Development of a tailored Sustainability Strategy based on Regional Material Flow Management for the municipality Baños de Agua Santa, Tungurahua province, Ecuador

Master Thesis (M.Sc.) International Cooperation Policy

in the context of the Dual German-Japanese Degree Master of International Material Flow Management - IMAT

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15th of July, 2013

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The world we have created today as a result of our thinking thus far has problems that cannot be solved by thinking the way we thought when we created them.

- Albert Einstein

Certification Page

In the light of academic moral and ethics principles, I hereby, Ariane Christine Albers Wetzl, declare that this report with the title:

"Development of a tailored Sustainability Strategy based on Regional Material Flow Management for the municipality Baños de Agua Santa, Tungurahua province, Ecuador",

represents original research efforts that I have made on the advice of my academic supervisors. I have tried all my best to cite each portion in this report that uses other sources of information with proper referencing procedure. And whosever work that has been used as content or to support any part of this report is clearly detailed explicitly in the reference section.

Ariane Christine ALBERS Wetzl
Baños de Agua Santa, 15th of July 2013

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List of acronyms

%	Percentage
BMU	German Federal Ministry for The Environment, Environmental Protection and Reactor Safety
CE	Circular Economy
CH4	Methane Gas
CHP	Combined Heat and Power
CO2	Carbon Dioxide
CP	Cleaner Production
CP	Cleaner Production
CSP	Concentrated Solar Power
EC	European Commission
ETC	European Travel Commission
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FITs	Feed-in-tariffs
GDP	Gross Domestic Product
GDP	Gross Domestic Product
GHG	Greenhouse gases
GWh	Gigawatt hour
HCE	Heat-Collection Element
IE	Industrial Ecology
KP	Kyoto Protocol
kWh	Kilowatt per hour
m ASL	Metres above sea level
MF	Material Flow
MFA	Material Flow Analysis
MFM	Material Flow Management
MSW	Municipal Solid Waste
MSWM	Municipal Solid Waste Management
MW	Megawatt
MWh_{el}	Megawatt hour electricity
NOx	Nitrogen Oxides
PE	Population equivalent
PIUS	Product Integrated Environmental Protection
PV	Photovoltaic
RES	Renewable Energy Source(S)
RLP	Rhineland Palatinate State Of Germany
RMFM	Regional Material Flow Management
RoR	Run-of-river
RPS	Renewable Portfolio Standards
SD	Sustainable Development

SS	Suspended solids
SWM	Sustainable Waste Management
SWWM	Sustainable Waste Water Management
TWh	Terawatt hour
UNCED	United Nations Conference On Environment And Development
UNCSD	United Nations Conference On Sustainable Development
UNEP	United Nations Environmental Programme
UNFCCC	United Nations Framework Conversion On Climate Change
UNWTO	World Tourism Organization of the United Nations
WWM	Waste Water Management
ZE	Zero Emissions
MBT	Mechanical-biological treatment
RCC	Resource Recovery Centre

List of measurement (international standard)

cm	Centimetre
ha	Hectare(s)
kg	Kilograms
km	Kilometre(s)
km^2	Square kilometres
km^3	Cubic kilometres
m	Metre(s)
mm	Millimetres
t	Tonne(s)
l	Litre(s)
m^3	Cubic metre(s)

Executive resume

The research aims to develop a tailored sustainability strategy for the municipality of Baños de Agua Santa, aka “Baños”, in the Ecuadorian Andean region, based on the Regional Material Flow Management (RMFM) methodology and its foundational concepts: Zero-Emissions, Circular Economy, etc. The strategy would yield a number of projects addressing some of the key problems in the municipality, namely, waste and waste water management and tourism. The financial elements of such analysis exceed the scope of this research, yet a brief relation of innovative financing tools is included.

Baños is an agricultural and touristic region, surrounded by mountains and an active volcano, featuring rivers, waterfalls and a luxurious vegetation. The region is located in the limit between the highlands and the rain forest region, thus benefiting from mild weather and abundant water, factors exploited by agriculture and tourism. Baños receives one million tourists per year and features more than 150 accommodation options. Moreover, a hydroelectric generation plant operates nearby and the active Tungurahua volcano occasionally erupts and causes certain problems (pyroclastic material and ash fallouts) in the region since 1999.

The Baños municipality currently disposes all municipal solid waste at a local landfill, without gas recovery or flaring, and the city’s sewage waters are discharged to the local river without treatment. Additionally, growing tourism adds pressure to those systems. In consequence, the main proposed projects address to those pressing needs. Proposed projects contributing to the sustainability strategy include a MSW separation and treatment scheme, featuring recycling of suitable fractions and biogas production by means of anaerobic digestion of the organic fractions. Moreover, household/small scale biogas reactors are proposed for rural agricultural areas, as a solution for the management of animal manure and certain agricultural residues. Other proposals are tourism-oriented, such as a pedestrian downtown area and an ecological trail. Landslide reduction initiatives are also suggested, because the region is prone to landslides due to rain, volcanic activity and deforestation. An alternative reed bed filter system for waste water is proposed in order to contribute to the currently non-existing waste water treatment in the city.

All the abovementioned projects, as part of a sustainability strategy for the municipality, contribute to improve socio-economic conditions and environmental performance. Further research should focus on detailed engineering and financing schemes to develop the proposed projects, as well as a communications strategy for the municipality to notify of the strategy and its intended results.

Keywords: *Sustainable Development*, *Climate Change*, *Circular Economy*, *Zero Emissions*, *Regional Material Flow Management*, *Sustainable Tourism*, *Systems Thinking*

1 Introduction

The continuously growing world population and overexploitation of natural resources lead to the question of how global exponentially increasing consumption habits could be satisfied with the remaining resources and the fast degrading natural environment. The ecosystem has a carrying capacity and a tipping point which should not be overstepped. In other words: resources provided by nature should not be consumed faster than they can be replenished and the load on ecosystems should not exceed its regeneration pace.

The integration of environmental protection and resource management in daily life and business is far from realisation. Natural, social and cultural resources are drawn to their limits and exploited without regulation. This has led to serious threats to ecosystems, socio-economic environment, human health, livelihoods and more. Additionally, modern societies are facing global challenges related to climate change due to extensive greenhouse gas (GHG) emission releases, as well as a rapid decline of fossil fuel reserves and therefore steadily escalating energy prices. Those challenges are particularly pressing in developing and transition economies such as China and India, as their populations grows faster than in developed nations. Also, those countries' dependency on extraction of natural resources drives their societies away from sustainable development.

There is no way to continue on this path without developing necessary changes which take sustainability into consideration. To this end, new integrative approaches have been developed based on Sustainable Development adopted by the Conference on Environment and Development of Rio de Janeiro in 1992 in order to overcome global challenges of the 21th century by involving economic, environmental and social issues.

Among those tools, the framework of Regional Material Flow Management (RMFM) has been developed to enable the practical implementation of sustainability strategies at the regional level. RMFM pursues the optimisation of resource and energy use of single regions or communities by simultaneously creating additional added-values; which brings economic, environmental and social benefits to the regions and municipalities.

The following study attempts to analyse the Ecuadorian municipality Baños de Agua Santa located in the highlands of the Tungurahua province, in order to develop a tailored sustainability strategy. The proposed strategy would be based on the RMFM methodology under consideration of different concepts and management tools for sustainable development.

1.1 Research objectives

The main objectives of this research are: a) to elaborate a detailed material and energy flow analysis of Baños de Agua Santa (in short: Baños) located in the Tungurahua province, Ecuador; based on the RMFM methodology and related concepts, including Zero Emissions, Circular Economy, municipal solid waste management, wastewater management, sustainable tourism, sustainable agriculture and renewable energies; and b) to develop a tailored sustainability strategy for the municipality indicating sustainable optimisation potentials.

The proposed sustainability strategy should be applicable and enhance the current economic, environmental and social conditions of Baños. Thereby, among others, more specific objectives are taken into consideration:

- Examination of possibilities to reduce environmental damage and preserve biodiversity, cultural landscapes and natural ecosystems.
- Integration of political and social issues as well as policy conditions of Ecuador and the municipality.
- Valorisation of output materials (e.g. waste, wastewater) which could be turned into valuable input materials.
- Analysis and involvement of stakeholders as well as network creation.
- Identification of solutions mitigating climate change issues.
- Application of renewable energy technologies for sustainable and decentralised energy supply, which are profit-generating over time.
- Identification of win-win-situations and value-added potentials (e.g. new jobs creation, capacity building).
- Support and reinforcement of local authorities in terms of policy development, resource management, decision-making and financing.

1.2 Research boundary and limitations

It would not be possible to determine all realisable optimisation potentials for the municipality in the scheduled time frame. Therefore, the tailored sustainability strategy will present the results of a preliminary field study, and offer the suggestions for improvement deemed more feasible and relevant by the author. Moreover, the study will provide material for further elaboration of complementary sustainability strategies.

Regarding practical limitations, regional integration of sustainability strategies represent a great challenge. Several impediments arise, particularly in developing countries like Ecuador where the cost factor and environmental burden reduction are not easy to combine. Further limitations could be related to stakeholder’s unwillingness to cooperate and collaborate, lack of awareness and skills of public authorities, insufficient information and data availability, lack of environmental awareness and understanding for ecosystems and biodiversity in the society and the local community, and deficiencies in environmental legislation.

1.3 Research methodology and conceptual framework

1.3.1 Methodology

The research includes primary and secondary data sources. The theoretical framework applied during the initial part of the research basically relies on a literature review of different concepts and definitions related to sustainable development, previously discussed by researchers and experts. A significant part of the research is based on primary data due to the practical orientation of the study. This is carried out through personal communication with stakeholders and experts under the form of interviews, permanent exchange of information by electronic mail or telephone, etc. To gather all the necessary information and data an appropriate field study have been conducted. According to this, both methods imply qualitative as well as quantitative research methods.

Furthermore, the research reflects the step-by-step methodology of RMFM, determined by the German Institute for Applied Material Flow Management (IfaS) and applied in their projects, as follows (Heck, Knaus, Helling, Kato, personal communication 2010-2012):

1. Description of the target area and analysis of current situation
2. Analysis of material and energy flows (initial potential analysis)
3. Determination of target conditions (material flow master plan)
4. Identification of eligible green technologies
5. Analysis of economic profitability and sound financial mechanisms

1.3.2 Conceptual framework

In line with the abovementioned RMFM methodology guideline, the conceptual framework of the study will be structured as illustrated in Figure 1:

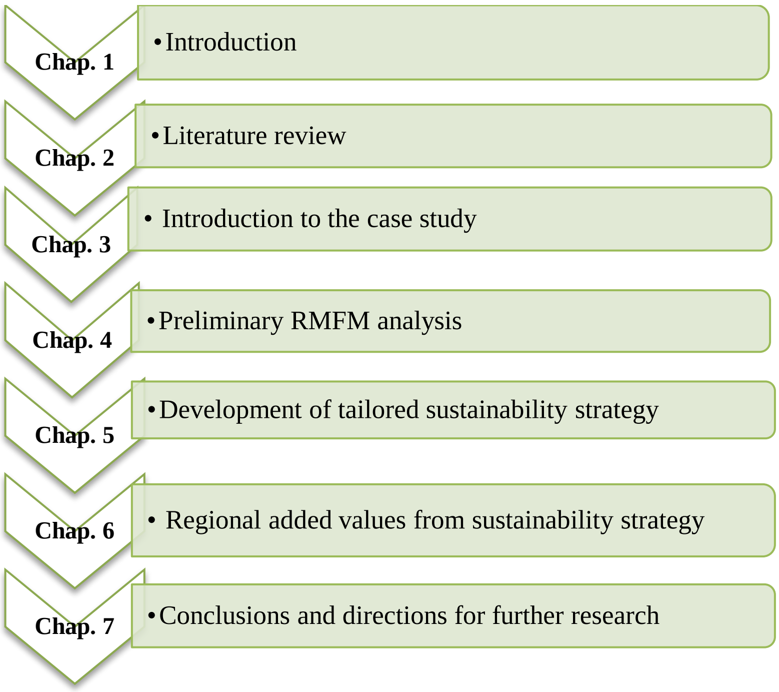


Figure 1: Conceptual framework of the research work
Source: own elaboration

According to that, the content of each chapter would be as follows:

Chapter 1: Introduction to the research field by describing research objectives, boundaries and limitations and methodological framework.

Chapter 2: Literature review on historical background and objectives of sustainable development and climate change policies. Introduction to theoretical concepts for sustainable development such has zero emission and circular economy. Description of practical oriented approaches, including management of waste, wastewater, tourism, agriculture and renewable energies; towards a holistic management approach for the municipality. This chapter defines several concepts and approaches, which in combination can build up towards a tailored sustainability strategy featuring economic, environmental and social aspects for the community of Baños de Agua Santa.

Chapter 3: Introduction and description of the case study in consideration of current political and legal conditions of the target area. This chapter also conducts a general insight view into possible existing initiatives and management strategies related to sustainability in Ecuador and the municipality.

Chapter 4: Preliminary RMFM analysis of Baños in order to identify and classify the flows and stocks of materials and energies. This analysis leads to identifying sustainable local optimisation potentials.

Chapter 5: Development of a tailored sustainability strategy based on the theoretical background and the preliminary analysis (field study) of the target region conducted in the previous chapters.

Chapter 6: Discussion of the achieved results by demonstrating potential benefits through the development of added values related to the tailored sustainability strategy.

Chapter 7: Drawing conclusion of the practical-oriented research and conducting directions for further research.

2 Literature Review

In the view of climate change and the increasing instability in global economy due to resource depletion, environmental degradation and escalating prices for energy, the development for new economic models becomes more crucial. For this reason, many nations attempt to integrate new concepts and tools into existing economic practices (business as usual applications) in order to assure future prosperity, which relies on sustainable use of materials and improves economic performance. The following subchapters attempt to give an overview of economic development approaches practiced over of the last decades towards the overall goal of sustainable development.

2.1 Concepts and management tools for Sustainable Development

In the last years, economic growth in a globalised world has accelerated by enabling international trade. It has boosted increasing consumption and production all over the world. This globalised development has generated several economic benefits for developed nations as well as for developing countries. Nonetheless, environmental concerns on exploitation of resources, in recent times reinforced by catastrophic events, have drawn the attention of the public of the need for sustainable solutions which carry on economic growth, but simultaneously protect the environment and contribute to social welfare (UNCSD, 2010).

The term Sustainable Development (SD) has been created and defined in various ways, but the best recognized definition worldwide is from the *Brundtland Report* (also known as Our Common Future). According to it, SD pursuits a development

> *"[…] that meets the needs of the present without compromising the ability of future generations to meet their own needs"* (UNCED, 1987).

Based on the *Brundtland Report* (1987), the SD concept has been adopted on the Earth Submit by the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro (1992), aka the Earth Summit; with the participation of representatives from over 180 nations. For the purpose of meeting the intergenerational needs, SD implies "a progressive transformation of economy and society" (UNCED, 1987) as a new global challenge to aspire better human living conditions. In this concern, the conference acknowledged the significance of economic and environmental synergies.

On the Earth Summit the nations present agreed on the Agenda 21 and the Rio Declaration Principles. The former is a “programme of action” which is to be carried out into the 21th century; while the latter consists of 27 principles defining the correlation between nations as well as between nations and their society. The declarations of the principles encounter for instance principles such as, particular emphasis on developing countries, recognition and support of indigenous people and their communities as they play an essential role in environmental management and development, creation of cooperation between global partnership corporation to preserve and repair the ecosystem, among others (Blanc, Liu, O’Connor, & Zubcevic, 2012).

Beyond Agenda 21 and the Rio Declarations, the following international conventions have been adopted:

- UN Framework Convention on Climate Change (UNFCCC)
- Convention on Biological Biodiversity (UNCBD)
- Convention to Combat Desertification (UNCCD)

Ten years later, as a follow-up to the Earth Summit, the World Summit on Sustainable Development (WSSD) took place in 2002 in Johannesburg (South Africa) which pointed out that, besides the environmental conservation aspect, it is essential to consider economic progress in order to improve human’s quality of life (Edwards, 2005).

