
4 Case study on cassava starch industry as a practice for production processes approaching zero emissions

4.1 The description of cassava production processes

Cassava known as Tapioca, Manioc or Juca is one of the tuber crops grown in 90 countries all over the world in the humid tropics. There are many operations during cassava starch production processes. Principally, it is divided into four stages including primary treatment, secondary treatment, dewatering and milling and packing stage. The processes are shown in Figure 4.

- *Preliminary stage – raw material preparation*: Cassava fresh root is harvested after 10–12 months. After harvesting, the root is transported to factories to process. Here, cassava root is loaded for weighing, trimming and peeling. It is also washed then. Cassava root is then crushed in this operation. It is then processed in a rotating screen. The rinsed roots are subsequently grinded before being transferred into an extractor tank. The suspension containing starch and water, called starch milk, is transferred into a first series of settling tanks.
- *Primary treatment stage*: In this stage, separation of cassava needs fine screens and water. The screen is vibrated by eccentric rotation, while water is used to dilute the cassava pulp to make the separation process easily. Fibrous material will be retained on the fine screen, mixed water and tapioca starch. Then the fibrous material will pass the screen and flow to the sedimentation basin. Cassava milk settles out of water and is separated here. After that, it flows into the sieves with the diameter of 250 mm and 350 mm. The sedimentation is also carried out in this operation. The basins are normally made of concrete to maintain the cleanliness of product. The product of primary stage is cassava milk. Continuously, starch milk is left in the first settling during 7–10 h. It is then mixed thoroughly with water, bleached and left for secondary settlement within 12–14 h. After the release supernatant, dirt starch (pulp) is moved to another tank. The remaining suspension is then transferred from the mixing tank into the third settling tank for further starch recovery; it will take approx. 12–14 h to complete the third settling.
- *The secondary – dewatering*: cassava milk is dewatered here, using a basket centrifuge and hydraulic press or a screw press to produce a thick cassava cake of 45–47% moisture content. After dewatering the milk is dried. The fermented cake is broken down into small pieces and fed directly into a fried rotary louver dryer at temperatures of 75°–100°C, where moisture content is further reduced to give the cassava cake a long shelf life.
- *The final stage – milling and packing*: the oversized particles of cassava cake or grit are milled to the particle size of the sieve. A further drying process is done in this operation by putting the starch in winnowing tray. Every tray has about 1.5–2 kg starch. Usually the drying period is from 2–3 days. After drying process, the starch is then milled. The grinder is hammer mill typed. Packaging in the plastic baggies is a final step in the operation.

Figure 4 Flowchart considered for cassava starch production processes (see online version for colours)



4.2 A methodology of AIZES

A methodology towards models of a zero emissions system is established including three basic steps. The methodology starts with analysing the material and energy flows that run through the agro-based industrial systems and partly end up in wastes. Analysing various possibilities to prevent the generation of wastes is done in the second step. The third step concentrates on identifying, analysing and designing potential offsite recovery and reuse options. It also entails the identification of remaining wastes in this step to find define appropriate treatments in order to follow a reasonable method toward a zero emissions approach.

4.3 Input-output analysis of AIZES model

The AIZES model is introduced with a case study on the cassava starch production processes at Khiet Tam Village, Thu Duc District in Vietnam. The capacity of the plant is 30 ton/day. A chain route of the production originates continuously from raw material, primary, secondary and final product processors for the consumer market. Production activities require input materials for the process, including cassava fresh roots, water, chemicals and energy. The AIZES model starts with the analysis of the amount of cassava residues generated during the production. The material flow is simulated in Figure 5. In the model, water is supplied from the located wells. Electricity powers all stages of processing. Wastewater discharged from the process is now treated in the wastewater treatment plant. After treatment the water meets the standard for the discharge of industrial wastewater as backer-used for irrigation, cassava yields or plants in the company. Organic waste which is actually thrown frequently into landfills is now collected and used as input material for a digester in anaerobic fermentation. The product of the digestion is fertilizer; it could be used as plant fertilizer. Biogas, which is also the product of digestion, can be used directly as gasification for lighting and boiler demand in the factory.

- *Inputs of AIZES model*: Cassava starch processing industry expands from northern to southern of Vietnam. In the south, this processing industry is concentrated as industrial-clusters at Thu Duc District in HCM City. The amount of input materials for a cassava starch production depends of course partly on the capacity of the production processes, for example the equivalent kind of small-scale, medium-scale or large-scale enterprises. However, it basically consists of energy, chemicals and supply water. Demand of raw materials depends on capacity of processing industry. In the production water is one of essential sources. Water is used for many operation steps including washing roots, crushing, trimming, grinding, starch extracting by centrifuges, absorption sulphur, mixing and washing floor and equipment after each sieves, etc. Water supply demand is mainly supplied from Tha La River and the located wells.

- *Non-waste*: In the AIZES model, cassava waste generated from the production is collected, gathered and put into a digester for the fermentation. Digester is obtained from cassava waste, livestock manure and sludge from the wastewater treatment plant and waste from the factory. Approximately 180–200 kg of waste is generated from one ton of cassava. The products of anaerobic digestion are biogas used as renewable energy and fertilizer for agriculture.

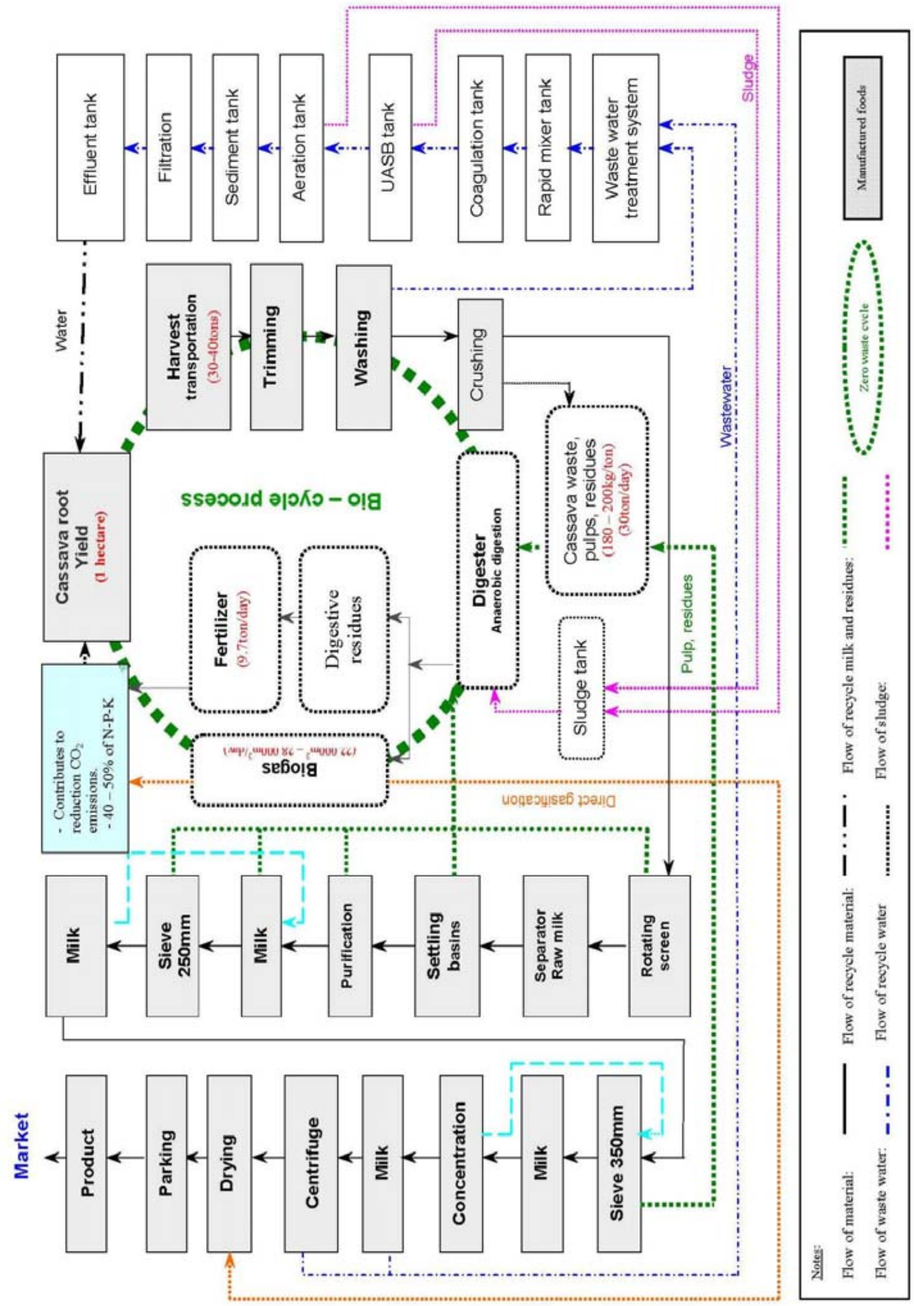
- *Non-wastewater*: To process one ton of fresh tapioca root, water demand is approx. 20–25 m^3. It is used for all processes, mainly supplied from the local well. The example company pumped 350 m^3/day. Wastewater discharged was as much as 350 m^3/day is to be collected and then piped directly to the wastewater treatment system. A part of the wastewater after treatment is used to mix up the substrates in the digester for biogas production. What is left is piped into the treatment system. The wastewater treatment system is applied as a combination of physical, biological and chemical treatment methods to remove suspended solids, organic matters and bacteria population. Treated water that meets the industrial Standard B is discharged and is used back as water for irrigation systems in agriculture or satisfied for pouring plant.

- *Output of AIZES model*: the composition of solid waste consists of waste the production (cassava residues) and organic waste from the company, total amount of 30 ton/day. Wastewater discharged from the production as much as 350 m^3/day is piped directly to cassava starch wastewater treatment system.

- *Fertilizer and biogas*: besides the output as cassava package, corresponding to input materials of production capacity, outputs from production were also waste (solid and liquid), odours and air-polluting exhausts. However, the effects by exhausts from the process on the environment and human population were not serious.

In the AIZES model, the system outperforms its design goals by a significant margin: for instance all waste from the production is used as input substrates and treated wastewater is used as supply water for mixing up substrates (waste, manure) for anaerobic digestion. Biogas conversion was efficient throughout our experiments regarding cassava residues (methane concentration of 80.5% was far more than anticipated) (Nguyen Ngoc, 2007). Normally methane concentration in biogas yield is between 50–70%. Before we examine the experiments we did not sure about the ability of the biogas yield from the fermentation because of the high content of cellulose as well as cyanogenic glucosides in the peels. After the practical fermentation, what we can conclude is that, cassava peel is very good for biogas production and it can be applied as a process of AIZES model. If possible, inside the factory, the obtained gas is combusted. This is due to the high content of cellulose as well as cyanogenic glucosides in the peels. After the practical fermentation, what we can conclude is that, cassava peel is very good for biogas production and it can be applied as a process of AIZES model. If possible, inside the factory, the obtained gas is combusted. After all, an additional advantage of the AIZES model is that newly gained energy can lower energy costs, bringing economic benefits from these savings. Of course, the use of sludge as fertilizer can also yield economic benefits.

Figure 5 Flowchart considered for a zero missions agro-based system on cassava starch production processes (see online version for colours)



4.4 Materials and energy balances

Material balances are fundamental to control production processes, particularly in the control of product yields. The calculation of material balances is based on material, waste, wastewater and energy in the process. The material balance in this case study is formulated according to the law of conservation of mass. The basic formula is:

$$\mathrm{Mass}_{\mathrm{in}} = \mathrm{Mass}_{\mathrm{out}} + \mathrm{Mass}_{\mathrm{stored}} + \mathrm{Mass}_{\mathrm{lost}} \tag{13}$$

$$\text{Mass Materials} = \text{products} + \text{wastes} + \text{stored materials} + \text{losses} \tag{14}$$

$$\Sigma \mathrm{m_R} = \Sigma \mathrm{m_p} + \Sigma \mathrm{m_w} + \Sigma \mathrm{m_s} + \Sigma \mathrm{m_L} \tag{15}$$