To this end, the three pillars of sustainability, the so called “Three Es” (Edwards, 2005, p. 20) have been established, as depicted in Figure 2:

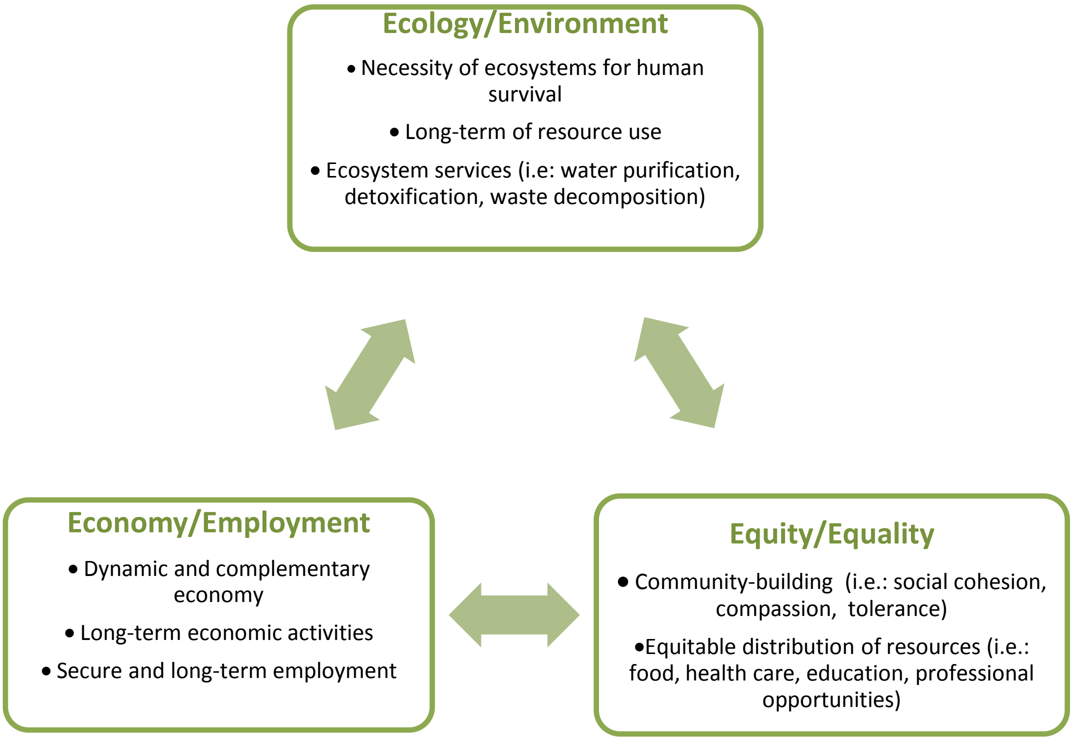


Figure 2: The "Three Es" of Sustainability
Source: own elaboration in line with (Edwards 2005, pp. 20-23)

According to Edwards (2005) the "Three Es" would be more efficacious by additionally supporting education, as it contributes to better understanding of the correlation between the environmental, economic and social aspects and the worldwide challenges.

Considering the Earth Submit and the interrelationship of the "Three Es" of sustainability, the overall SD policy on a global level emphasizes on the following main course of action (Blanc, Liu, O'Connor, & Zubcevic, 2012):

- Industrialised countries would have to alter their consumption and production behaviour model.
- Developing nations would continue their development objective but take into consideration SD means.
- Industrialised countries would commit to promote developing nations through financial support, technical transfer and adequate reforms for international economic and financial models or practice.

Regarding the abovementioned understanding and policies of SD, sustainability and SD could be in his essence summarised according to Wackernagel and Rees (1996) as: "living in material comfort and peacefully with each other within the means of nature [the so called] ecological bottom line" (Wackernagel & Rees, 1996, p. 32+38). Hence, decisions on businesses, resource utilisation and technological development have to be in conformity with this aspiration.

In order for societies to evolve their ways towards sustainable development, a number of behavioural patterns need to be also changed or adapted according to the sustainability approaches and concepts explained in the following subchapters.

2.1.1 Climate Change Policy

Greenhouse gases (GHG) released to the atmosphere, such as carbon dioxide (CO2), methane (CH4) and nitrogen oxides (NOx); have been increasing significantly in the last decades, especially since the industrialization in the 19th century, which led to globally higher temperatures. The causes of this phenomenon are regularly researched by several climatologists and related in the report of the Intergovernmental Panel on Climate Change (IPCC). The latest IPCC report results showed that the risks of Climate Change are higher than expected before. However, it is evident that the effects are most likely to be anthropogenic; there are still doubts that humans are responsible for Climate Change (Oberthühr & Ott, 1999).

The impacts of higher temperatures vary according to the geographical location, whereby some regions, mainly in the higher latitudes, are more affected than others. Dramatic consequences are forecasted and observed such as heavier storms, frequent floorings, longer droughts, loss of fragile ecosystems and wetlands, and a higher extinction rate of animal species. Significant changes are already observed in rising sea levels (around 20 cm each year), due to higher temperatures and rapidly melting ice in the Arctic Ocean (Maslin, 2007).

The abovementioned disastrous repercussions have significant impacts on society (e.g. health risks, shortage of food and water, etc), environment (e.g. forest damages, ecosystem unbalancing, extinction of species, etc) and economy (e.g. endangering agriculture, fishery, infrastructure, etc); mainly in poor countries.

Table 1 lists the main emitters of GHG emissions. According to these estimations, the main players are China, United States, the European Union and India. However, in terms of emissions per capita the main emitters are Australia, U.S., Canada followed by Russia and EU.

Table 1: Greenhouse gas emissions of the main players

Country	Population 2011 (billion)	Total annual GHG emission estimations (in billion t)	GHG emissions per capita (t per capita)
China	1,34	8,2	6,12
US	0,31	5,49	17,71
EU	0,50	4,72	9,44
India	1,21	2,06	1,70
Russia	0,14	1,68	12,00
Japan	0,13	1,13	8,69
Canada	0,03	0,518	17,27
Indonesia	0,25	0,476	1,90
Brazil	0,21	0,419	2,00
Australia	0,02	0,365	18,25

Source: own elaboration based on data from (CIA, 2012; Allianz, 2013)

Therefore the Kyoto Protocol, as the first international agreement on Climate Change, was adopted 1997 in Kyoto (Japan) together with the United Nations Framework Conversion on Climate Change (UNFCCC) in order to reduce around 5.2% of the global GHG emission compared to 1990 levels during the core commitment period 2008-2012. “As such it was intended to be a first step towards a long term, but still unspecified objective” (Aldy & Stavins, 2007, p. 8). After several years of negotiations and agreements finally in 2005 the KP entered into force, binding legally industrialised countries (Annex I countries) who committed themselves to reduce GHG emissions below 1990 levels, whereby the United States did not take part on this agreement.

Under the KP three different flexible mechanisms have been created for Annex I countries (industrialised countries) to achieve the commitment targets with higher cost effectiveness, apart from domestic reduction efforts. Thus, industrialised countries can develop projects among each other under the Joint Implementation (JI) mechanism or can carry out projects in developing countries under the Clean Development Mechanism (CDM). The CDM is the only mechanism which allows developing countries to take part in the global reduction efforts of the KP and enables them to profit from technology transfer and financial support. Additionally, Annex I countries can trade their surplus of emission allowances in an international emission market (UNFCCC, United Nations Framework Conversion on Climate Change, 2013).

After the expiration of the first commitment period, when most of the committed countries did not achieve their stated objectives, one question still remains: “What systems of governance will promise to deliver the steering mechanism needed to achieve drastic cuts in greenhouse gas emissions?” (Biermann, Pattberg, & Zelli, 2010, p.1). Therefore, new expectations towards enhanced climate mitigation actions and strategies have been initiated in order to maintain the global temperature increase below 2 degrees and avoid dramatic consequences with significant impacts on society, environment and economy.

2.1.2 Systems thinking − a sustainability principle

“Thinking in Systems” is an essential instrument to deal with behavioural patterns in today’s complex and changing world. According to Wright & Meadows (2009), it is a helpful tool not only to recognize the origin of problems and deal with them, but also to identify new possibilities. Therefore, systems (i.e. molecule, cell, person, company, school, city, municipality, region, etc) consist of a set of components which are connected and interact with one another (Kato, 2012).

Figure 3 illustrates the complexity of a system consisting of subsystems which have their own components and correlate to each other. The system boundary isolates and defines the system to the outer world (environment). In reality there is no isolation between a system and its environment due to the influences through input-output events in form of materials, energies and information (Jackson, 2003).

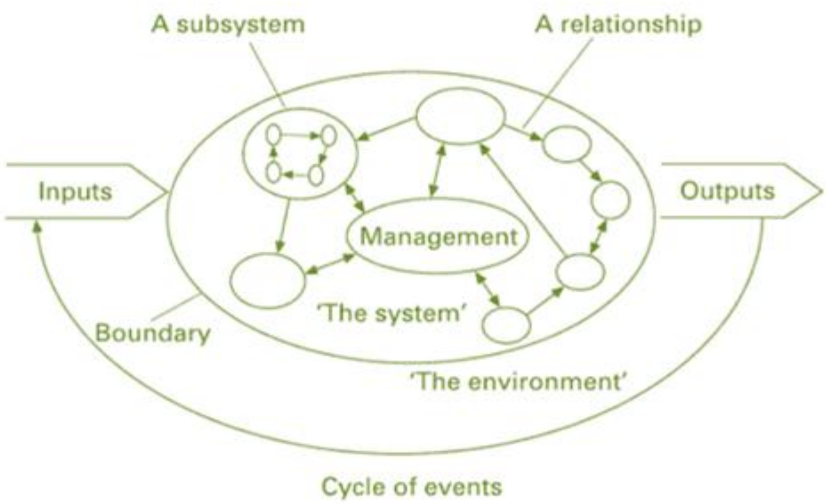


Figure 3: Biology and interaction of systems
Source: (Jackson, 2003, p. 6)

Thus, an outside occurrence could influence a system's behaviour in a given way, but eventually differently on another system depending on the individual way of each system to act in response to an outer influence. In respect thereof, for a system thinker, it is essential to comprehend a system as a whole as well as the relationship of the components within it. This is usually not easy to identify, because a system's function/purpose is usually not obviously shown and the needed information for it is not always directly accessible. That is why the behaviour of the elements within the system has to be understood in order to understand the purpose of the system (Wright & Meadows, 2009).
For instance, a better understanding of systems thinking provides the common speech: "Don't miss the forest for the trees" introduced by Brown & Lerch (2008, p. 79). It reflects how system thinking perceives systems, namely that it considers the whole forest and not only the trees. Forests consist of several parts (i.e. trees, soil, water, animals, etc) which are in reciprocal relationship.

Furthermore, systems have the resilience to overcome disturbances due to its feedback loops which can either reinforce a system (reinforcing loop) or bring it back to its balanced state (balancing loop) (Bellinger, 2004). Based on this viewpoint, a system could not be seen as linear but as "a diverse system with multiple pathways and redundancies [which] is more stable and less vulnerable to external shock than a uniform system with little diversity" (Wright & Meadows, 2009, p. 3).

The whole systems thinking approach is founded by the following perception aspects which combined together enable systems thinkers the management of systems (Gharajedaghi, 2011, p. 23):

- Holistic Thinking: integration of structure, function, process and context
- Operation Thinking: dynamics of multi-loop feedback systems (chaos and complexity)
- Design Thinking: creating feasible whole from infeasible parts
- Sociocultural Model: movement toward predefined order (self organization)

By applying the systems thinking approach, it is possible to understand how systems work and why they work in a certain way. Once this is clear, it is possible to identify leverage points of a system. They indicate specific influences/issues which could be stimulated in order to cause essential changes. In this consideration, systems thinking leads to optimization approaches of the entire system (Bellinger, 2004).

In the case of municipalities and regions, system thinking in combination with stakeholder management and networking is a key tool for a desirable shift towards sustainability.

2.1.3 Zero Emissions

Zero Emissions (ZE) is an innovative and interdisciplinary concept which integrates SD approaches into businesses and industries. It has been founded by Gunter Pauli through the global Zero Emissions Research and Initiative (ZERI) network at the United Nations University (UNU) in 1994 as a proposal to the Agenda 21 of the Rio Conference (1992).

According to Pauli (1998), ZE reflects the ideology of a natural cycle: "nothing will be wasted […], residues can either be re-used within the industry's own activities, or as a value-added input for other industries" (Pauli, 1998, p. 70). That means that ZE enables the usage of waste or by-products of one business as an input material/energy for another business. This is achieved by establishing collaborations across different industries/sectors. For this reason, the ZE conception represents an industrial evolutionary development shifted from pollution and emission control solutions (End-of-the-Pipe) over redesigning processes to avoid pollution/emissions (Cleaner Production) to the utilisation of output products as input materials or energies (Zero Emissions), illustrated in Figure 4:

Figure 4: Industrial evolution for emission and pollution control and reduction
Source: own elaboration in line with (UNU/ZEF, 2002)

Hence, ZE goes beyond the abovementioned End-of-pipe and Cleaner Production solutions, because it “represents the ultimate solution to pollution problems that threaten ecosystems” (UNU/ZEF, 2002), as waste is re-utilized as raw material to its maximum, reducing resource consumption and emissions to the environment. To this effect, waste becomes a resource.

According to the Zero Emissions Research Institute (ZERI), ZE approach could be achieved through taking into consideration processes from nature, improving resource efficiency and clustering industries (iisd, 2013). Therefore, industries have to activate their symbiotic relationship to each other in order to satisfy their needs of raw materials and energy. In conformity with Pauli (1998), industrial clusters are networks between businesses aiming to create added values from waste streams or by-products, which usually are considered as valueless materials, but through their exchange across different sectors, those valueless output materials from one sector become valuable input material for another (according to the ZE concept). The generation of added-values, as the main purpose of ZE, leads directly to “upsizing” industries through increased productivity of resources, investments and at the same time reinforces competitiveness and new business opportunities (**see Box 1**). To this end, additional added-values are the creation of new jobs and the reduction of impacts to the environment (Pauli, 1998).

Box 1: ZE and Upsizing of brewing industry

Conventional breweries produce mainly organic waste and consume huge quantities of water (one litre of beer requires more than 20 litres of water) and energy. The organic waste represents a negative added-value as the breweries have to pay for the disposal. According to ZE concept, the organic matter should be seen as a valuable material due to high fibre, nutritional and protein-rich content, obtained from the grains after the brewing process. Taking this into consideration under the “cascading” principle it could be identified that those contents could be utilized in bakeries replacing flour to produce bread. Optional, the fibre could be mixed up with other fibres and employed for the cultivation of mushrooms, which represent a worldwide growing market. The mushrooms are used as supplementary food for livestock as they have the ability to make grains more digestible and additionally provide more protein which supports livestock growth with improved meat quality.

As a further step, the waste water from the breweries is added to a biogas plant[1] (digester) together with the livestock manure in order to generate biogas and nutritional substrate. The biogas could either be sold or used in the brewery itself for energy generation. The nutritional substrate is photosynthesized by algae in a basin which on the other hand represent natural food for fishes.

This ZE strategy has been implemented successfully by several breweries in Namibia, Canada, Sweden and Japan, which have created additional value added by processing the organic waste and creating clusters with livestock and fishery industry.

Source: (ZERI, 2012)

On this background, ZE conception is particularity applied to industries and business and is *de facto* similar to the Industrial Symbiosis (IS) approach, a division of Industrial Ecology (IE)[2]. IS, as defined by Chertow M.R. (2000), “engages traditionally separate entities in a collective approach to competitive advantage involving physical exchange of materials, energy, water, and by-products” (Chertow, 2007, p. 12). To this effect, both, ZE and IE, aim cooperation between businesses and make use of the synergies within their geographical site location, whereby the creation of Eco-Industrial Parks is associated to IE.

Besides the industrial application of ZE, the concept idea has been adapted on national and regional levels. Therefore, a new economic conception is developed: “Circular Economy”, which is explained in the next subchapter.

2.1.3 Circular Economy − Green Economy

Circular Economy (CE) has gained importance worldwide in the recent years, as a more sophisticated economic approach supporting SD realisation. It derives from the ZE concept, but is applied on whole economies on a national, regional or local level by additionally considering legal and governmental policy features as well as dynamic economic models. For instance, the Chinese National Development and Reform

[1] In a biogas plant organic matter is digested by microorganisms in the absence of oxygen (anaerobic process). The resulting bio gas consists of around 60% methane (CH4) which is utilized for energy generation (FNR, 2013).

[2] Industrial Ecology (IE) perceives industrial systems as natural ecosystems. It firstly introduced in the 1970s, implying a detailed understanding of both systems (i.e. how they function, how they interact, etc.) in order to restructure industries according to natural ecosystems (Erkman, 1997).

Commission (NDRC) adopted the CE approach in their national five year plan due to the high pollution, energy consumption and resource depletion rates.

CE is characterised for resource and energy efficiency as well as emission and pollution reduction (UNEP, 2012a.). In respect to this, CE refers to economies whose vision is oriented to ecosystem-based natural models in which materials (biomass, waste and energy) are not wasted but re-circulate within a region. Therefore, the CE concept incorporates the 3R principles "Reduce, Reuse and Recycle" (Jia & Zhang, 2011, p. 637), in order to reduce input materials (consumption of resources), reuse goods and recycle output materials. To this end, conventional linear models (Throughput Economy) are transformed to closed loop systems (Circular Economy), as illustrated in Figure 5.