In which:

$$\Sigma \mathrm{m_P} = \mathrm{m_{P1}} + \mathrm{m_{P2}} + \mathrm{m_{P3}} + \ldots + \mathrm{m_{Pn}} \ : \text{ Total products} \tag{16}$$

$$\Sigma \mathrm{m_w} = \mathrm{m_{w1}} + \mathrm{m_{w2}} + \mathrm{m_{w3}} + \ldots + \mathrm{m_{wn}} \ : \text{ Total wastes} \tag{17}$$

$$\Sigma \mathrm{m_s} = \mathrm{m_{s1}} + \mathrm{m_{s2}} + \mathrm{m_{s3}} + \ldots + \mathrm{m_{sn}} \ : \text{ Total stored products} \tag{18}$$

$$\Sigma \mathrm{m_M} = \mathrm{m_{M1}} + \mathrm{m_{M2}} + \ldots + \mathrm{m_{Mn}} \ : \text{ Total materials} \tag{19}$$

$$\Sigma \mathrm{m_L} = \mathrm{m_{L1}} + \mathrm{m_{L2}} + \ldots \mathrm{m_{Ln}} \ : \text{ Losses are unidentified materials.} \tag{20}$$

Material balance

Material balances on AIZES model are calculated for 'mass in' and 'mass out' in the starch production processes. To process one ton cassava fresh root, approximately 180–200 kg waste is generated, starting from peeling, trimming, crushing, sieving and dewatering. However, this waste is collected and put into the digester.

- Mass in

  Total supply water used

$$\Sigma \mathrm{m_W} = \mathrm{m_{W1}} + \mathrm{m_{W2}} + \mathrm{m_{W3}} + \ldots + \mathrm{m_{Wn}} \tag{21}$$

$$\begin{aligned}\Sigma \mathrm{m_{Water}} = {} & \mathrm{m_{washing}} + \mathrm{m_{cleaning}} + \mathrm{m_{triming}} + \mathrm{m_{purification}} + \mathrm{m_{crushing}} \\ & + \mathrm{m_{rotating}} + \mathrm{m_{others}} = 350\mathrm{m^3/day}\end{aligned} \tag{22}$$

  Basic 1 $\mathrm{m^3}$ of water = 1,000 kg

  Total fresh cassava root supplied

$$\Sigma \mathrm{m_R} = \mathrm{m_{Rloading\ weighing}} = \Sigma \mathrm{m_R} = 30 \text{ ton / day}$$

  Calcium hydroxide: $\mathrm{m_{Ca(OH)2,\ process}}$ 40 ton/year

  Total chlorine used

$$\Sigma \mathrm{m_{Cl}} = \mathrm{m_{Clprocess}} + \mathrm{m_{ClW.W.T.P}} \Sigma \mathrm{m_{Cl}} = 650 \text{ kg / year} \tag{23}$$

  Total sulphur used

$$\Sigma m_S = m_{Sprocess} + m_{SW.W.T.P} \Sigma m_S = 38 \text{ ton / year} \tag{24}$$

Total NaOH used

$$\Sigma m_{NaOH} = m_{NaOHprocess} + m_{NaOHW.W.T.P} = 500 \text{ kg / year} \tag{25}$$

Total sulphur used

$$\Sigma m_S = 500 \text{ kg / year}$$

- Mass out

Total cassava residues

$$\Sigma m_W = \Sigma m_{peel} + m_{organic} + m_{pulp} + m_{fibrous\ resides} = 30.0 \text{ ton / day} \tag{26}$$

Water for digester: Σm_{mixing} 72–100 m^3/day

Total wastewater

$$\begin{aligned}\Sigma m_{Water} &= m_{wwash} + m_{wcrushing} + m_{wsettling} \\ &+ m_{wprification} + m_{wdewatering} = 350 \text{ m}^3 \text{ / day}\end{aligned} \tag{27}$$

Total substrate loading

$\Sigma m_{Rloading}$ = 32.4 ton/day

$$\text{Fertilizer mass} = 30\% x m_{loading} = 0.30 \times 32.4 = 9.7 \text{ ton / day.} \tag{28}$$

Energy balance

Energy balances are normally not simple because they can be inter-converted, e.g., mechanical energy to heat energy, but overall the quantities must be balanced. As mass conserved, energy coming into a unit operation of cassava production can be balanced by energy (electricity) coming out and energy stored (thermal energy). Energy usage in the factory can be split up into various forms, for instance electrical energy is used in the process and lighting, drying, compressing air, heating, etc.

$$\text{Energy}_{in} = \text{Energy}_{stored} + \text{Energy}_{out} \tag{29}$$

$$\text{Energy}_{stored} = \Sigma E_E$$

$$\text{Energy}_{out} = \Sigma E_L + \Sigma E_P$$

In which:

ΣE_e: Total energy entering the process

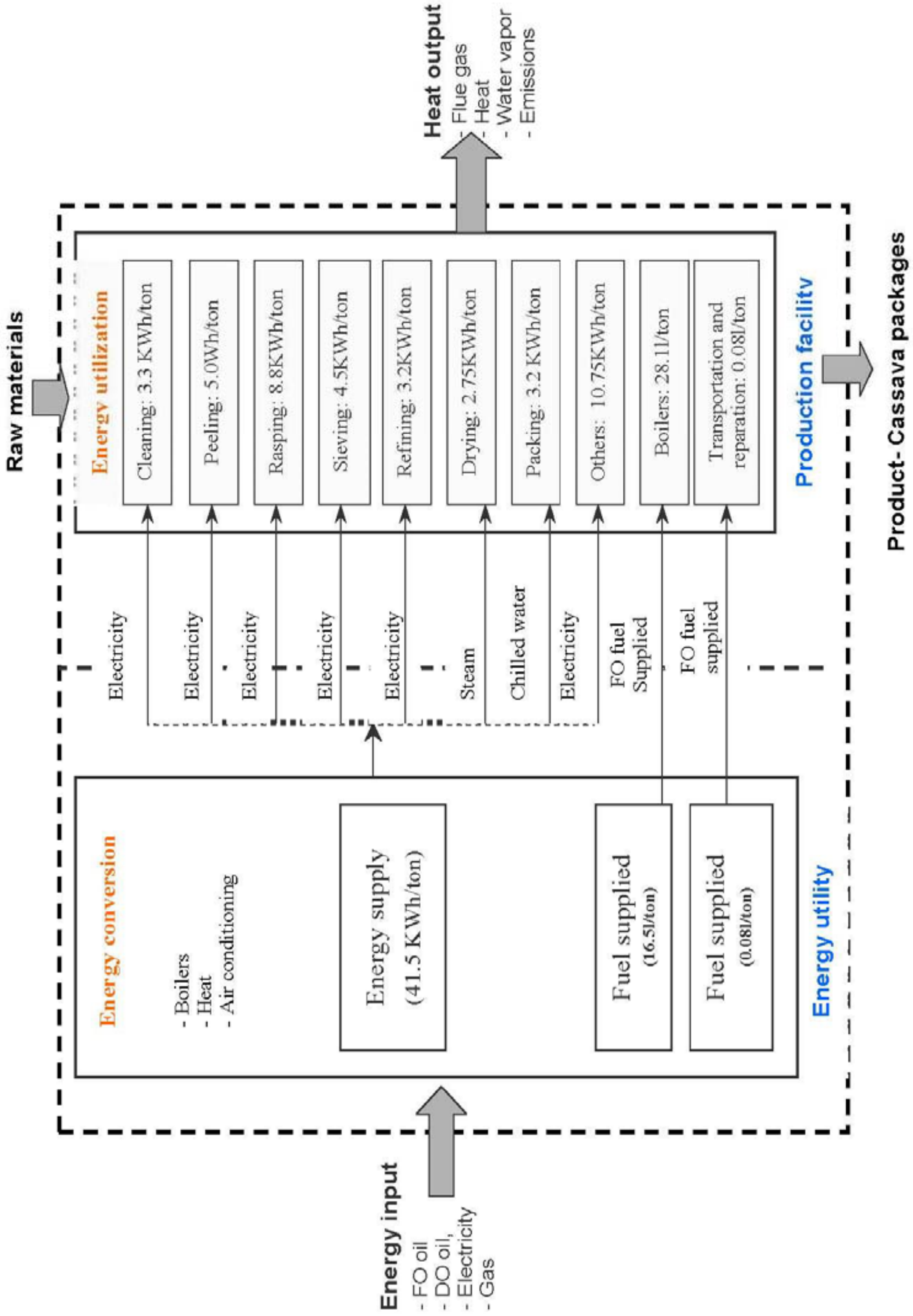
ΣE_P: Total energy leaving with the products

ΣE_L: Total energy lost to surroundings.

Then:

$$\Sigma E_{In} = \Sigma E_e + \Sigma E_L + \Sigma E_P \tag{30}$$

Figure 6 Flowchart of energy balance on cassava starch production processes (see online version for colours)



Total energy entering for the process

$$\begin{aligned}\Sigma E_e = E_{cleaning} + E_{washing} + E_{crushing} + E_{peeling} + E_{rotating} + E_{sieving250mm} \\ + E_{sieving350mm} + E_{centrifuge} + E_{drying} + E_{others}\end{aligned} \tag{31}$$

$$\Sigma E_e = 34.17 \text{ KWh / ton}$$

Total energy leavings with products

$$\Sigma E_P = E_{P1} + E_{P2} + E_{P3\ldots} + E_{Pn} = E_{Process} + E_{Plighting} + E_{Potheract} \tag{32}$$

$$\Sigma E_P = 0.34 \text{ KWh/ton}$$

Total energy lost to surrounds

$$\Sigma E_L = \Sigma E_l + \Sigma E_{L2} + \Sigma E_{L3} + \Sigma E_{Ln} = \Sigma E_{Lboilers} + \Sigma E_{Lprocess} = \Sigma E_{process} \tag{33}$$

$$\Sigma E_L = 10\% \times 37.6 = 3.76 \text{ KWh / ton}$$

Total energy to process each ton product:

$$\Sigma E_{In} = \Sigma E_e + \Sigma E_L + \Sigma E_P \tag{34}$$

$$\Sigma E_{In} = 41.5 \text{ KWh / ton.}$$

4.5 Fermentation introduced in AIZES model

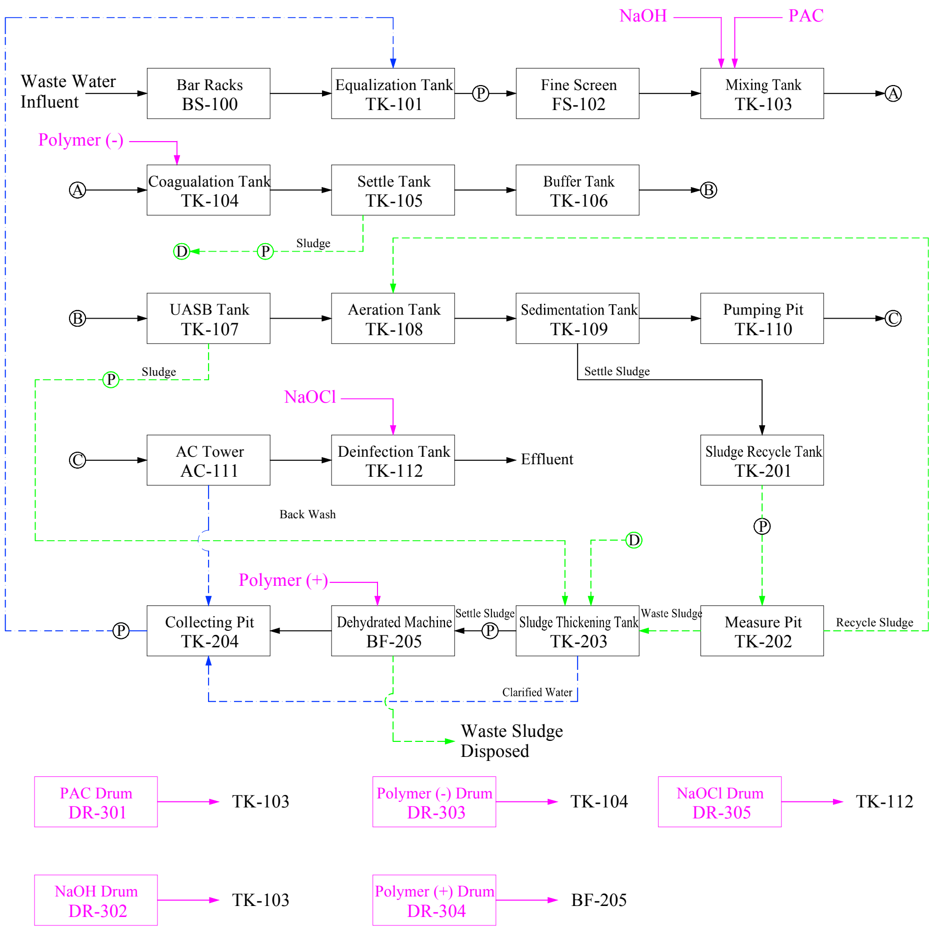
Anaerobic fermentation is introduced in AIZES model. In the digestion progress, organic matter is digested in the absence of air to produce biogas. A digester consists of a mixing tank, sludge tank, an engine generator set and liquid storage. The digester is an in-ground concrete tank and coated by epoxy. When gas production has ceased, the digester is emptied and refilled with a new batch. Retention time of fermentation is within 28–35 days. For our biogas experiments some experiments have examined longer than 30 days but biogas yield collected was not much higher. In first week the amount of biogas generated slower but the yield was still released slowly until the end of fermentation phase. PH value was 6.0–8.0, efficient digestion occurs at a pH near neutrality. The calculation on biogas yield in our experiment was 22,000 m^3–28,000 m^3/day. Biogas yield produced from the fermentation (70–80.5% of methane) can burn back for the drying requirements and lighting during the production processes. Gas of this quality can be used to generate electricity. Biogas volume measurement will be measured at batch reactor headspace by using a system pressure gauge. The biogas in the reactors headspace was released under water to prevent any gas exchange between the reactor and the air. The digester is sealed from the inside to prevent biogas leakage and insulated to maintain temperature. The separated liquids will flow to the storage by gravity, where the liquid is centrifuged used as fertilizer. With production capacity from the cassava production, the amount of fertilizer per day is estimated approximately 30.5 ton/day used as fertilizer for plant. Input materials for the fermentation were cassava peels, manure (swine, chicken and cow) and waste form households. The iterations are done for inoculums and each substrate. Gas production was followed daily in the morning and evening. An unusual input material – cassava residue has 30% cellulose, very little protein and cyanogenic glycosides (CHN) – but the biogas yield was high from the mixture between cassava residues and inoculums. Nevertheless in the biogas experiments done, biogas yield and methane content was very high (its maximum value was 80.5%) although there was a short delay when using cassava residues as substrate for biogas production. It started slowly during the first four days but afterwards digestion acted normally.

4.6 Treatment method for wastewater

Cassava starch processing operations discharge a substantial amount of wastewater that is characterised by a high organic content, high strength chemical oxygen demand (35,000 mg/l), biochemical oxygen demand (14,000 mg/l), total suspended (15,000 mg/l), temperature of 30°–45°C and hydrogen cyanide (HCN: 19–28 mg/l). The starch wastewater also has high cyanide content; HCN goes up to 19–28 mg/l. The block-diagram of wastewater treatment system simulates in Figure 7.

The physical treatment method is applied first to remove coarse by letting the wastewater flow through bar rack. Then the wastewater flows into an equalisation tank to control hydraulic velocity or flow rate. Equalisation of flow prevents short and high volumes of incoming flow. Solids are ground by a powerful and loose organic material separated in bar rack and fine screen in equalisation tank. Flow equalisation also controls the flow through each stage of the treatment system, allowing adequate time for the physical, biological and chemical processes to take place. Wastewater is then pumped into the mixing tank and coagulation tank to increase the removal of solids because with the addition of specific chemicals, solids become heavier than water gravity and will settle down. Then, the large masses of particles will settle faster. Hydraulic retention time proposes approx. five to ten minutes. The aeration tank can be considered as a biological phase in the system to remove up to 90% of the organic matter in the wastewater. The sedimentation tank is also called settling tank, a vessel in which solids settle out of water by gravity through pulling particles to the bottom of the tank. It is installed after the aeration tank. Effluent from sedimentation tank is pumped into the AC tower to pure the contaminant concentration through a bed of activated carbon, called a mass transfer zone. Although the effluent is treated, it contains many types of human enteric organisms that are associated with various waterborne diseases. The chlorine contract tank and the associated chemical dosing facilities will be designed to meet the E.coli criteria discharge. The effluent is channelled into a clean water reservoir with a volume of 220m^3/day is going to be used back as irrigation water for agriculture, for example cassava yield or water needs for the plants in the company.

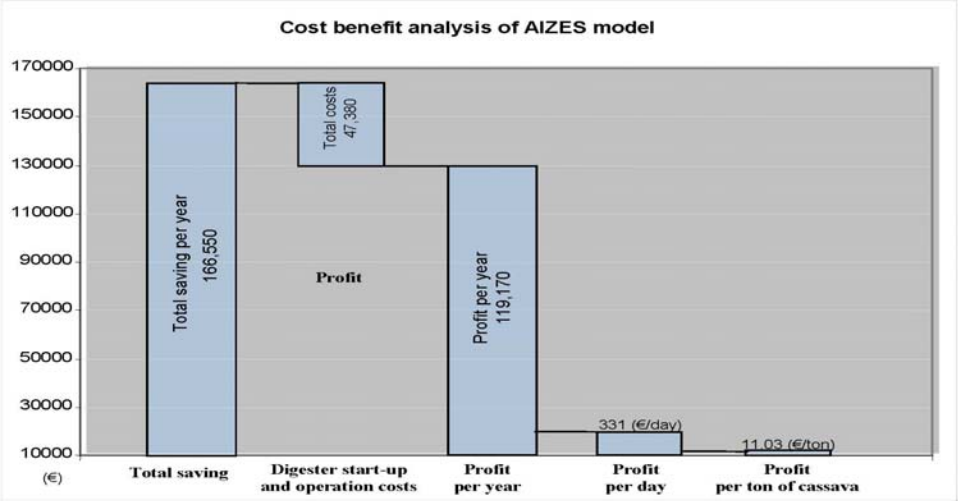
Figure 7 Block diagram of wastewater treatment system (see online version for colours)



4.7 *Economic considerations*

An economic aspect is one of aspects considered for the decisions to choose or implement between one and other options. In this case study, the economic consideration is also given. It is calculated on the costs for establishment, investment and operation. In details, it is shown by the calculation on the costs for the production, wastewater treatment system and start-up as well as costs for operation of a digester and fertilizer production. The costs are described in Figure 8, where the profit (11.03 €/ton) per each ton of cassava root processed is also calculated. The interest on capital is assumed 3.5%, payback between one to five years, and the increased cost of operation is 2% per year.

Figure 8 Cost and benefit analysis of AIZES on cassava starch industry (see online version for colours)



4.8 Lessons have identified from AIZES

It is not easy to avoid the generation of organic waste in the cassava production, generally in food processing industry. However the case study revealed for perishable and biodegradable waste, the logical solutions for waste reduction including prevention and minimisation at source, converting organic waste to fertilizers through composting or producing biogas and fertilizes through anaerobic fermentation, and proper treatment of wastes before discharge.

The failures in environmental management, in particular in developing countries, can be indicated by three major following points: State environmental management authorities; Environmental and economic agencies are not strict enough to encourage producers and production units improving their production efficiencies; Research for improvements in production processes and environmental protection is inadequate.

Besides the analysis and calculation of the AIZES in this case study indicates a AIZES will be especially suitable to apply to the food industry which generate high amounts of wastes. The economic and ecologic advantages exceed cost of implementation and operation shown in case study. It means waste can be a resource if it is put a right place. Its advantages can be listed by:

- *Solving the huge amount of waste generated*. If waste is collected and used for the fermentation. It does not only save the costs for waste treatment, reducing pollution in the urban and rural environment, but also reduce the burden of disposal.

- *Supports a SD*. AIZES supports all three of the generally accepted goals of sustainability including the ability of environmental protection, an economic aspect and social aspect of human well being.

- *Support economic beneficial considerations and saving money*. Since waste is a sign of inefficiency, the reduction of waste usually reduces costs. The criteria also include the reductions in energy consumption, increased recycling and reducing waste at the source leading to economical benefits.

- *Faster progress*. AIZES is improved upon cleaner production and pollution prevention techniques by providing a visionary endpoint that leads us to take larger and more innovative steps. This not only results in a faster progress and significant cost savings, but also will move more quickly towards a SD.

It seems feasible to approach the goal of a zero waste in food industry due to simple and easy analysis methods of materials and energy flow. Important steps towards the realisation of the concept were achieved in the case study. However one disadvantage can also be realised from this case study is having a group of enterprises which can not use each other's products or reuse by products or waste. Material flow network, which is often essential to reach the aim of zero emissions, can be created by including enterprises that use and produce different inputs and outputs. Anyway except some by-products such as wrapping materials, most organic by-products from food processing industry are suitable for a new production to produce biogas, fertilizers, livestock feed, animal feed, industrial grade alcohol, etc.

5 The relation between a zero emissions agro-based industrial system and SD

5.1 What is SD?

In the 1980s the concept of SD entered the debate on development and the environment. This concept not only helped to forge a compromise between the demands for economic growth on the one hand and environmental protection and conservation on the other hand, but also stimulated the exchange of views on development in general.

Although SD has been defined in many different ways since after the 1980s, 'there is no formal definition of SD' after publication of the report of the World Commission on Environment and Development. In 1992, leaders at the Earth Summit built upon the framework of the Brundtland Report to create agreements and conventions on critical issues such as climate change, desertification and deforestation (US Department of Energy, 1992). The definition is presented in the Brundtland Report (1987): 'SD is development that meets the needs of the present without compromising the ability of future generations to meet their own needs'.

In its definition the concept of SD contains two key elements, listed by: 'the concept of needs, in particular the essential needs of the world's poor, to which overriding priority should be given; and 'the idea of limitations imposed by the state of technology and social organisation on the environment's ability to meet present and future needs'.

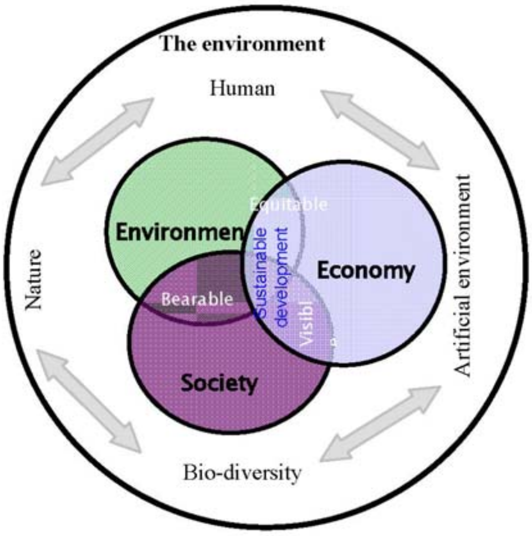
5.2 The spectrum of SD

The concept of SD is rooted from this sort of system thinking. The concept of SD normally involves sustainable community, industry, economy and agriculture. This concept is also related to the quality of life asking whether the economic, social and environmental systems that make up the community are providing a healthy, productive, meaningful life for all community residents, present and future. SD is understood as the connections and achieved balance among the social, economic and environmental pieces of a community, shown in the Figure 9. When the interaction of the factors of society, economy and environment are viewed as separate, unrelated parts of a community, the community's problems are also viewed as isolated issues. However the factors which exist inside the surrounding environment are usually interacted by anthropogenic activities and even SD offers a vision of progress that integrates immediate and longer term needs; local and global needs; and social, economic and environmental needs as inseparable and interdependent components of human progress (The Brundtland Report, 1987).

The concept of SD requires looking at our surrounding environment as a system which connects to time and space. Additionally, the world as a system over time in which economic policies as well as rapid industrial development will have an impact on the environment, society and urban poverty. For instance, building a dam for water-electricity needs is a ‘green’ in short-term but has climate-change effected (degrading plants) and perception affects (when lifetime of consumption ends) in the long-term. Our quality of life is a system which will certainly be affected too. If industrial development is unsustainable, it will put the stresses on the environment on the water, land and resources and on the environmental systems of our planet. Hence economic growth and development obviously involve changes in the physical ecosystem.