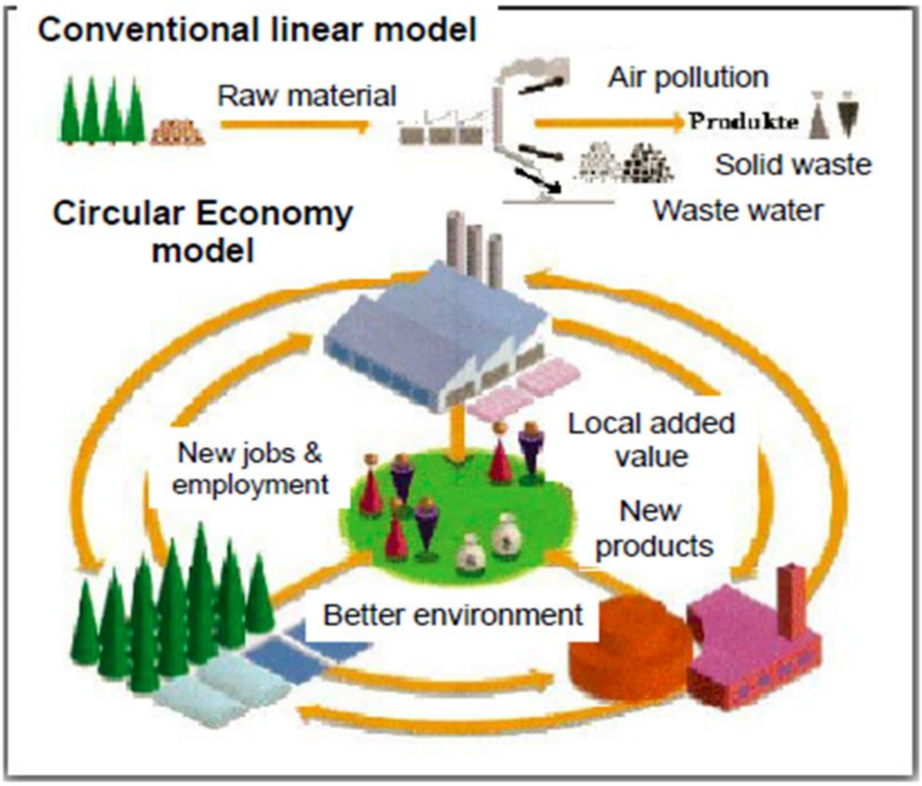


Figure 5: Conventional linear model versus ZE model
Source: (Pauli, 1998, p. 100) modified by IfaS (2010)

As depicted in Figure 5, CE encompasses economic (added-value generation and new product creation) with environmental (nature and resource preservation) and social (new job foundation and job maintenance) aspects. Under this consideration, the objectives of CE are as follows (MUFV, 2008; P. Heck, 2006):

- Conservation of the environment, resources and natural sinks
- Protection of cultural areas and intact nature
- Minimisation of material and energy supply dependency
- Reduction of operational cost (energy, water etc.) and raw material purchase
- Augmentation of regional purchasing power
- Creation and maintenance of regional employment
- Development of networks
- Enhancement of economic competitiveness
- Promotion of regional products

A particular issue related to CE is energy, which according to the abovementioned objective, should be generated in a decentralised manner, independently from external suppliers. Therefore, energy production should be based on renewable energy sources (P. Heck, 2006).

The implementation of a CE approach requires practical approaches with a well defined methodology including SD goals. One of the sophisticated instruments available is Regional Material Flow Management (RMFM), which has demonstrated great ability to deal with future challenges by tackling the turning point. RMFM enables the shift of a throughput society to circular economy on microeconomic (industrial) as well as on macroeconomic (regional) levels through analysing efficiency potentials and green business opportunities (Figure 6).

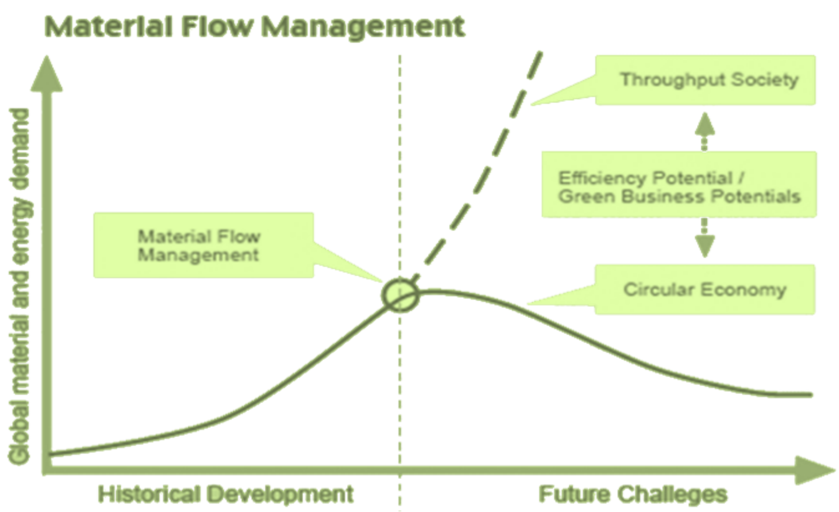


Figure 6: MFM's contribution to Circular Economy
Source: (IfaS, 2010)

The practical application of CE through RMFM has been effectively adopted and carried out by German Ministries in the state of Rhineland-Palatinate (RLP) (see Box 2) as well as by individual companies and communities.

Box 2: Case study on the CE state of Rhineland-Palatinate (Germany)
The German Ministry of Environment, Forests and Consumer Protection (MUFV) and the Ministry for the Economy, Commerce, Agriculture and Viticulture (MWKEL) of Rhineland-Palatinate (RLP) in Mainz implemented successfully the CE concept all over the State through the RMFM approach, in order to combine economic growth with environmental protection aspects. To achieve this, the government emphasizes on the optimisation of material and energy flows within the state under the consideration of resource efficiency and waste management strategies. For the realisation of CE, RLP takes into account natural ecosystem cycles and material flow management tools on regional, communal and industrial level as well as the following application instruments: • **PIUS/CP**: The product integrated environmental protection tool (PIUS, German: Produktintegrierte Umweltschutz), internationally known as Cleaner Production (CP), particularly aims to "the continuous application of an integrated preventive environmental strategy applied to processes, products, and services to increase eco-efficiency and reduce risks to humans and the environment" (UNEP, 2002, p. 5). Therefore, PIUS is an integrated approach of the Environmental Management System (EMS) of an organization. To this end, the state of RLP offers to small and medium sized companies, verification services of the production processes and industrial facilities and provides an information website with guidelines, studies, check lists, expert discussions and informative reports of projects. • **EffNet**: The Efficiency Network Rhineland-Palatinate (EffNet) is a platform developed in co-operation between the ministries for environment and economy of RLP in order to offer consulting services of experts and nominated institutions, efficiency checks particularly in medium sized enterprises and benchmarking in the areas of raw materials, energy efficiency, etc. • **Energy Efficient Buildings**: The state of RLP supports the construction of energy efficient buildings (i.e. energy plus houses with the integration of photo-voltaic and heat pumps) as well as the implementation of energy and material efficiency checks of buildings which could lead to energy saving of around 80%. • **Renewable Energies:** Several innovative companies have been established in RLP which produces renewable energy technologies for the regional as well as for the international market. • **Waste prevention** and constitution of a **recycling society**: Under the EU Waste Framework Directive the state of RLP included the aspect of waste prevention (overall objective in the waste hierarchy programme of the EU Commission) in the waste management strategies and set the goal of establishing a recycling society. Of particular consideration is the utilisation and the energy recovery of waste in order to protect the environment, reduce the dependency of raw material suppliers, create new jobs and generate new added value. • Liquid waste and sewage water: The government of RLP advocates sustainable and natural wastewater treatment facilities such as constructed wetland treatment plants in sparsely inhabited areas and in more populated areas.
Source: (MUFV, 2008; Jung, 2010; UNEP, 2002)

The following subchapter attempts to provide a detailed overview of the RMFM concept and framework, on whose methodology this study relies on.

2.2 Regional material flow management

Material resources such as minerals, agricultural soil, wood, chemicals, fuels, agricultural products and livestock are exploited or harvested from the environment for worldwide economic wealth and growth. The utilisation of these resources demands high energy consumption for mining, extraction, cultivation, production processes, transportation, provision of goods and final disposal. Additionally, all the abovementioned processes cause high pressure on the environment (e.g. heavily contributing to climate change). According to projections related to population growth and economic development, material utilisation and energy consumption, as well as environmental degradation, would continue to accelerate dramatically in the future. It is for this reason that materials flowing through economies have to be managed in a sustainable and efficient manner. Therefore, the framework of regional material flow management has been developed to tackle this issue on an industrial or regional level as explained in the following subchapter.

2.2.1 Defining RMFM

The management of materials derives from two background aspects (Philipp Schepelmann 1997-2004 and Bringezu, Moll, and Schütz 2002):

- 1970-1980s: Minimisation or elimination of harmful substances and pollution to the environment (detoxification).
- 1990s: Augmentation of resource efficiency by reducing raw material input through unlinking economic growth and material utilisation (dematerialization).

To this end, an approach has been developed as a multidisciplinary tool to facilitate the practical deployment of CE approaches, reflected in the definition by the Commission of Inquiry of the 12th Deutsche Bundestag in 1994 on the "Protection of Mankind and Environment" of material flow management (MFM):

> *"Management of material flows by the involved stakeholders refers to the objective-oriented, responsible, integrated and efficient controlling of*

material systems, with the objectives arising from both the economic and ecological sector and with the inclusion of social aspects" (Enquete-Kommission, 1994, p. 549).

Generally, MFM means the examination and optimal handling of material and energy streams resulting from production processes and allocation of services within a specific system boundary such as for example: a) internal process of a company, b) entire company, c) supplier liaison along a value added chain (across companies), d) entire value added chain, e) region or f) a whole nation (supraregional) (Bernd & Enzler, 2005).

According to Cencic & Rechberger (2008), MFM conducts an input/output analysis, by means of a Material Flow Analysis (MFA) of material flows and stocks. MFA attempts to determine input materials (i.e. fossil fuels, minerals, biomass) of a system which could either leave a system as output materials (i.e. waste, waste water, emissions), accumulate as "physical growth" (P. Heck, 2006, p. 14) or persist in the system through recycling. Therefore, the balance equation of material flows within a system is the sum of material inflows which result from the sum of all material outflows and the change in stock, as indicated in Equation 1. From an economic viewpoint, MFA could also be defined as monetary value flows (Baccini & Brunner, 1991).

$$\sum inputs = \sum outputs + change\ in\ stock$$ **Equation 1**

Regarding MFM on a regional level it is referred to as Regional Material Flow Management (RMFM), which pursues the optimisation of resource utilisation of single regions or communities by simultaneously creating additional added-values; which brings economic, environmental and social benefits to the regions or municipalities. It includes Circular Economy strategies aiming to decentralise activities.

Usually, conventional linear economies (throughput societies) neglect their own native potentials, making them dependent on resources from outside their boundaries. The result is an unsustainable and economically inefficient development of a region on a long term perspective. But the performance of a regional MFA, and thereby the creation of a tailored RMFM strategies adapted to local conditions, reduces the dependency on material and energy imports by activating regional resources/potentials (Figure 7).

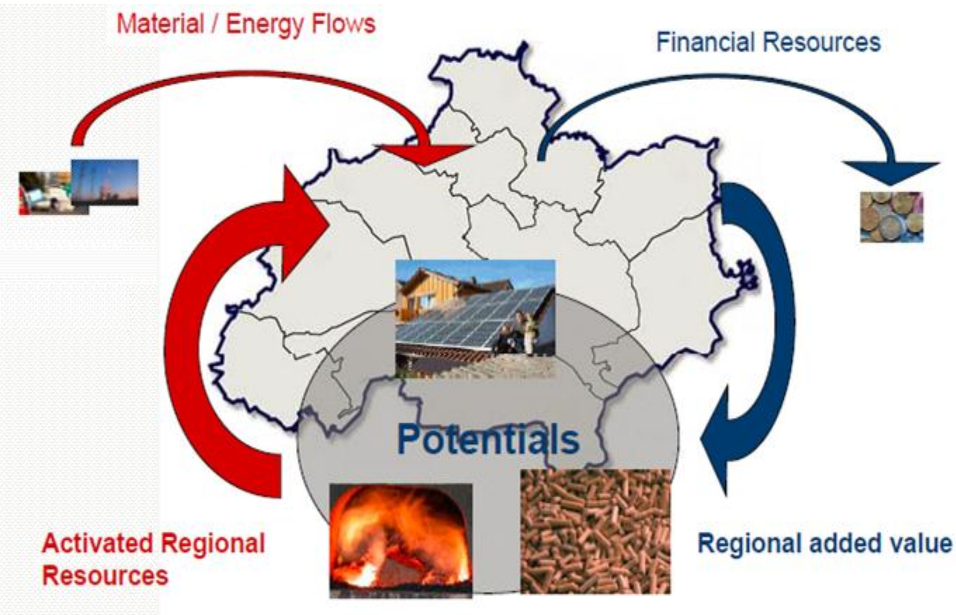


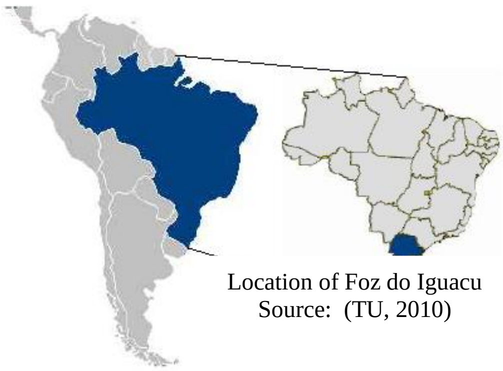
Figure 7: RMFM approach considering CE
Source: (IfaS, 2010)

According to this, regional potentials could be identified inter alia in wastes (municipal solid waste, fats, oils, waste water, etc), fossil energy sources, renewable energies; infrastructure, agriculture, and tourism. By considering those potentials, regional added-value is generated leading to increased financial resources and decentralised energy and material supply within the region. More employment could be created enhancing regional purchasing power and competitiveness in global markets. Under RMFM economic and social improvements are combined with environmental protection aspects and pollution reductions to soils, water bodies and atmosphere through the integration of clean technologies and taking into account natural cycles (Heck, Peter; Helling, Klaus; Weinbub, Iris, 2005).

To achieve the above mentioned circular based regional economy, RMFM encompasses, besides MFA, also stakeholder analysis and networks creation in order to establish co-operation between decision makers and generate win-win situations. This enables a broad range of applications and improvement of systems as a whole (Bernd & Enzler, 2005). This approach has been successfully implemented in various countries particularly in developing and least developed countries (Box 3).

In respect to MFA under consideration of environmental aspects, material and energy flows are measured bearing in mind "thermodynamic laws of conservation and entropy of energy and matter [in order] to assess the pressure of such throughput on the carrying capacity of natural systems" (P. Heck, 2006, p. 14).

Box 3: RMFM application at the region Foz do Iguaçu, Brazil



Location of Foz do Iguacu
Source: (TU, 2010)

Foz do Iguaçu is located at the state of Paraná of Brazil at the border to Paraguay and Argentina with around 310 000 inhabitants. The region is frequently visited by tourist due to the popular Iguaçu Falls "Cataratas do Iguaçu" and the Iguaçu National Park.

After carrying out a broad analysis of the region (location, population, climate, economic and environmental situation etc.) as well as a MFA analysis (e.g. MSW, landfill, free market, waste water, public transportation, fossil fuels, etc) of the city and the national park according to RMFM methodology, several regional potentials could be identified in order to optimize the material flows, contribute to value added generation, produce renewable energies and mitigate climate change. Therefore, options for improvements are as follows:

- **Zero Emission visitor centre (VC):** Transformation of the existing VC at the entrance of the national park to a Zero Emission VC to sensitize and educate visitors about environmental concerns and nature conservation practices. Furthermore, the installation of innovative renewable energies such as photovoltaics (for electricity generation) and solar collector systems (for cooling) would lead self-sufficiency of the VC and CO2-emission reductions. The produced electricity would be used for installed LED lights of the Zero Emission VC as well as for electric vehicles and scooters of the employees within the park as an eco-friendly transportation option. The conventional air cooling systems would be replaced by solar cooling units. Additionally, constructed wet land treatment plants are installed in order to treat waste water (toilet, kitchen etc.) from the VC. Furthermore, rain water collection systems would be implemented for irrigation and toilet flashing purposes.
- **Oil mill and biogas plant:** Installation of an oil mill to produce regional vegetable oil from available oil plants (e.g. linseed oil, sun flowers, soy-beans) cultivated at the buffer zone of the national park which is sold as a regional product. Next to the oil mill, a biogas plant would be installed, in which the press-cake, a by-product of the oil mill plant, would be processed together with the organic waste (around 50% of total product waste of the region coming from domestic households, hotels, restaurants etc.) into biogas and energy through CHP technology. Optional the biogas could be used as fuel for public buses.
- **Street lighting in the Foz do Iguacu**: the overall electricity consumption of Foz do Iguacu could be reduced by changing the conventional street light bulbs to energy saving LED lights. This technology in Foz do Iguaçu has, additionally, CO2 saving potentials of around 3 000 t per annum.

Source: (TU project of IfaS, 2010)

2.2.2 Benefits through RMFM

There is a broad range of RMFM benefits which are specific for each region, whereby generally it highlights regional value-added benefits in the following sustainability aspects described in Table 2.