SD is actually not a new idea. With more than 100 possible definitions, SD has become the basic building blocks of any social understanding of the relationship between humanity and its physical environment (Krieger, 2002). Yet, the sheer multitude of definitions also makes it a contested concept which can be used in often contradictory ways (McManus, 1996). However such a rich discourse SD is a natural numerous attempt to give more systematic shape to the debate have been made in the progress of the industrial development. Many cultures over the course of human history have recognised SD as actually human’s need for harmony between the environment, society and economy. So what is new is an articulation of SD with these ideas in the context of a global industrial development and information society. The industry can provide a typical example of a sectoral aspect of SD. Ideally, industrial development which satisfies the needs of human does not impact on the environment is a benign and longevity idea. Concerning the information society, the idea of sustainability aims to reconcile the modern character of both human to nature and human-to-human relationships in order to address the moral and social implications of society’s ecological impacts and inequities within and between communities. Sustainability is radical (from the roots), firstly, in that its definition of community encompasses everything from the maple to the mosquito to the mayor. Secondly, it is purposeful in that it directs a community in a certain direction by imposing constraints. At the heart of the debate surrounding sustainability, SD is the issue of whether or not human capital can be substituted for natural capital and whether or not there are limits for the growth. Many ecologists and a few economists argue that natural capital is not infinitely substitutable; this is sometimes termed a strong SD. On the other hand, is achieved if the aggregate stock of natural and human capital is not decreasing and one is substitutable for the other (Kuehr, 2007).

Figure 9 Connections of a SD (see online version for colours)



Concerning environmental and economic sustainability, economic system is sustainable unless it accommodates the ecosystems on which it depends. Our current system, based on the notion of perpetual economic expansion on a finite planet, is seriously flawed. We urgently need to apply human ingenuity to the goal of using far less from nature to meet our needs which is a different goal from exploiting nature. To pursue this, we must learn the ways to develop the economy that does not impact negatively on the environment. With this goal the aim of economic sustainability through the development that meets the needs of the present without compromising the ability of future generations. Social sustainability is focused on the development of programs and processes that promote social interaction and cultural enrichment. It emphasises protecting the vulnerable, respecting social diversity and ensuring that we all put priority on social capital. It can be said that social harmony and definition of collection wealth in society are to avoid critical imbalances without discouraging production individuals from competitive behaviour. Also, it covers the broadest aspects of business operations and the effect that they have on employees, suppliers, investors, local and global communities and customers. Of course social sustainability can not be created simply through the physical design of the community but then neither can environmental sustainability be created by physical design alone. In addition, socially, SD must include sustainable urban development because it meets basic needs for food, shelter, education, work, income and safe living and working conditions; is equitable and ensure the benefits of development that are distributed fairly across society; promotes education, creativity and the development of human potential for the whole population; enhances or at least does not impair, the physical, mental and social well-being of the population; and promotes conviviality, with people living together harmoniously and in mutual support of each other; or is democratic and promotes citizen participation and involvement.

5.3 The relation between AIZES and SD

The sectors of agro-based industry can be an important component of the economy of the region and even the country. It can enhance self-sufficiency, import substitution or even resource exploitation. It can add to the value of the primary products for local consumption as well as providing inputs for exporting. Development of this sector has been pursued for socio-economic, political strategy and regional and national purposes. The major sub-sectors in agro-based industry which have been significantly influenced on economic development can be listed by ten following industries: Food and fruit processing industries, dairies, edible oil industries, fermentation industries – distilleries and breweries, flour mills, jute retting units and textile industries, pulp and paper industries, starch manufacturing industry, sugar mills, coir retting units.

As we know, the basic definition of SD means to satisfy the needs of the society in a way those future generations can satisfy their needs as well. This requires the maintenance of natural resources as well as ensuring opportunities to maintain and improve the quality of life. AIZES can address four major dimensions of SD including economic, environmental, social and institutional dimensions in the ways which support sustainability through zero emissions into the environment – environmental dimension, support economic benefit through using waste as input materials, bio-products and saving money for agro-based industrial production processes – economical dimension, supply a faster and environmentally friendly production progress and adapt to social indicators of SD – social dimensions.

The contribution of AIZES to SD can be found in an indicator set of 96 indicators of SD. Table 1 lists the indicators that make up the thematic and sub-thematic framework of guidelines of indicators of SD, adopted in 2007 by the United Nations.

Table 1 Indicators of AIZES in SD

Theme	*Sub-theme*	*Core indicators*
Environment	Air quality	Ambient concentration of air pollutions in urban areas
	Agriculture	Proportion of use of efficient fertilizers
	Freshwater	Proportion of total water resources used as usable water
	Water quality	Water use intensity by economic activity
	Ecosystem	Proportion of area protected and ecological area
	Sanitation	Proportion of population using an improved sanitation facility
	Land use and status forests	Land use and degradation, land affected by desertification area of forest under sustainable forest management
	Application of organic farming oceans, seas and coasts	Organic farming rate forest trees damaged by defoliation
		Population living in coastal areas, marine environment and fisheries

Table 1 Indicators of AIZES in SD (continued)

Theme	*Sub-theme*	*Core indicators*
Economy	Macroeconomic performance	Investment share in gross domestic product
		Gross domestic product per capita
		Employment and population ratio
	Information and technologies	Fixed telephone line per 100 population
	Material use and consumption	Intensity of material use
	Energy use	Annual energy consumption per capita
		Intensity of energy use on manufacturing
		Intensity of energy use on residential sector renewable energy share in energy and electricity
	Waste generation and management	Ration of solid waste generation of waste and waste treatment
		Waste recycling and reuse
	Transportation	Energy intensity of transport
Society	Income poverty	Proportion of population
	Income inequality	Ration of share in national income of highest to lowest quintile
	Health	Mortality, health care, nutritional status, health status and risks and proportion of population using improved sanitation facility
	Assess to energy	Share of houses without electricity
Institution	Natural SD	Proportion of natural SD
	Human and economic loss	Human and economic loss due to natural disasters
	Expenditure on research	Gross domestic expenditure as a percent of GDP
	Education level	Education level, literacy, awareness
	Health and population	Mortality rate and healthy life expectancy rate
	Governance	Percentage of population having paid bribes, corruption and crime