Table 2: Added value benefits through RMFM

Benefits Criteria		Benefits Description
Economical added value	Cost efficiency	Reduction of operational and material expenses
		Utilisation of resources to their full economic potential
		Reduction of purchase costs
	Sustainable Financing	Provision of sound financial mechanisms and sources
		Identification of existing funding sources and financial gaps
		Creation of more financial transparency
		Accessibility to financial information and support in financial decision making
	Regional Development	Promotion of innovation and enhancement of competitiveness
		Facilitation of decentralised and sustainable economy development
		Establishment of Win-Win situations
		Activation of local resources and energies
		Enhancement of product quality and sustainable productivity
		Support innovative small and middle enterprises (SME)
		Establishment of regional net products
		Minimisation of outflows of purchasing power
		Development of networks between potential stakeholders
		Creation of new jobs and maintenance of existing jobs
	Resource and energy optimization	Optimization of material utilisation through separation of secondary raw materials
		Enabling energy efficiency
		Support of technology innovation and technology-efficiency
		Promotion of clean technologies and renewable energies
		Diminish dependency on resource and energy suppliers through decentralisation
		Realisation of energy efficient buildings (heat recovery, PV and solar thermal installation, daylight guidance system, facade integrated PV, etc.)
		Enabling resource recovery
	Knowledge Transfer	Figure out opportunities to stimulate and improve business
		Recognition of qualified management potentials
		Provides relevant research and skills

	Benefits Criteria	Benefits Description
Environmental added valve	Climate Change mitigation	Reduction of harmful green-house gases (GHG) emissions Consideration of CO2 neutral production processes
	Environmental protection	Conservation of ecosystems Protection of biodiversity (habitat for animal and plant species) Reduction of harmful substances and pollution to the environment Preservation of environmental sources and sinks Stabilisation of unspoiled nature and maintenance of cultural areas Minimization of final disposal areas (waste landfills, dump sites etc.)
	Bioenergy and alternative energies	Generation of renewable energies (solar-, bio-, hydro-, wind energy) Reduction of exploitation of non-renewable energies Utilisation of biomass as fertiliser, soil conditioner or for energy purposes
	Agroforestry/ sustainable land use	Promotion of sustainable agricultural practices and land use utilisation Restoration of soil nutrients and soil biota Preservation of wildlife
Social added value	Quality of life	Enhancement of quality of life Ameliorations of social living and working conditions (insurance, health system etc.) Improvement of sanitary facilities and drinking water sources
	Capacity building	Improvements of educational system Establishment of public relation and training Creation of networks to enhance and support capacity building
	Citizen participation	Reinforcement of communal responsibilities and participation Strengthening of communal spirit and feeling of solidarity Creation of new possibilities of income and training
	Integration of social groups	Integration and legalisation of the activities of the informal sector (waste pickers) Consideration of most vulnerable social groups
	Food Security	Security of food and water provision Reduction of undernourishment in vulnerable countries

Source: own elaboration base d on (Heck, Peter; Bemmann, Ulrich, 2002, p. 20; Heck, Peter; Helling, Klaus; Weinbub, Iris, 2005)

2.2.3 Methodology of RMFM

There is no standardised theoretical methodology of RMFM which provides a well defined method for implementation, as each case has to be undertaken individually in line with specific local conditions and interests. The more practical oriented RMFM methodology applied in this study has been carried out by the German Institute for Applied Material Flow Management (IfaS) and taught in various countries by the International Material Flow Management (IMAT) programme, as a sophisticated methodology, effectively implemented in diverse projects worldwide, as illustrated in the Figure 8 and subsequently explained.

1. Preliminary analysis of the region		
Current situation analysis • Policies • Legacy • Economy • Environment	Stakeholder Analysis • Key stakeholders • Decision makers • Economic drivers • Institutions	Management Approaches • Municipal Solid Waste Management • Waste Water Management • Energy Management • Environmental Management

↓

2. Material Flow Analysis (MFA)			
Definition of potential material and energy flows within the system	Quantities of defined material and energy flows	Qualities of defined material flows	Place of Origin/Logistics of defined material flows

↓

3. Potential Analysis		
Efficiency Potentials	Sufficiency Potentials	Clean technology potentials

↓

4. Master Plan (projects portfolio)		
Business planning and financing	Joint-Venture(s)	Environmental impact assessment

↓

5. RMFM holding and project implementation

Figure 8: RMFM Methodology
Source: own elaboration based on IMAT lectures by Heck, Knaus, Helling, Kato (2011-2012)

1. ***Preliminary analysis of the region:*** initially, the target region or community as a system has to be preliminarily analysed considering inter alia political, legal, economical and environmental development aspects. Additionally, stakeholders such as decision makers, economic players and institutions have to be identified and involved along the whole investigation process. In this respect, it is possible to find out existing urban management systems concerning waste, waste water, energy, environment etc. and possible optimisation potentials.
2. ***Material Flow Analysis (MFA):*** a step further involves a broad MFA analysis incorporating firstly an overall description of the material and energy flows within the region or communities which subsequently leads to a more specific

analysis according to the quantity and quality of the of energy and material flows as well as their place of origin, including logistics and infrastructure.

3. ***Potential Analysis:*** the previously described MFA enables the identification of optimisation potentials within the region or community considering efficiency, sufficiency as well as clean technology aspects in order to achieve renewable energy supply, energy and costs savings, optimal resource allocation, efficient utilisation of energy and resources, reduction of emissions etc. Those findings are integrated in RMFM strategic development defined as projects ideas.
4. ***Master Plan (project portfolio):*** the master plan represents a project portfolio indicating several strategies for optimising material and energy flows in order to generate social, economic and environmental regional added value which are based on the previous findings through MFA and optimisation analysis. This project portfolio includes business planning and financing possibilities for the implementation of RMFM strategies under consideration of environmental impact assessment as well as joint-venture(s) opportunities.
5. ***RMFM holding and project implementation:*** after negotiations with project partners (i.e. stakeholders, institutions, companies) concerning responsibilities and financial provision, the eligible projects in the frame of the RMFM master plan are carried out and monitored during a defined period of time.

The practical application of the RMFM methodology in projects has always to take into consideration the following aspects (Heck, Peter; Helling, Klaus; Weinbub, Iris, 2005, p. 8):

- “Enabling policy framework and appropriate institutional arrangements,
- Cost-effective technologies,
- Sound financial mechanisms”

2.3 Dimensions of material flow management

2.3.1 Sustainable waste management

Waste is defined by the Waste Framework Directive (WFD) of the European Commission as “any substance or object the holder discards, intends to discard or is required to discard” (Directive 2008/98/EC). Typical disposal methods are landfills which require large areas of land, cause significant environmental problems such as climate change due to methane generation from the organic waste and are costly.

The increasing amount of solid waste worldwide is strongly influenced by two factors: a) constantly increasing population, which will reach around 9 billion people in 2050 according to estimations from the UN Population Division, and b) the Gross Domestic Product (GDP) related to income which according to estimations from OECD countries has demonstrated that “1% increase in national income creates a 0.69% increase in municipal solid waste amount” (Mavropoulos, 2011). An additional global waste management issue is the changing composition and complexity of waste streams. In the last few years the amount of e-waste (electronic waste) such as computers, televisions, cell phones have been rising rapidly. This kind of waste can reach globally up to 50 million tonnes (ScienceDaily, 2009).

Regarding the worldwide issues related to solid waste the integrative approach of Sustainable Waste Management (SWM) has been developed. It integrates the three pillars of SD in the sense of “environmentally effective, economically affordable and socially acceptable” (McDougall & Franke, 2001, p. 18) explained as follows:

- Environmentally effective: emphasises on the mitigation of environmental burden and air pollution as much as possible as well as protection of the environment against hazardous substances.
- Economically affordable: refers to the costs which are needed in order to implement sustainable management strategies. The strategies have to be playable by a community and the society and it should not surmount already existing waste treatment costs.
- Socially acceptable: means management conditions that are compatible with specific needs of the society by conducting communication strategies in order to exchange information and educate people.

The three sustainable aspects take the whole regarded system into consideration and develop methods which are modelled according to the needs of a municipality or region including the best suitable collection, treatment and disposal techniques. SWM strategies assume that there are huge potentials to convert waste into useful materials or energy with an appropriate waste management.

To promote and achieve a SWM conception two initiatives are developed a) Waste Hierarchy and b) Zero Waste which are explained as follows:

a) Waste Hierarchy

It has been adopted by the EU Directive 2008/98/EC of the EU Commission based on management skills, which prevents environmental damage and human health risks and risks to "water, air, soil, plants or animals, without causing a nuisance through noise or odours" (EU Commision, 2012). The aim of the waste hierarchy is to use the maximum of a product and produce the minimum amount of waste. The figure below indicates a hierarchy consisting of five levels on which waste management strategies should be build on. The best solution would be to prevent as much as possible that products become waste. If this could not be avoided then the following levels should be considered. The re-use of waste as a resource for example in manufacturing processes is much better than waste recycling or recovery, which is again better than final disposal. In this sense, disposal should be the last option taking into account safety and appropriate measurements.

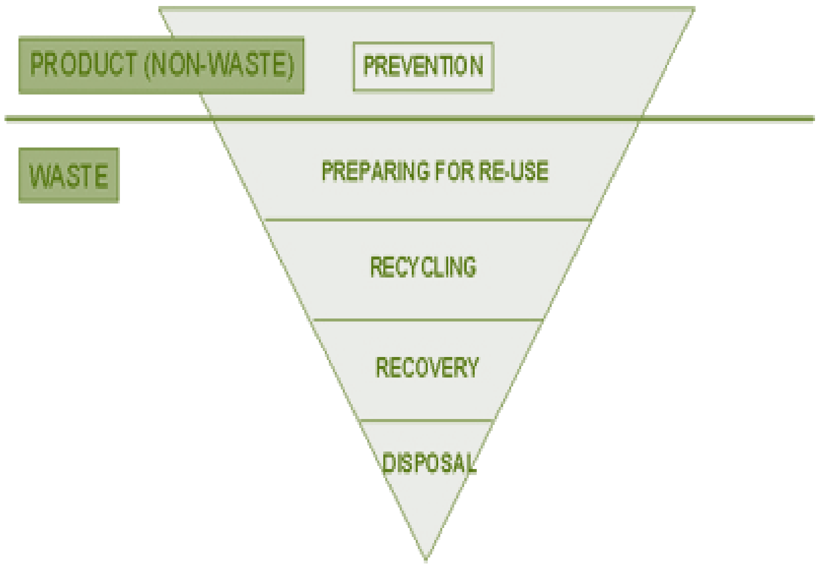


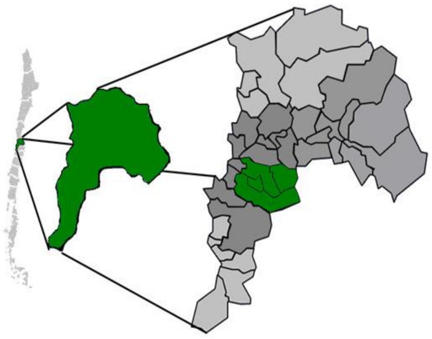
Figure 9: Waste Hierarchy by the EU Directive
Source: (EU Commission, 2012)

b) Zero Waste

This strategy takes inspiration from nature by examining nature processes (nature as a model). Nature does not produce waste because "waste of one organism becomes food for another" (Hitchcock & Willard, 2006, p. 70). This can be for example observed in trees. In autumn the leaves fall down onto the soil and are processed by microorganisms to humus. In spring time the leaves grow again. In this sense, Zero Waste principle intends to see waste as by-products which can be converted into resources or which already represent a resource. The strategies connected to this concept consider the life cycle thinking of materials in a closed-loop system.

Waste can be classified in different ways as the composition of waste can be distinct from country to country. But the best known methods of waste classification are by their biological, chemical and physical characteristics. According to these, appropriate technologies for different treatment methods can be selected (see Box 4). The selection of alternative technologies implies assessment measurements and evaluation methods in order to mitigate environmental impacts and determine applicability in different regions and conditions.

Box 4: Waste Treatment Centre Marga-Marga, Valparaiso, Chile



Location of Marga-Marga
Source: (IfaS, 2010)

The municipal solid waste management, namely CIDITEC at the region of Marga-Marga in Valparaíso/Chile (including four municipalities: Limanche, Olmué, Quilpué and Villa Alemana), is carried out by the German Institute of Applied Material Flow Management (IfaS) under the patronage of the German Federal Ministry of Environment, Nature conservation and nuclear safety (BMU).

Currently, around 100 000 tons of solid waste is produced annually with an increase rate of 2.7%. Thereof, around 50% is organic waste. The four municipalities spend high costs on transportation and final disposal due to long distances to the landfill. Additional issues are: emissions and pollution through landfilling, low recycling rate, lacking technical know-how and information about waste composition, no material utilisation and energy recovery of different waste fractions and therefore no generation of additional added-value. Additionally, this sector consists as well of an informal sector, the waste pickers, who work under poor working conditions.

After an extensive sampling, sorting, collecting, analysing and characterising the waste fractions at the landfill of the region, IfaS and partners on-site came to the conclusion of implementing a waste treatment centre based on mechanical-biological treatment techniques, whereby the mechanical treatment includes manual pre-sorting and trommel technology for the separation of materials; and the biological treatment of the organic fraction incorporates hydro mechanical pre-treatment as well as either aerobic digestion for composting or anaerobic digestion for biogas generation and additional composting.

The resulting benefits for the region are inter alia as follows:

- Generation of renewable energies through biogas
- Production of high qualitative compost
- Revenue-generation of the recyclables
- Creation of new jobs
- Integration of the informal sector (waste pickers)
- Mitigation of Climate Change and Environmental protection
- Enhancement of the social conditions (health system, labour conditions) as well as living conditions
- Transfer of know-how and capacity building

Source: (IfaS, 2010 b.); (IMAT lecture, Martínez-Gómez, 2013)

2.3.2 Sustainable wastewater management

Worldwide around 1.4 billion km^3 water is available, whereby freshwater resources represent only 2.5% of which around 69.7% of consist of glaciers, icecaps and snow at monotonous regions and glaciers in Greenland and Antarctica and the remaining reserves consist of 30% groundwater and 0.3% surface water (i.e. rivers, lakes, reservoirs, wetlands) as illustrated in Figure 10.

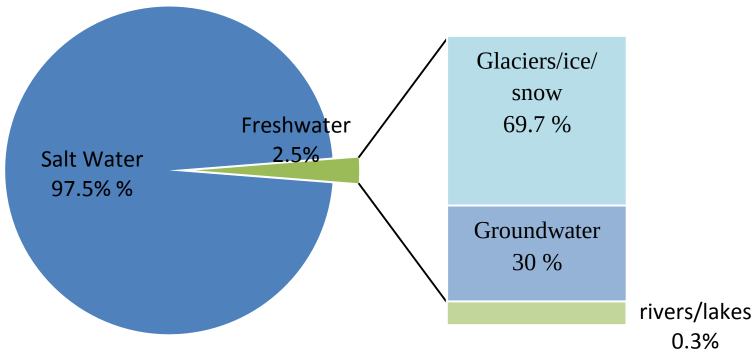


Figure 10: Total world water resources and breakdown of freshwater resources
Source: own elaboration based on (UN-Water, 2013)

Considering Figure 10, freshwater is a limited and valuable source worldwide. Since the last five decades water withdrawal has tripled due to population growth and concurrent agricultural as well as industrial expansion. This has led to more wastewater generation and water shortage in the world involving also conflicts between countries. Of particular concern are arid and semi-arid areas where people suffer from water shortage and proper sanitary facilities. In respect to agriculture, around "70% of all freshwater withdrawals go to irrigated agriculture" (UNESCO, 2009). Thus, limitations in water supply cause food price increase and most likely dependency on food importations.

Additional impacts to freshwater resources are related to climate change, which according to several studies, drive to rising temperatures and therefore variations in precipitations, evapotranspiration of plants, weather patterns (e.g. extreme rain falls, heavy storms) river runoffs, ice melts, see levels, etc. The mentioned changes could affect water quality, ecosystems and the usage of water by increasing the rate of pollutants, suspended solids (SS), algae production, salt concentration, and acidification in water bodies (IPCC, 2007).

To this end, it becomes increasingly important to conserve freshwater resources by preventing pollution of water bodies and damages to water biota caused by domestic and industrial wastewater as well as through agricultural practices in order to preserve natural freshwater resources, reduce drinking water consumption and minimise risks to human health (FAO, 1992). Although, several countries have implemented regulations as well as technical treatment and reuse options —inter alia wastewater treatment plants (WWTP)— there is still lacking awareness and of this issue particularly in developing nations where water is discharged untreated into water bodies.

The main goal of WWTP is to treat domestic and industrial residual water to such an extent (depending on microbiological and chemical quality parameters of regions) that it could be discharged into water bodies or could be reutilised for irrigation purposes in agriculture or landscapes without causing any risks to human health or environment. Conventional municipal WWTP are characterised by combining three main treatment steps namely physical (primary), chemical (secondary) and biological (tertiary) treatment processes involving preliminary and/or advanced processes in order to eliminate or reduce organic matter, SS, heavy metals, and other contaminants contained in the wastewater. The mentioned treatment steps are described as follows (FAO, 1992):

- *Preliminary treatment*: before raw wastewater undergoes the three main treatment steps, coarse matter has to be removed from the wastewater by means of screens and grits as well as shredders to comminute and diminish the size of large particles if necessary.
- *Primary treatment (physical):* the pre-treated wastewater flows into basins in order to remove floating materials (e.g. oil, grease) as well as organic and inorganic

matter by sedimentation and particle skimming respectively. Thus, a great part of the SS (50-70%), floating matter, heavy metals and a quarter to half of the BOD_5[3] could be removed by this process. The settled matter the ground of the basin and the scrum at the surface represent the primary sludge which is pumped to a post-sludge treatment element[4].