5.4 Environmental dimension

Adequate and affordable industry has been a key to develop the economy and transit subsistence agricultural societies to modern industrial service oriented. The agro-based industry can be central to improved social and economic well-being. It is also important for relieving poverty, improving human welfare and raising living standards. Ideally this industry can adapt to environmental issues and regulation in production progress and ensure high sanitary standards, sustainable economy and a clean environment. The manufacturing industry approaching ‘zero emissions’ is not only good for itself but also is valuable as far as it can satisfy the environmental and regulation issues. The economic processes of industrial production and consumption draw a greater or lesser extent on services provided by resources of the natural-physical environment. The distribution and use of materials and energy in the production create the pressures on the environment in the household, workplace and city, at the national, regional and global levels. Certainly the environmental impacts depend greatly on how final products produced, how materials used, how energy used, how the structure of production system is, how many ton of waste generated per day, how gaseous missions from the burning of fossil fuels polluted the atmosphere, etc. All the questions are pressured on the production because these pollutants from the production can damage human health, leading to respiratory problems, cancer and pathogen.

However, the environmental indicators of AIZES display the themes of water quality, waste generation, agriculture, atmosphere, air quality, land and sanitation that are not affected by the production because most of waste (liquid, solid) generated from production processes are reused for another processes. Additionally, the use of materials for agro-based industrial production processes may not result in environmental degradation because most of agricultural materials used for AIZES are organic and degradable materials. The use of waste as process input in the new production in AIZES is also a bio-production. This avoids the negative impacts on the environment as deforestation, environmental degradation and damage, erosion and soil loss.

5.5 Economic dimension

The industrial production process (and its structural transformation) has always been recognised at the core of industrial development. It is still the most important precondition for the fulfilment of human needs and for any lasting improvements in living conditions. In addition to the industrial aspects of development, an increasing number of qualitative aspects has come to be recognised too (Socolow, et al., 2001). Generally industrial development is crucially dependent on economic development, both respect to the industrial sector’s pivotal contribution to economic growth and even more regarding the structural transformation of an economy. The importance of the latter is underlined by the fact that economic development is largely thought of as being synonymous with industrialisation. The indicators in Table 1 (macroeconomic performance, materials use and consumption, energy use, waste management, diversification and price and information and technologies) present the economic dimension of the industrial sectors to SD. For example, it can make a faster, safe and sustainable production progress. This leads to its contribution to increasing Gross domestic product and income or reducing energy use, reducing the costs for waste management and treatment, reducing the pressure on transportation, enhancing zero waste production trends, etc. However, to support the goals of SD, materials and energy which need for the production must be available at all times, in sufficient quantities and at affordable prices. This is definitely necessary to an agro-based industrial production.

5.6 Social dimension

A AIZES has an indirect effect on employment opportunities, education, demographic transition, poverty, indoor pollution, health welfare and gender and age-related implications. In the rich countries, AIZES is available at the flip of a switch. In the poor countries although the economic development can change in better way, the industrial production processes still lack of modern technologies and clean-technologies. Up to six hours a day is required by some households to collect wood and dung for cooking and heating. In areas where coal, charcoal and paraffin are commercially available, these fuels take up a large portion of the monthly household income. Inadequate equipment and ventilation means that these fuels are burned inside the house and cause a high toll of disease and death through air pollution and fires. The health indicators have the sub-theme of social safety, income poverty, income inequality, health, assess to energy, conversion, distribution and use of materials and energy. Seen from a broad angle, development of AIZES encompasses the strengthening of material income base as well as an enhancement of capabilities and enlargement of choices.

5.7 Institutional dimension

Actually, it is hard to identify clearly the relationship between zero emissions systems and SD because of two reasons. First, they tend to address issues that are, by nature, difficult to measure in quantitative terms. Many of these issues relate to the future and require dynamic analysis of production, use and investment. Secondly, the variables measured by institutional indicators tend to be structural or policy responses to SD needs.

6 Concluding remarks

The concept of AIZES can in principle be applied to small, medium and large sized companies. However there are in practice several key differences as the technological options vary widely different scales of operation. Actually, small firms or small companies obviously have very limited finance and human resources available for environmental improvements. In addition, government institutions pay limited attention to the environmental performance of smaller industries and are more closely observing large-scale enterprises. Because of this, bringing the food processing industrial sectors together in industrial bigger zones will offer the bigger advantages at two sides. Firstly, we can collect more waste for reusing and recycling in environmentally friendly new production processes so maybe the economic benefits are getting more. Secondly, waste management will be more central therefore the costs for waste management and services will get less.

Truly, our industrial system was primarily linear, with a ‘take-make-waste’ process: materials are extracted from the earth’s crust, transported to manufacturing sites, used to produce products, which are then transported to consumers and finally, at the end-of-life, discarded as waste. Not only is this inefficient and costly, but also these products often contain persistent or toxic materials that negatively impact the environment when they are incinerated or disposed of landfills. In the recent years, forward ways to fulfil the equation ‘waste = resource’ and the term of ‘zero emissions’ gained popularity. The opportunities of waste management towards a zero emissions approach make an application of AIZES rational because of its advantages. AIZES can apply on production, manufacturing and consumption of goods and services towards a development that is sustainable and harmless to the environment. However, how can we deliver the environmental awareness in society? This can be found in many publications and communications such as environmental news, newspapers, papers and books, etc. The paper wishes sharing information towards a deeper environmental understanding because environmental concerns have become key issues in the present global industrial activities. Something will be missing if we do not raise environmental awareness especially on the difficulties in dealing properly with environmental pollution and waste management as well as the limits of natural resources.

The definition as well as the principles of AIZES; the overview, concept, benefits, vision of AIZES and SD; the spectrum of SD; and the relation of AIZES and SD are at the heart of this paper. The flame of innovation that powered industrial and economic growth since science's beginnings is now also powering the protection of human health, the environment and environmental education in the recent decades. This paper contains environmental understanding regarding zero emissions agro-based industrial systems and SD from the individual viewpoint to contribute to the goal of sustainability through science. Many goals have been set out as challenges to humanity. Just as it has been that science and technology was the motor to achieve those noble goals, it too will provide the motor that takes us down the pathway toward sustainability.

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