- *Secondary treatment (biological):* commonly a further step follows after primary wastewater treatment through aerobic biological treatment processes (biological reactor) involving nitrification [5] and denitrification [6] reaction processes. The digestion of the remaining organic matter increases the volume of microorganisms which are removed by sedimentation and pumped usually to the same sludge treatment element of the primary sludge for treatment. Additionally, a further treatment process (i.e. activated sludge, trickling or bio-filters, oxidation ditches and rotation biological contactors) is carried out in this step in order to treat high polluted water with organic matter. This high rated process enables the removal of around 85% of the BOD_5 and SS as well as some heavy metals.
- *Tertiary and/or advanced treatment (chemical):* a third treatment step is carried out to remove remaining components which could not be removed before by adding chemicals. Advanced treatment refers either to a subsequently step of secondary treatment or in combination with primary treatment.
- *Disinfection*: treated wastewater is disinfected in some plants either by adding a chlorine solution of usually 5-15 mg/l or implying an ozone and ultra violet irradiation.

Typically, conventional WWTP are large, centrally controlled treatment plants which involve complex and cost intensive infrastructures such as pipes, water conduits, reserves and processing plants. Furthermore, they feature high energy consumption and the utilisation of chemicals, emissions to the air due to gas realises and the generation of sewage sludge which requires additional treatment (Hospido, Moreira, Fernández-

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3 Biochemical oxygen demand (BOD_5) is a measurement specified by taking samples of wastewater during five days and which indicates the oxygen consumed for the decomposition of organic matter by microorganisms in the presence of oxygen (anaerobe). WWTP have to reduce the BOD in wastewater according to requirements before discharging it into water bodies.

4 In post-sludge treatment elements sludge is either digested aerobically (in presence of oxygen) or anaerobically (in absence of oxygen) by microorganisms, whereby the latter generates CH4. Other utilised treatment methods are inter alia lagoons, drying beds (for landfilling or incineration) and stabilization ponds (FAO, 1992).

5 Nitrification is characterised by the conversion of nitrogen in form of ammonia (NH3) contained in waste water through oxidation into nitrite (NO2) and subsequently to nitrate (NO3) (EPA, 2007).

6 Denitrification is a recycling process of nitrates applied in WWTP by the reduction of nitrates into nitrogen gas (N) by heterotrophic bacteria. The gas is then realised to the atmosphere (EPA, 2007).

Couto, & Feijoo, 2004). Regarding energy consumption, around 7% of all energy produced [worldwide] is used [to withdraw groundwater, pump it and] to treat both groundwater and wastewater" (UNESCO, 2009, p. 16).

In reaction to the mentioned concerns, conventional wastewater treatment systems are revised considering sustainable and alternative treatment methods. Therefore, sustainable wastewater management (WWM) is becoming increasingly important in order to reduce energy and chemical inputs and to support decentralised, on-site WWM systems serving municipalities and households. It "is characterised by integrated infrastructure and biophysical systems, which consider social, economic, environmental and political contexts, provision of water for ecological and human uses, and a long term perspective" (Meene, Brown, & Farrelly, 2010, p. 1117). Although, some alternative concepts are developed in this field, the realisations of sustainable WWM solutions still represent a complex approach due to its multidisciplinary character.

Sustainable WWM approaches involve, among others, the following treatment systems in combination with conventional systems (Abou-Elela & S. Hellal, 2012):

- Constructed wetlands (see Box 5)
- Septic tanks
- Up flow anaerobic sludge blanket (UASB)
- Oxidation lagoons

Box 5: Constructed wetlands

Initial research on constructed wetlands (CWs) has been carried out in the 1950s at the Max-Planck Institute in Germany by Dr. Käthe Seidel as an alternative system to treat various kinds of wastewater for instance particularly from households and municipalities but also from industries, agriculture, runoffs as well as wastewater sludge, landfill leachate and storm water overflow by utilising natural processes like plants and microbial activity. Although CWs were confronted to distrust related to odours, fly attraction and non-cold weather resistance, nowadays there are several reliable designs of successfully implemented CWs, with the following characteristics:

- Free water surface constructed wetlands (FWS CWs):
- Horizontal flow constructed wetlands (HF CWs)
- Vertical flow constructed wetlands (VF CWs)
- Hybrid constructed wetland

All mentioned CWs types can effectively remove SS and organic material by aerobic and anaerobic processes, whereas phosphate is eliminated by sorption. Moreover, CWs have lower maintenance and operation costs (particularly in terms of energy with minimal or without fossil fuel consumption) compared to conventional treatment technologies. Furthermore, CWs have the ability to convert pollutants in wastewater into undamaging by-products or nutrients which could be utilised for other purposes Additionally, CWs "may provide other ecosystems services such as flood control, carbon sequestration or wildlife habit" (Vymazal, 2010, p. 542).

Case study: Constructed wetland Dornweiler/Germany

The government of Dornweiler in Germany decided to build a VF CW plant for the biological treatment of domestic wastewater of 350 inhabitants and water runoffs from streets, rain, and snow instead of connecting the wastewater system to a central treatment plant. The total size of the CW is of 1 800 m^2 with ground filters enabling high O2 levels. The effluent is clear water without odours, flowing into the river.

Project data (DWC, 2007):

- Wastewater quality: 90 m3/day
- Wastewater peak: 140 m3/day
- Achieved purification rate: >95%
- Construction costs: 150 000 EUR
- Operation costs: 0 EUR

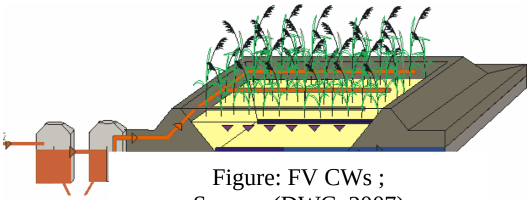

Figure: FV CWs ;
Source: (DWC, 2007)

Source: (Vymazal, 2010; DWC, 2007)

The additional consideration of material flows in wastewater drive to more sophisticated and sustainable solutions by means of reuse or recycling of water and its nutrients such as nitrogen (N), phosphorous (P), potassium (K), carbon (C), etc. The global demand and therefore the price for nutrients has been steadily increasing in the last decades, but natural reserves of most of the nutrients are limited on Earth and high rates of the reserves are almost depleted such as P, which is a crucial component for plant growth together with N and K. Conventional WWTP typically aims to eliminate those essential nutrient (i.e. through burning wastewater sludge)s in order to avoid eutrophication and oxygen depletion in water bodies (Takaoka, Oshita, Sun, Matsukawa, & Fujiwara, 2010; IfaS , 2010).

To this end, innovative technologies were developed in order to recover valuable nutrients from waste water. According to the IfaS (2008), wastewater streams in the sense of material flows should be separated into yellow, brown, grey and rain water to extract nutrients and facilitate waste to be treated more efficiently. Therefore, added-values could be generated (i.e. fertiliser, soil conditioner, recycled water) and make use of the energetic content of anaerobically digested wastewater (i.e. biogas), as illustrated in Figure 11. Additionally, recycled water could optional be utilised for irrigation purposes in agriculture.

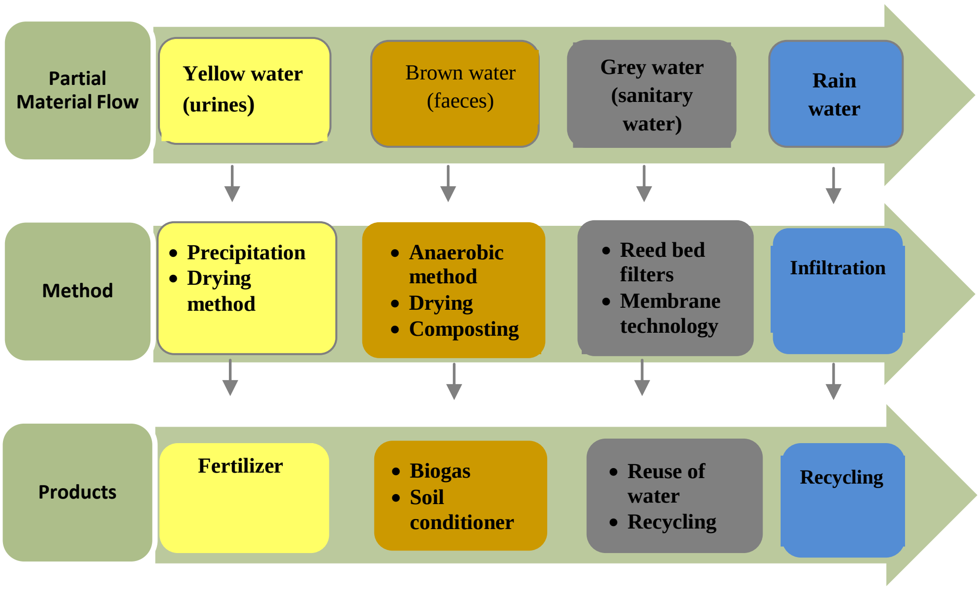

Figure 11: Separation of wastewater in material flows
Source: own elaboration in line with (IfaS, 2008)

However, the separation of wastewater streams still represents challenges due to restructuration of sanitary infrastructure which enables the separation of wastewater in households. Thus far, it has been practiced on industrial-scales (ecobine, web).

2.3.3 Sustainable tourism management

In the last decades, the demand for international tourism services has increased worldwide and is predicted to continue growing. This thriving service sector represents a great beneficial effect as a key income source of many countries, especially in developing and newly industrialised nations such as Thailand, Egypt, Ecuador, Brazil and many others. It accounts with 8% to global employment, 5% to the global Gross Domestic Product (GDP) and represents 30% of service exports worldwide (UNEP, 2011, p. 418). Moreover, according to the United Nations World Tourism Organization (UNWTO), international tourist arrivals have been continuously increasing and are predicted to reach 1.8 billion in 2030 from 1 billion in 2012 (UNWTO, 2012, p. 14).

Nevertheless, conventional tourism is complexly interrelated with the environment. Many activities associated with tourism, including the construction of the required infrastructure such as roads, airports, tourism facilities, etc; deteriorate the environment by exploiting resources and causing pollution to the environment as any other industry. It involves increased solid waste and wastewater generation, fresh water consumption, biodiversity loss and endangers indigenous cultures as well as traditions in local areas.

Of additional concern are GHG emissions contributing with around 5% of total emissions, mainly caused through the transportation of tourists (UNWTO/UNEP, 2008). The main mode of transport – particularity based on fossil fuels – is by air (51%) and by road (41%) as illustrated in Figure 12.

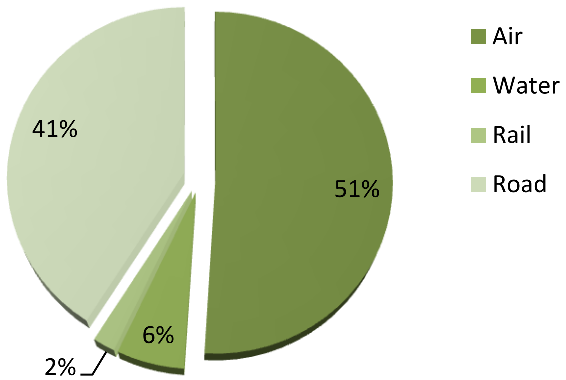

Figure 12: Inbound tourism by mode of transport (2011)
Source: (UNWTO, 2012, p. 4)

In that score, increasing awareness of tourism impacts have driven sustainable tourism management to a focus point in the latest years. But it does not focus on a specific type of tourism; it rather endeavours sustainable development in all areas related to tourism. Therefore, negative impacts of conventional tourism should be enhanced, removed or replaced by alternative and sustainable forms of tourism (Tosun, 2000).

The sustainable tourism approach is often associated to the term "ecotourism" which represents one segment of tourism (e.g. wellness, beach and adventure) and is emphasised mainly on environmental concerns (ETC, 2012). On the contrary, sustainable tourism refers to the enhancement of all tourism segments including "policies, practices and programmes that take into account not only expectations of tourists regarding responsible natural resource management (demand), but […] benefits local communities and raises awareness and support for the sustainable use of natural resources" (UNEP, 2011, p. 420). To point out, there are beneficial contributions to communities based on sustainable actions such as providing for example employment, income, local development, economic growth, better living standards and support of cultural identity in a long term perspective.

To this end, sustainable tourism aims to satisfy the needs of travellers by concurrently reducing negative impacts at the destination places on (Middleton & Hawkins, 1998):

a) the physical environment: encounter threats to nature and ecosystems such as extreme freshwater water utilisation for swimming pools, for irrigation of golf courses, deforestation of mountains for skiing, pollution of water bodies through untreated wastewater effluents, emission release though tourist transportation.

b) the social and cultural environment: involves threats and interference into to local traditions and costumes at the destination place through conversion of indigenous rituals into touristic entertainments, promotion of prostitution, derogation of indigenous way of living, deterioration of cultural heritage.

To achieve the abovementioned objectives, the UNEP and the UNWTO developed strategies supporting sustainable tourism management involving the following points (UNEP, web):

- Involve sustainability aspects into tourism policies
- Create corporations along the tourism sector for instance hoteliers, travel organizations, transport services etc.
- Increase the interest on sustainable tourism
- Encourage sustainable production paradigm along the supply chain associate to tourism
- Support local, regional and international authorities and stakeholders
- Cooperate with NGOs which support activities related to sustainable tourism in order to establish consumer based activities.

Those strategies have not been widely implemented and most of the applications are still focused mainly on environmental aspects such as ecotourism. But in the recent years, the approach has gained importance and the sustainability objectives are considered more precisely as demonstrated in the exemplary case study of Costa Rica (Box 6).

Box 6: Certification for Sustainable Tourism in Costa Rica

Over one million international travellers visit annually Costa Rican located at Central America. The country emphasised on long-term sustainable tourism development through officially recognised certification programmes. The idea has been encourage by already existing ecotourism projects (private reserves) supported by the government to promote conservation of biodiversity, inherent natural beauty and water bodies as well as reduction of CO_2 emissions.

Hence, the Costa Rican Tourism Board (ICT) carried out the programme Certification for Sustainable Development (CST) at the beginning of the 1990s, in order to distinguish businesses in the tourism sector according to their accomplishment to a well defined sustainability model governed by the Costa Rican National Accreditation Commission. To this end, all business related to tourism undergo a volunteer sustainability evaluation procedure consisting of questionnaire with 153 questions after the following criteria:

1. Physical-biological parameters: interplay of the business with the neighbouring natural habitat
2. Infrastructure and services (exclusive for lodging companies): business operation and management related to infrastructure in terms of energy reduction, water pollution prevention and waste treatment strategy and technologies
3. Service Management (exclusive for tour operator agencies): consideration of how well the touristic product fulfils market trends and adapts to the conditions of the locations where it takes place
4. External Client: interaction of the business with customers and the active involvement of customers into the sustainability strategies of the business
5. Socio-economic environment: contribution and communication of the business to the surrounding community in terms of local communal development (i.e. new jobs etc.)

The businesses are evaluated in accordance to a score from 0 to 5 in order to indicate their level of achievement. Therefore, level 1 signifies that the business has taken first actions towards sustainability and the highest level namely 5 means that the business has fulfilled all sustainability criteria's. To this effect, this evaluation procedure acts as an incentive for businesses to operate in a sustainable manner.

The main goal of this action is to utilise natural and cultural resources appropriately, enhance the quality of life of the local society with communal participation and succeed economically with the objective to enable further programme developments nationwide.

Source: (CST, 2010; UNWTO, 2005)

2.3.4 Sustainable agriculture

Agricultural development has been influenced significantly by the invention of machines and synthetic chemicals (i.e. pesticides, herbicides and fertilisers) as well as antibiotics during the industrial revolution, and currently driven by growing global markets. Since then, agricultural practices (farming) could expand rapidly through acceleration of crop productivity and livestock growth, prevention of diseases and pests, specialisation and mechanisation. For instance, wheat yield increased from 0.5 to 2 metric tonnes per hectare (ha) within 1000 years and jumped to 6 metric tonnes per ha in just 40 years (IFPRI, 2003, p. 2). This rapid development is known as the Green Revolution at the 1970s; in which particularly rice and wheat production could be doubled until the 1990s by planting high-yield varieties (HYVs) and applying chemicals, as well as irrigating arable land.

These modern agricultural practices —referred to machinery intensive and industrialised agriculture— have also been implemented by some developing countries in South America, Africa and Asia, but mainly by big landowners or foreign farmers with sufficient assets. The abovementioned modern agricultural practices incorporate also extensive application of antibiotics in the livestock industry (e.g. 70 % of Denmark's antibiotics are utilised for animals) as well as the production of genetically modified organisms (GMOs) [7] or so called genetically engineered crops, mainly introduced in U.S, Canada and Argentina (Halberg, Alroe, Knudsen, & Kristensen, 2006, pp. 6-8).

Although, modern agriculture aimed to reduce world hunger and nourish the ever growing world population, it has driven to overproduction rates in developed nations with consequential malnutrition effects in developing and least developed countries, making them even poorer through food import dependency. According to the Global Hunger Index (GHI) published by the International Food Policy Research Institute (IFPRI, 2011), 26 countries in South Asia and Sub-Saharan Africa are extremely alarming and alarming regarding access to food (undernourishment and underweight). Worldwide, there are almost 870 million people —every eighth person in the world or 15% of the world's population— who suffer from starvation (FAO/WFP/IFAD, 2012). One of the reasons is due to highly subsidised agricultural products of developed nations particularly members of the OECD (Australia, Canada, EU countries and U.S.) which lead to international market distortions by hindering developing countries' farmers from competing with world prices. For instance, the EU is the second main exporter of subsidised sugar (Centad, web).

In addition, modern agricultural practices have led to serious impacts on biodiversity and animal welfare such as: soil degradation, groundwater as well as surface water pollution, landscape deterioration, resource exploitation, deforestation, fertile soil degradation (e.g. nutrient depletion, soil erosions, salinisation, acidification, soil compaction, etc.), loss of indigenous sustainable agriculture techniques, and increased health-impacts. The mentioned negative effects increased by intensified specialisation (i.e. pig and poultry production) as well as monoculture practices (e.g. wheat, maize,

[7] Genetically modified organisms (GMOs) involve flora and fauna as well as microorganisms (bacteria, parasites, fungi) "in which the genetic material has been altered in a way that does not occur naturally through fertilisation and/or natural recombination" (etsa, 2012).

cotton, soybeans, fruits, flowers and viticulture) and therefore increased water as well as fossil fuel based energy consumption (Halberg, Alroe, Knudsen, & Kristensen, 2006).

Moreover, modern agricultural practices are one of the key contributors to climate change —although agriculture has the ability to function as a carbon sink— and concurrently it is one of the most vulnerable sectors to changes in climatic patterns. It is estimated that the share of GHG emissions from agriculture account for almost 14% (Figure 13), whereby 60% of the global nitrous oxide (N2O) emissions are generated through soil cultivation and animal husbandry and half of the global methane (CH4) emissions come from enteric fermentation, manure management and rice farming. Additionally, the growing world meat demand and diet changes boosted GHG emissions. For instance the annual meat consumption in developing countries has increased from 11 to 24 kg per person during the period of 1967-1997 and are estimated to rise worldwide up to 60% by 2020 (IPCC, 2007, p. 63).

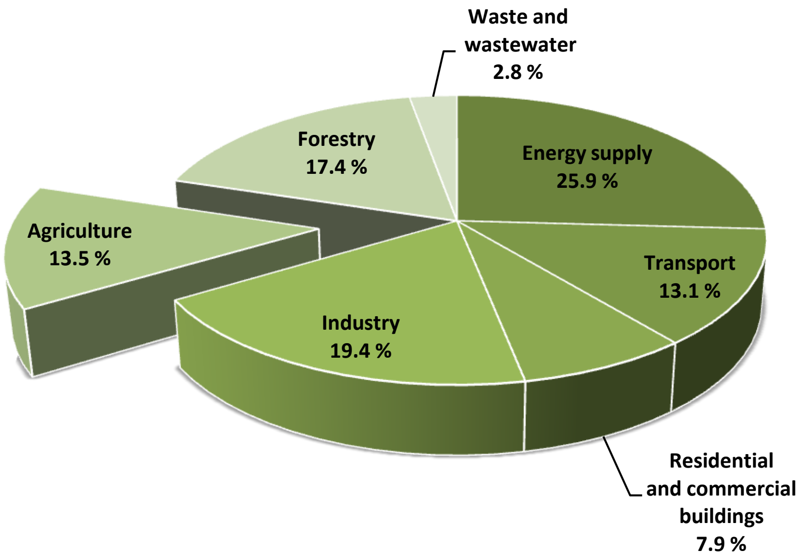

Figure 13: Worldwide GHG emissions of agriculture compared to other sectors (2004)
Source: (IPCC, 2007, p. 29)

Additionally, the rising promotion of energy crops for renewable energy production has implications – despite its positive effects - on agriculture and forestry having serious impacts on environment, local development, food security and crop price elevations. But development of bioenergy and its effects on agricultural practices remains unclear (World Bank, 2010).

Industrialised agriculture and its vulnerability to climate change have serious consequences on food security[8] particularly in already endangered areas and poor countries. In order to reduce GHG emissions, secure food supply and eliminate world hunger, modern agriculture has to be adopted to sustainable approaches which —on a long run— "contribute to overall welfare by providing sufficient food and other goods and services in ways that are economically efficient and profitable, socially responsible, and environmentally sound" (UNCSD, 2011, p. 1). To this end, sustainable agriculture has become a priority issue for several countries as it has been declared in the final submission texts at Rio+20.

Thus, sustainable agriculture (also known as organic farming, biological farming and alternative agriculture) implies adopting biological cycles in order to replace synthetic fertilisers and chemicals by organic fertilisers produced from composting and through the application of combined sustainable agricultural practices. These practices include intercropping, crop rotation, biodynamics, and permaculture. Such approaches allow balancing nitrogen and carbon levels in soils, and reduce weeds, diseases and insects. Accordingly, key characteristics of sustainable agriculture conception are as follows (Mason, 2003):

- Consideration of natural biological cycles and ecosystems including soil biota (microorganisms and animals in the soil)
- Efficient and sustainable usage of regional resources including re-utilisation of materials and reducing dependency on external resources
- Reduction of on-site and off-site pollution
- Preservation of local genetic varieties

Organic food production and its certification have been increasing in the last years. Regarding the socio-economic effects of this development, it indicates the ability to improve and promote local food markets and concurrently provide more job opportunities and therefore contribute to reduction of world hunger[9] in developing countries. Furthermore, it offers solutions for small and poor farmers in developing

8 Food security is an essential concern worldwide implying that „all people, at all times, have access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life" (UNCSD, 2011, p. 1).

9 To halve world hunger and eradicate extreme poverty until 2015 is one of the Millennium Development Goals (MDGs) of the United Nations (UN MDGs, web).

countries and strengthens organisations for social issues and natural resource conservation (see case study in Box 7). However, sustainable agriculture is still confronted with the widely expanded industrialised practices and global markets and has a long way to go (Halberg, Alroe, Knudsen, & Kristensen, 2006).

Box 7: Successful case study on sustainable agriculture in Cuba

Cuba experienced in the past rapid economic developed and modernisation compared to any other developing country in Latin America, through trade alliance with the Soviet Union enabling industrialised agriculture. Cuba could benefit from favourable petroleum, machine, chemicals, and synthetic fertilisers imports as well as high export crop prices, particularly for sugar, which was 5.4 times higher than in other countries. This international trade development has brought short-term socio-economic profits for the inhabitants such as GNP increase, lower children mortality, higher education for women, etc.

On the other hand, Cuba became heavily dependent on external imports maintain crop exportations. Additionally, expanded monoculture sugarcane plantations have occupied most of the arable land, excluding farmland for own food production with the consequence that almost 60% of Cuban food had to be imported. Furthermore, agrarian reform in 1959 and 1962 respectively, transformed large cattle farms and most of agricultural areas to state property. Only around 20% of arable land remained owned by small farmers.

In 1989 the relationship with the Soviet Union/Russia collapsed, leading to cut downs of imports and foreign exchange rate. Thus, Cuban population experienced serious food shortages. To overcome the food crisis, the Cuban government initiated nationwide endeavours to promote traditional old agriculture techniques and self-sufficient farming methods involving local products (natural rock phosphate, green manure, organic residues) and composting systems to substitute mineral fertilisers. Moreover, bio-pesticides were introduced as well "resistant plant varieties, crop rotations and microbial antagonists to combat plant pathogens, and better rotations, and cover cropping to suppress weeds" (Rosset, 2000). Even the government of Havana City has forbidden by law the usage of synthetic fertilisers. Additionally, heavy fossil fuel based machines were replaced by animal-drawn plowing.

To this end, small farmers rapidly had the ability to adapt to the given conditions and improve agriculture production. A new system was created under the programme "linking people with the land". Therefore, small-scale cooperatives namely Basic Units of Cooperative Production (UBPCs) have been developed to additionally support small farmers. Income increased and around 22% more jobs could be generated in 2003 (Kisner, 2008). Thus, Cuba recovered from food shortages through self-sufficiency of small farmers and gardeners and by considering alternative agricultural techniques such as:

- *Agroecological practices* in order to substitute inorganic fertilisers and chemicals
- *Fair crop prices* as incentives for farmers produce more
- *Land redistribution* to small and medium sized farmers as they have the ability to produce more than large scale production units
- *Local and regional production* to secure food supply (decentralised) and support local development as well as ecology-friendly production techniques with lower energy inputs.

Concluding, Cuba is an extraordinary example demonstrating that sustainable agricultural practices are economically feasible, environmental sound and socially compatible under the consideration of abovementioned criteria.

Source: (Rosset, 2000; Kisner, 2008)

2.3.5 Renewable energy sources

Worldwide energy consumption almost doubled in the last three decades, leading to rapidly increasing energy consumption, particularly due to the new emerging economies such as China and India, which account for one third of the global population and around 40% of the world's energy consumption (Yuksel & Kaygusuz, 2011). Until now the most widespread energy sources have been fossil fuels (crude oil, coal and gas) and nuclear power. The former —besides the large associated emissions of GHG and other toxic gases— would be depleted worldwide in a few decades due to its extensive utilisation. The latter is frequently debated due to its high risk and harmful potential on human health and environment which have been experienced in several nuclear and radiation disasters such as the Three Mile Island (1961, U.S.), Chernobyl (1986, Ukraine) and Fukushima Daiichi (2011, Japan).

Therefore, renewable energy sources (RES) have become increasingly important for the supply of alternative and sustainable energy sources namely solar, biomass, wind, geothermal, hydropower and tidal energy. In contrast with fossil fuels and nuclear energy, RES are considered as alternative and clean energy sources with positive climate change mitigation effects without destructive effects to human and environment in long term perspective.

According to the annual REN 21 *Renewables Global Status Report* (GSR) 2012, the final renewable energy share worldwide reached almost 17% in 2010, whereby modern renewables[10] accounted for 8.2% and traditional biomass[11] for 8.5% (see Figure 14). The largest share of renewables is utilised for the generation of electricity.

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[10] Modern renewables is energy based on renewable energy sources such as biomass, sun, wind, hydro and geothermal in order to generate gaseous or liquid energy such as electricity, heat, cooling and transportation fuels.

[11] Traditional biomass is mainly utilized in rural areas in developing nations for cooking and heating purposes. It accounts to renewable energies, although it is called into question whether it is sustainable or not, due to environmental and health impacts.

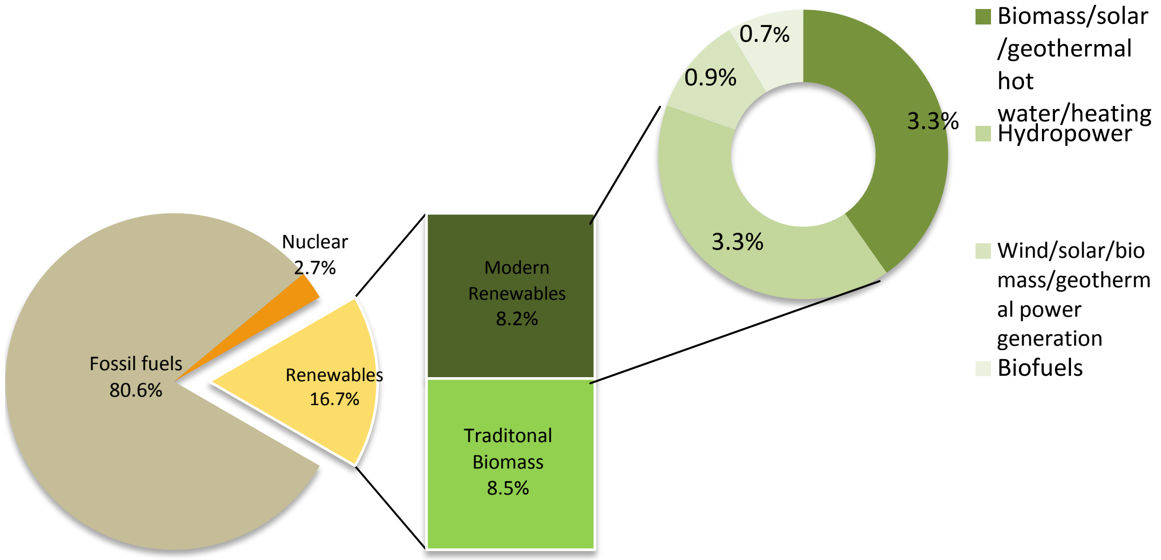


Figure 14: Worldwide primary energy demand and RES share, 2010
Source: own elaboration based on data from (REN21, 2012)

In the last decade the market for renewables increased rapidly and will continue to grow, particularly in modern renewable energies in order to substitute fossil fuel based energy and mitigate GHG emissions, as well as reducing pollutants and small particles to the atmosphere. The fast development of renewables has been promoted by the GHG abatement mechanisms of the KP (see chapter 2.1.2) as well as several incentives through national policies such as the feed-in-tariffs (FITs) and renewable portfolio standards (RPS). In this respect, the European Commission (EC), under the Renewable Energy Directive, set the legally binding goal to achieve 20% final energy share from RES as well as 10% in the transport area by 2020, which could drive to annual monetary savings of approximately 10 billion Euros. Germany is the leading country in the European Union (EU) and one of the top consumers of renewable energies worldwide with a total final RES share of more than 12% (EC, 2013).

Furthermore, other countries such as China, United States, Italy and India have significantly increased their investments in RES, whereby in 2011 investments of developed nations remained almost twice as high as of developing countries. Continuous technological innovation and therefore cost reduction effects in the renewable energy market, combined with enhanced financing mechanisms, lead to more financial feasibility of renewable technologies and energy solutions, mainly for municipalities or individual investors in the developing world. Decentralised solutions in remote locations, where renewable power generation (off-grid) has been considered as more cost-effective than extensions of national grids, are of particular importance. However, the potential for RES worldwide is large; the market for renewables is different from country to country (REN21, 2012).

Some of the characteristics of commonly used RES technologies are explained in the following paragraphs (Baños, Manzano-Agugliaro, Montoya, Gil, Alcayde, & Gómez, 2010; Pishva, 2011; IPCC, 2012).

a) Solar Energy

- *Active Solar* is characterised by the transformation of sun light into power and water heat through the installation of photovoltaic panels or solar collectors. Over the last years the price of these technologies has been declining continuously, making it more affordable also for commercial use. Therefore, the production rate increased significantly in the last years. But large-scale applications require efficient energy storage systems which are still under research and development to make them more efficient and economic feasible.
  - *Solar photovoltaic (PV)* panels/cells absorb radiant energy from the sun and convert it directly into electricity. Various PV technologies are developed consisting of thin-layers of silicon or copper indium/gallium disulfide/selenide as well as cadmium telluride and dye-sensitised solar panels. This system is broadly used in watches, calculators, street lights, swimming pools as well as for the transmission of power to national grids through the integration of PV panels in buildings or creation of solar power stations.
  - *Solar thermal collectors,* or solar water heating collectors, have the ability to convert sun radiation into heat at temperatures from about 30 up to 120 degrees which is utilised in households, industries as well as for agricultural purposes and cooking. The heated water is usually stored in water tanks. There are two types of collector namely flat plate and evacuated tubes which could be connected to hot water system of buildings.
  - *Concentrated solar power (CSP)* leads to optical concentration of sunlight to a specific point (point focus) or a line (line focus), heating up fluids or materials (i.e. oil and molten salt) which transfer the heat through steam turbines in order to drive generators for electricity generation. Similarly, parabolic reflectors rotate according to the sun irradiation and concentrated the light to a linear heat-collection element (HCE). The mentioned technology has a great potential

to generate more power than other solar based systems and it has the capacity to store heat for around fifteen hours, but the manufacturing time and capital cost are comparatively high.

- *Solar fuel* technology transforms sunlight energy into valuable chemical fuels such as methanol, diesel, artificial gas or hydrogen. Hydrogen for example is produced by using PV or CSP solar systems in order to hydrolyse water. Furthermore, fuel production processes utilise photochemical reactions processes known know from photosynthesis of plants.

- *Passive solar* takes into consideration aspects of designing energy efficient buildings in order to minimise energy consumption for lighting, heating and cooling by almost 40 %.

b) Wind Energy

- *Onshore wind* or landwards wind energy has been utilised traditionally in windmills for grinding grains and pumping water. Nowadays, with the technology of wind turbines, typically arranged together to wind farms, it is possible to generate electric energy from the moving air (kinetic energy). The electricity generation capacity depends on the height of the wind turbines as well as on wind velocity, whereby the installed energy capacity is between 1 and 2.5 MW. Onshore wind turbines usually have a height of 50 to 100 m, whereby the future trend indicates turbines of 250 m height.
- *Offshore wind* is characterised by the allocation of wind turbines (wind farms) along the coast line in the ocean due to better wind conditions (higher wind velocity, more constant winds) which consequently lead to higher power generation rates up to 50% compared to onshore wind farms. The installed power capacity is usually 24 MWe. Investment costs however are higher than onshore wind farms particularly for the foundations.

c) Hydraulic Energy

Hydraulic power is energy generated from water movements by falling water from a higher to lower level. Worldwide, hydroelectric power contributes to one fifth of the global electricity demand, whereby only five countries (China, Brazil, U.S. and Russia) have more than half of worldwide installed capacity. The largest hydroelectric power plants, considering installed energy capacity, are the Three Gorges Dam (China), Itaipú (Brazil) and Guri Dam (Venezuela). There are various types of hydroelectric power generation plants such as:

- *Hydroelectric power plants* (so called dams) which according to the law of gravity utilises the force of failing water (potential energy) in order to drive water turbines and generators for electricity production. Therefore the height is an important criterion for power capacity.
- *Pumped-storage hydroelectric power station*: this technology has the purpose to store water at a higher level and not to generate net electricity in order to meet peak demands of electricity by realising the stored water into a lower level.
- *Run-of-river (RoR) hydroelectric power station*: it represents small hydropower plants with small or no storage device which is applied for instant electricity generation.

d) Geothermal Energy

Geothermal energy is extracted from the heat inside the Earth and stored in liquid water, rocks or steam. Temperatures below the Earth's surface are constant all over the year, 24 hours a day, without any interruption. Geothermal energy is not only used for heating but also to generate electricity. Application areas are for example greenhouses, buildings, fish ponds, swimming pools, bathing, purification and desalination of water etc. This energy has a great potential worldwide but it is still not expanded widely due to high investment cost, although the operation cost are low.

- *Geothermal heat pumps* are utilised for heating buildings during winter and cooling them down during summer periods with the help of heat exchangers, due to the fact that earth temperature remains warmer in winter and cooler in summer.

e) Bioenergy

Bioenergy is obtained from biomass, a term for biological matter coming from plants, animals, organic wastes, wood, straw etc. It has a great potential worldwide to generate gaseous (biogas), liquid (biofuel) or solid (wood pellets) energy carriers, as well as power and heat. This form of energy represents a growing market worldwide.

- *Biogas plants* enables the gasification of biomass through fermentation processes in order to produce methane gas (biogas) for cooking, transportation, heating etc. or to generate power and heat in combination with combined heat and power (CHP) engines so called gas turbines. The typically installed power capacity of a CHP is 9 MWel with an electrical conversion efficiency of 30%.

- *Biofuels* such as biodiesel or bioethanol are produced from vegetable oils or energy crops such as maize, sugarcane, sugarbeets etc. Typically both fuel types are blended with gasoline or diesel so that it could be utilise in vehicles without engine modification. But countries like Brazil have introduced special vehicles which could run on 100 % bioethanol. In the last years, biofuels are debated over their long-term economic, environmental and social impacts.

2.4 Innovative financing for RMFM projects

A number of innovative financing mechanisms for sustainability projects, including adaptation to climate change, have been developed by countries, international organisations such as UN bodies and the private sector. Incentives for the private sector to engage in financing of this type of projects include regulatory compliance (e.g. taxes, fines, polluter-pays principle, subsidies), direct business benefits (e.g. business opportunities; secure, sustain or reduce costs of key natural resource inputs required for business operations; securing license to operate and avoiding losses from protests), indirect business benefits (e.g. “green” branding, marketing, improved staff pride and morale and enhanced recruitment, reflecting broader business values), and philanthropy (GM, 2012).

International mechanisms such as the Kyoto Protocol’s CDM and voluntary markets have been used by “South” countries to advance development and sustainable development projects, yet on a minor scale. For instance, from almost 9 000 CDM projects worldwide, 13.5% of them take place in Latin America (less than 50 in Ecuador) (UNEP, 2013). Carbon financing is a growing market, and Ecuador should profit from its opportunities.

Other alternatives may include public-private partnerships (PPP), green branding of the municipality and green tourism as arguments for private financing, sustainable forestry management [12], profit of the national government’s environmental initiatives and

[12] A number of mechanisms for sustainable forestry financing are discussed in (FAO, 2009)

mechanisms, international development banks[13], commodity-backed loans (e.g. biogas), concessions (e.g. ecological trails and circuits), etc.

Municipality-level financing issues and alternative solutions are widely discussed in development literature (e.g. Kitchen, 2006; CLGF, 2011).

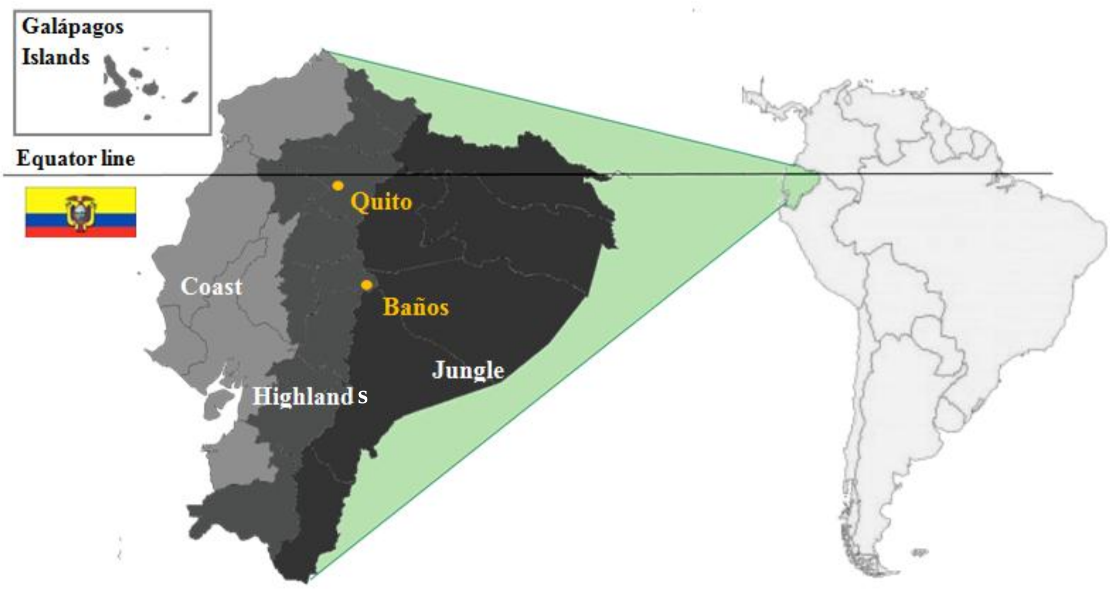
13 For instance, the European Investment Bank finances energy, transport and water works in Latin America, (EIB, 2011) For instance, the European Investment Bank finances energy, transport and water works in Latin America, (EIB, 2011)

3 Introduction to the case study

The focus of this study is the municipality Baños de Agua Santa, located at the eastern Tungurahua province of central Ecuador. Before conducting a RMFM analysis of this municipality, however, it is essential to have a general understanding of the country, in the sense of systems thinking, before introducing a detailed analysis of the municipality.

3.1 Introduction to Ecuador

Ecuador is a small country in north-western South-America bordering with Colombia to the north and Peru to the south. The total population encounters around 15,4 million inhabitants with a population growth rate of 1.4%. The area accounts for $283{,}561\ km^2$ and is divided into four regions: Jungle (Amazonian region), Highlands (Andean region), Coast (Coastal region) and the Galápagos Archipelago (Island region) involving 16 provinces. The equator line passes through all three regions, as depicted in Map 1



Map 1: Geographical location of Ecuador
Source: own elaboration

The country is endowed with a large cultural and ecosystem variety with a rich diversity in flora and fauna. Therefore, the regions are distinguished through their geography, culture, economy and ethnic group differences. For instance, the Amazonian region represents half of the country's territory of which a great part is barely affected by human activities, as the population density remains low. It is characterised by large tropical rainforest and crude oil reserves. On the other hand, the Highlands are characterised by a large mountain range and volcano activity. The capital Quito and other significant cities like Cuenca, Loja and Ambato belong to this region. Furthermore, the coastal region represents an important economic area, where historically most of the trade took place, mainly through Guayaquil, the largest city in Ecuador. The last region, the Galápagos Islands, are located around 1000 km on the west of the continent, is a touristic natural reserve adjacent to the equatorial line. According to the regions, the climate is differently due to its influence by the Andean mountains, equator line and the Pacific Ocean, which contribute to the vast diversity of ecosystems within the country. (EC, 2007; CIA, 2013).

Further facts about the country are illustrated in Appendix 9.1.

3.1.1 General policy environment

After a long period of military regime, the country re-established a democratic republic in 1979. However, in the following decades the government showed instability and weakness, which translated into the expulsion of several presidents, defined economic policies and political representation structures, deficiencies in maintaining and enforcing democracy as well as conflicts between the executive and legislative forces. One of the most critical events was the bank holiday of 1999, which threw the country into chaos: due to galloping inflation and poor economic management, several major banks went bankrupt and had to be taken over by the state. Thousands of customers lost their savings and the national currency devaluated in a few months more than 600% (IMF, 2004). The country adopted then the US dollar as currency in 2000.

The current president Rafael Correa Delgado, however, has completed a full tenure in office and has been re-elected this year. He represents a reform process known in Ecuador as “Revolución Ciudadana”, or the Citizen Revolution, which is achieving the social conquests all previous governments failed to achieve under neo-liberalism. The country shows since 2007 a strong economic development (~4% annual in the last years) coupled with dramatic improvements in social indicators, such as employment, public health, public education, public investment and thousands of people escaping poverty. A number of important infrastructure projects have been planned are being executed, including roads, railroads, communications, hydro-electrical plants (in the context of shifting the country’s energy mix towards more sustainable energy), oil refining capacity, etc. The Citizen’s Revolution government has renegotiated the country’s debt and has broken historical dependency to international loan organisations such as the World Bank and International Monetary Fund. Moreover, Ecuador supports and to some extent leads the emergence of new Latin American institutions, such as the Bolivarian Alliance for the Americas (ALBA) and the Bank of the South. All of these developments are part of the Citizen Revolution’s strategy for national development, construction of a plurinational and intercultural state, and Latin America’s integration (SENPLADES, 2009). Nonetheless, critical voices to the current government have risen.

With respect to social and environmental issues, the country has made noteworthy improvements in their constitutional and legal framework setting, concerning issues related to environmental protection, human rights, gender equality and acknowledgment of indigenous rights and culture, as they used to be until recently politically and socially suppressed. Moreover, the current government has focused on those aspects through increased investments in social issues and by additional commitments to the MDG for poverty reduction as well as improvements in the health system. However, the gap between legal framework and its enforcement is notable large (EC, 2007).

Considering local and regional governmental development in the last years, improvements could be achieved through the support of the Consortium of Provincial Councils of Ecuador (Consorcio de consejos provincials del Ecuador, CONCOPE) and the Association of Ecuadorian Municipalities (Asociación de municipalidades ecuatorianas, AME), which are aiming decentralised administration and budget power, in order to strengthen local governments and therefore regional development (EC, 2007).

Regarding external relationships with neighbouring countries, since 1995 Ecuador has signed peace agreements with Peru, but with Colombian there are still serious issues related to drug traffic, the Revolutionary Armed Forces of Colombia (FARC) and the Plan Colombia. This has led to increased security problems at the border. Therefore, Ecuador has hosted and hosts Colombian refugees.

The current economic, social and environmental situation, the latter with emphasis on energy; are detailed in the following sub-chapters.

3.1.2 Economic context

During 1998-2000 an over-inflation rate of 91% has driven the country to a financial crisis with consequences in bank ruptures and dollarization of the national currency into US Dollars. The following years the economy could be stabilized and the GDP rate increased significantly, reaching higher levels as other South American countries. The GDP development is related to rising petroleum production and oil price increase, inflating GDP growth, which reaches maximal 2% without oil consideration (EC, 2007).

Apart from oil exports, Ecuador's main foreign trade products are for instance: banana (main exporter in the world), plantain, fresh flowers particularly roses, shrimps, tuna, cocoa and coffee. The U.S. is the main export partner, followed by the EU. Trade regulations with the Andean communities remain weak. Furthermore, tourism plays also a significant role in Ecuador's economic development.

3.1.3 Energy sources and future development

a) Energy sector general

Ecuador has large oil reserves, transforming the country into the fifth largest oil exporter on Latin America, exporting up to 54% of the country's crude oil. Furthermore, during 200-2007, the governmental income was composed of 25-30% from oil exports by a daily production amount of 500 000 barrel (Larrea & Warnars, 2009).

Since 2007, Ecuador is again an oil exporting member of the Organization of the Petroleum Exporting Countries (OPEC), after leaving it in 1992. The main state-owned oil production companies are Petroecuador and Petroamazonas, whereas foreign companies are in a consortium with Chinese corporation companies, among others, Repsol, Eni, Enap and Andes Petroleum. Moreover, Ecuador has different loan contracts with China since 2009 which are repaid in oil deliveries. Those loans have to be utilised partially for infrastructure investments in the country including Chinese enterprises (EIA, 2012, pp. 1-3; Peláez-Samaniego, Garcia-Perez, Cortez, Oscullo, & Olmedo, 2007).

Although Ecuador disposes of oil reserves, it is not a self energy sufficient country, as it has to import processed petroleum (gasoline, diesel and liquefied petroleum gas (LPG)), in order to meet the country's high oil consumption dependency. The primary oil share accounts for 70%, as depicted on Figure 15. This is due to refinery capacity shortfalls and significant high oil consumption rate in the transport sector (50%), followed by residencies (17%) and industry (15%). (EIA, 2012; Rosero & Chiliquinga, 2011, pp. 11-13).

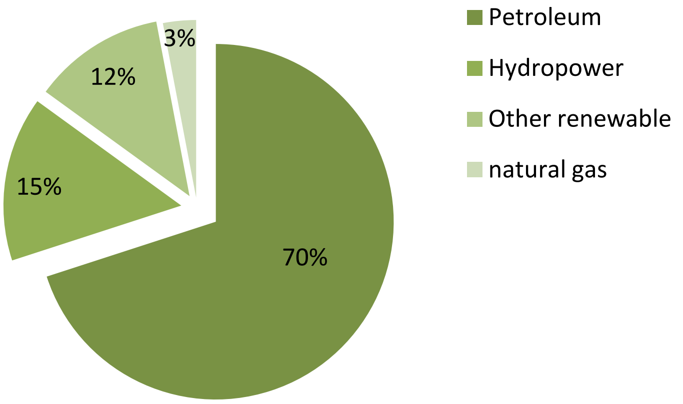


Figure 15: Total primary energy consumption in Ecuador by type (2010)
Source: (EIA, 2012, p. 2)

Natural gas reserves, on the other hand, are comparatively small and limited on the market. Anyhow, LPG is the main source in the residential sector, utilised for water heating and cooking. The Ecuadorian government has subsidised the LPG by selling 15 kilo tanks for $1.65, although the price is approximately $10-12 (Rosero & Chiliquinga, 2011, p. 13).

b)* *Power sector

In respect to the national energy balance of January 2013 published by the Ecuadorian National Council of Electricity (Consejo Nacional de Electricidad, CONELEC), the country produces around 23 TWh electricity. The non renewable share of national electricity generation accounts for approximately 45% consisting of conventional thermal power plants based on diesel (24%) as well as natural gas (10%) and petroleum

(11%), as depicted in Figure 16. The remaining share is supplied by renewable sources mainly hydropower and to a very low extend based on biomass obtained from the sugarcane bargasse in sugar production industry. In respect thereof, other renewable energies (i.e. solar, wind, biomass, geothermal) are barely employed or rather limited to small scale projects, although the country faces great potentials for renewable energy generation due to its favourable geographical location and resource availability.

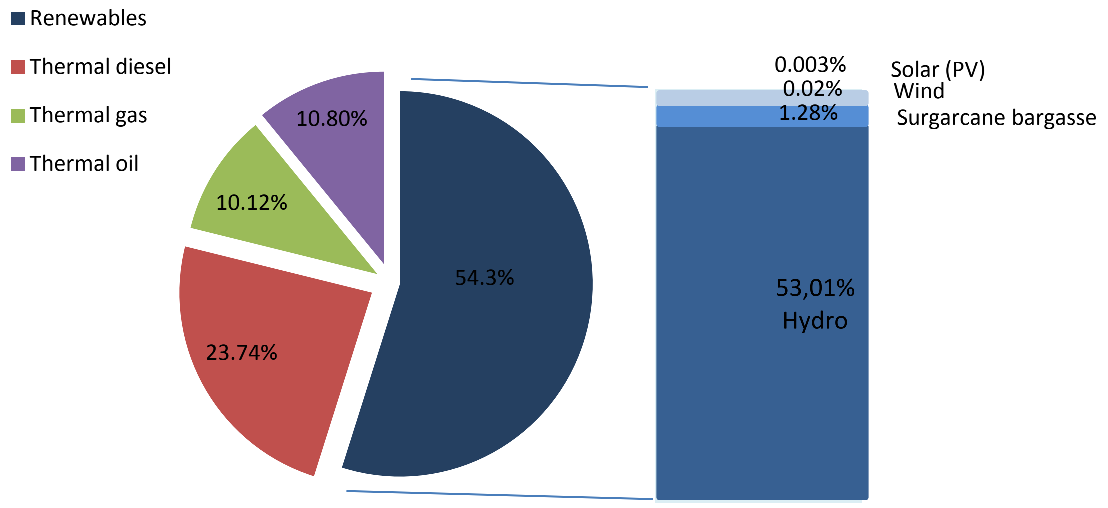


Figure 16: Ecuadorian primary electricity generation share of January 2013
Source: own elaboration based on data from (CONELEC web, 2011)

The annual power consumption is about 16 TWh, whereas 18% are losses in transmission, distribution and 14% are non-public distribution. According to CONELEC (2011), most electricity consumers are residencies (35%) and industry (31 %). However, the electricity service does not cover the population's energy need and those with electrical accessibility (around 92%) do have to purchase expensive and poor qualitative energy. In order to reduce residential energy consumption, a governmental "dignity rate" was implemented in 2007, by compensating energy savings in households (CELEC EP web, 2012; Rosero & Chiliquinga, 2011).

Thus far, the government did not have financial resources to carry out optimisation investments in the energy sector. Therefore, the electricity sector experiences energy deficiencies related to sub-maintain and inefficient diesel-fired engines. Additionally, power shortfalls are commonly during dry periods (October-March), particularly in 2009 when hydropower had declining generation capacities. In this regard, due to the high hydropower dependency, electricity is imported from neighbouring countries

Colombia and Peru through interconnection lines. Therefore, diesel and gas fired power has significantly increased over the period of 1999-2012, in order to meet the country's electricity demand and overcome energy shortages, as illustrated in Figure 17 (RECIPES, 2006; Rosero & Chiliquinga, 2011).

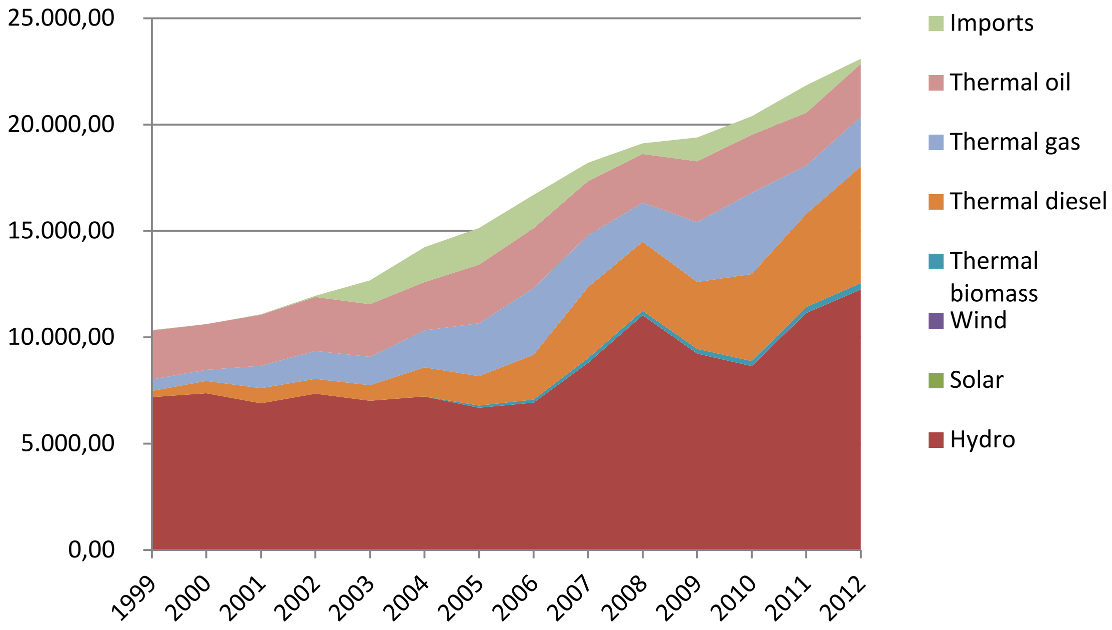


Figure 17: Primary electricity generation development by type of energy source (in MW)
Source: own elaboration in line with data of (CONELEC statistics, web)

c) Renewable Energies

Nonetheless, alternative energy sources have attributed importance in the country's energy supply. In 2007, the Ministry of Electricity and Renewable Energies (MEER) was founded, aiming efficient energy supply and renewable energy development in order to cover the rising country's energy demand and reduce GHG emissions. The renewable energy sector has been reinforced legally through the new Constitution for the Republic of 2008, consolidating all state electricity distributors into one with one single tariff (MEER, web).

To this end, the renewable energy market status and GHG mitigation initiatives in Ecuador are presented as follows:

- Hydropower

Given the potential rivers for hydroelectricity within the country, the government has considered further development of several hydropower facilities on a large scale in near future. So far, less than 10% of the country's hydropower potential has been exploited. To this effect, the MEER aims the construction of additional 226 hydropower facilities during the period of 2012-2020, in order to reach approximately 80% of primary energy share through this renewable source. The planed facilities are, among others: Coca Codo Sinclair (1500MW), Soplador (500MW), Mazar (160MW), Baba (42MW) (Tech4CDM, 2010).

The key existing country's hydropower generation plants are as follows:

- The state owned Hydropaute with an installed generation capacity of 1100 MWel, situated in eastern Ecuador at the Paute River, represents almost 60% of the nation's hydropower. This electricity operator has a cooperation project with other upstream hydropower generation plants namely Mazar (170 MW) and Molino (110 MW), which benefit from the same river basin and reduce sediment accumulation and increase generation capacity during dry periods (RECIPES, 2006; CELEC EP Hydropaute, 2010).
- Hydroagoyan and San Francisco plant (downstream from Hydroagoyán plant) along the Pastaza River, located at the Tungurahua province. The San Francisco plant benefits from the water reservoir of the Hydroagoyan, which deviates water from the river through an underground tunnel. Both plants have and installed capacity of each 230 MWel.
- Daule-Peripe on Daule and Peripe River with and installed electricity generation capacity of 130 MWel.

- *Wind energy*

Regarding wind energy, Ecuador has already several ongoing wind power projects and employed wind parks on San Cristóbal Island in the Galápagos archipelago (~ 2.4 MWel) and on Villonaco in the Loja province (~ 16.5 MWel). Furthermore, other projects are under development such as on Batra Santa-Cruz Island in the Galápagos archipelago (~2.25 MWel). Further wind energy projects are planned in Salinas, Huascachaca and Las Chinchas.

According to studies carried out by the MEER, on March of this year, Ecuador has a wind power potential of about 1.7 GWel, with an annual generation capacity of 2868.98 GWhel (Appendix 9.2, see Map 11).

- *Biofuels*

Considering biofuels, currently there are two projects: bioethanol named ECOPAIS in Guayaquil and biodiesel in Floreana (Galapagos Island). The former refers to gasoline mixed with 5% anhydrous ethanol with annual production rates up to 73 000 gallons; and the latter consists of biodiesel based on Jatropha curcas oil for power generation (Rosero & Chiliquinga, 2011, p. 51)

- *Solar energy*

In respect to solar energy, the government has initiated photovoltaic (PV) projects through the FERUM Fund, in order to provide electricity to rural and remote areas at the Peruvian border and in the Amazonian region. Additionally, a solar panel project with an installed energy capacity of ~2.1 MWel was initiated on the Galapagos Islands. Anyhow, the exploitation of this potential remains low (Peláez-Samaniego, Garcia-Perez, Cortez, Oscullo, & Olmedo, 2007).

- *Geothermal*

Geothermal energy potential is large due to the favourable geographical location of the country characterised by volcanic activity in the highlands. The geothermal potential is estimated at ~534 MW, but it is not employed yet, although project ideas have been developed (Peláez-Samaniego, Garcia-Perez, Cortez, Oscullo, & Olmedo, 2007).

- *Fixed renewable energy prices*

Under the new legal framework, CONELEC fixed preferential prices for non-conventional fossil-fuel based energy, as demonstrated in Table 3.

Table 3: Preferential renewable energy prices in USD cts

Renewable energy source	Continental Territory (USD cts/kWh)	Galápagos Territory (USD cts/kWh)
Wind	9.13	10.04
Photovoltaic	40.03	44.03
Biomass and bio-gas < 5MW	11.05	12.16
Biomass and bio-gas > 5MW	9.60	10.56
Geothermal	13.21	14.53
Hydropower (up to 10MW)	7.17	
Hydropower plants (10-30MW)	6.88	
Hydropower plants (30-50MW)	6.21	

Source: own elaboration based on data from (Rosero & Chiliquinga, 2011, p. 19) of CONELEC

d) The Yasuní ITT project

Ecuador has oil reserves in the Amazon region discovered since 1967. These reserves are estimated to last for the next 25 years with around 4.6 billion barrels. Thus, Ecuador exports petroleum since 1972. In the short term, oil exports brought prosperity to the country, but "since 1982 economic growth remained elusive, inequality increased and social conditions barely improved" (Larrea & Warnars, 2009, p. 220). For instance, the country's dependency on oil exports increased and the impacts to the environment have been of serious concerns related to annual deforestation rates of about 199 thousand ha (Larrea & Warnars, 2009).

To this end, the Ecuadorian government has developed a proposal called the Yasuní-Ishpingo-Tambococha-Tiputini (Yasuni-ITT) in 2007. The objective of this initiative is to impede indefinitely the extraction of the petroleum reserve within the Yasuní national park[14] and therefore preserve biodiversity of the area, avoid around 410 million tonnes of CO2 emission, prevent deforestation and protect the living conditions of indigenous in the Amazon region. The value of the Yasuní oil reserve reaches annually US$ 720 million with an estimated availability of 850 million barrels of crude oil. Although, the country would benefit from the petroleum extraction, the government seeks to compensate those losses through carbon trade market (carbon credits for developed nations) in the frame of the Kyoto Protocol. The proposal would be carried out in

[14] The Yasuní nation park, with an area of 928 000 ha, has been announced to the World Biosphere Reserves by the UNESCO in 1989 due to its exceptional and dense biodiversity, counting with around 2274 trees and plant species, 593 bird species and significant high number of bat, amphibian, reptile and other species (Larrea & Warnars, 2009).

cooperation with the UN as an internationally managed fund for investments related to preservation, non-conventional energies and social development (Rival, 2010).

This initiative supports converting "natural capital in actual monetary flows […] and moving the national economy away from its dependence on oil (Rival, 2010, p. 359). Additionally, an important social-cultural criterion is the protection of ethnic groups such as the Tagaeri and Taromenane (around 300 people) who live isolated from the civilized society according to their traditional culture. Other indigenous groups are the Waorani and Kichua. In respect thereof, the country is rethinking its values grounded in nature and indigenous way of living (Larrea & Warnars, 2009).

3.1.4 Social background

Ecuador has a high rate of population living below the poverty line, approximately 34-40%, leading to emigration flows in the last years, especially to Spain and Italy[15]. For instance, social instability is strongly connected to unequal resource allocation and social discrimination due to gender disparity, place of domicile, ethnic origin and age.

Ecuador has a considerable share of ethnic people, represented by three main groups: mestizos, indigenous and black. Therefore, the country has a multifaceted cultural identity, with 13 indigenous languages spoken apart from the official language Spanish. Since the Spanish conquest, land owned by indigenous was continuously confiscated. Furthermore, indigenous people were obliged to work under severe conditions for the white elite. Until recent years, indigenous and black people's culture and identity was not recognized and they still live in areas with low infrastructure, basic services, health care, job opportunities etc (Larrea & Warnars, 2009).

In the last decades, organisations standing out for indigenous rights were developed. The most recognised indigenous organization is the Confederation of Indigenous Nationalities of Ecuador (CONAIE), which have gradually improved the indigenous situation and who have even created a political party called Pachakutik. Nonetheless, indigenous people in Ecuador are still socially excluded and suffer from poverty (EC, 2007; CONAIE, web).

[15] However, due to the European economic crisis, many emigrated people are coming back to Ecuador to search for job opportunities.

Regarding gender inequality, several movements and actions have improved women's rights, educational and professional development; anyhow most of the women are victims of corporal aggressions (EC, 2007).

Moreover, the unemployment rate of youth people ranks 14%, comparatively high to the entire unemployment rate of about 4%. But, on the other hand, studies by the EC (2007), demonstrated that around 34% of minors between 10-14 years are employed, mainly in banana plantation. Additionally, there is a high number of sexual exploitation of children. Until now, the government is lacking in prevention measurements, although it has been working with international institutions such as the International Labour Organization (ILO) in order to tackle this issue (EC, 2007).

Furthermore, the number of Colombian citizens and refugees living in Ecuador has been rising in the last years resulting in social tensions between both nationalities. Reasons hereof are the great commercial skills of the Colombians, increasing their activities in the country. This is not very welcomed by Ecuadorians, due to their own economic situation and need of employment.

3.1.5 Environmental issues

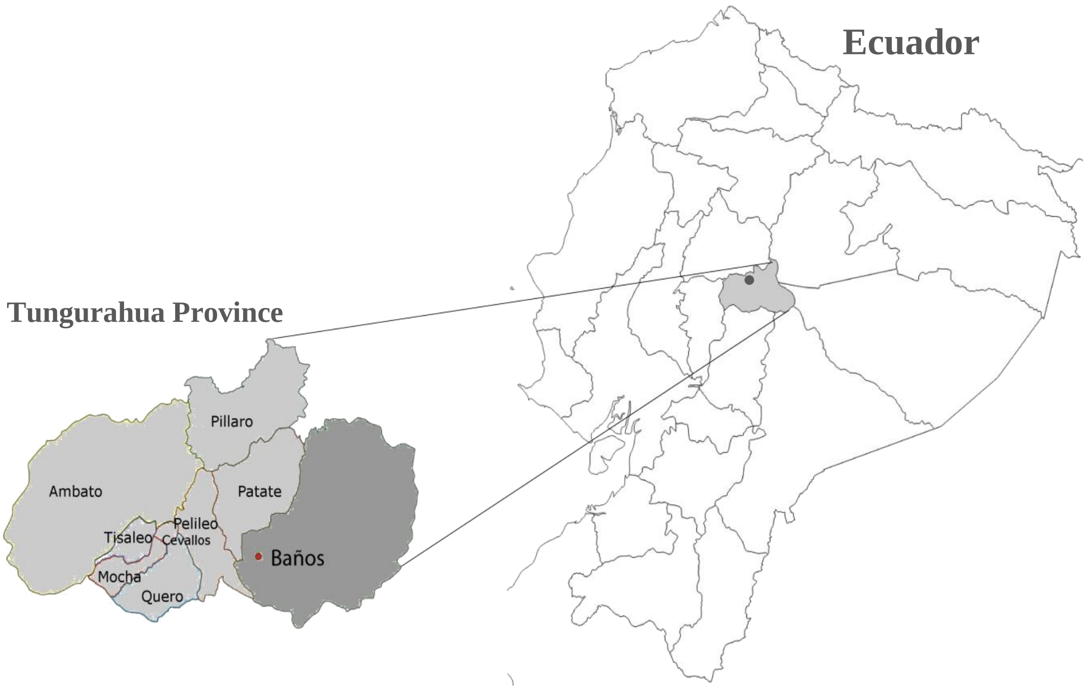
Ecuador has a strong vulnerability related to volcanic activities, seismologic events and severe climatic conditions namely the phenomenon of "El Niño" and "La Niña". On the other hand, Ecuador prospers from rich biodiverse ecosystems, wonderful natural reserves, great energy potentials as well as saturated water accessibility and mineral resource availability.

However, Ecuador is facing significant anthropologically induced environmental threats and degradation due to pollution issues and emission generation related to agricultural practices, logging, deforestation, mining, and hydrocarbon and oil extraction. All this have severely degradated the environment, causing erosion and desertification problems as well as contributing to climate change. It has been stated that the floodings related to *El Niño* have become more intensified and the glaciers of the Andean mountains are melting faster(CDE, 2009).

To this effect, several institutions and the government developed strategic plans and legislations and promoted, among others, the concept of ecotourism in order to protect the environment. But, this issue was not handled with priority and environmental policies were not enforced due to weak performance of the Ministry of the Environment in legal compliance and management.

3.2 Introduction to Baños de Agua Santa

The county Baños de Agua Santa (in English: Baths of Holy Water) is located at the eastern Tungurahua province of central Ecuador. Nationwide, it is known as the **“**Gateway to the Amazonas” or as the “Golden Gate” (PDOT-GADRAS municipal document, 2011, p. 147; Tourism Ministry, web). The Tungurahua province itself is divided into 9 different counties, namely: Ambato (the capital), Pillaro, Patate, Pelileo, Quero, Mocha, Tisaleo, Cevallos and Baños de Agua Santa, as depicted in Map 2



Map 2: Location of Baños de Agua Santa
Source: own elaboration

The relief of Baños de Agua Santa is characterised by the national parks Llanganates at the north and Sangay at the south-west in the Central Andes (Spanish: Cordillera Central). This area is part of the “Eco-Regional Complex of the Northern Andes” (PDOT-GADRAS municipal document, 2011, p. 59), which is ranging from Venezuela to the North of Perú. Furthermore, two active volcanoes are situated in this region: the Tungurahua volcano at the foothills of the Llanganates and the Sangay volcano at the natural reserve Sangay. The main River flowing through the county is the Pastaza River, formed by the Rivers Chambo and Patate up to the point where they meet and end up at the Amazonas River (AME, 2007).

The county Baños de Agua Santa encompasses both urban (municipality Baños de Agua Santa; typically referred to as Baños) and rural areas composed of four districts (Lligua, Ulba, Rio Verde and Rio Negro). Accordingly, this study has been focused mainly on the urban area exclusively, where over 73% of the county's population lives (see Appendix 9.3.) Furthermore, the urban areas include six rural communities: Illuchi Bajo, Runtún, Juive Chico, Jive Grande and Pondoa. The total area of the county encloses 1,070.13 km^2, which represents 31.6% of the provincial's area. Thereof, 15.6% are protected areas through the national parks Llanganates and Sangay (PDOT-GADRAS municipal document, 2011, pp. 210-212).

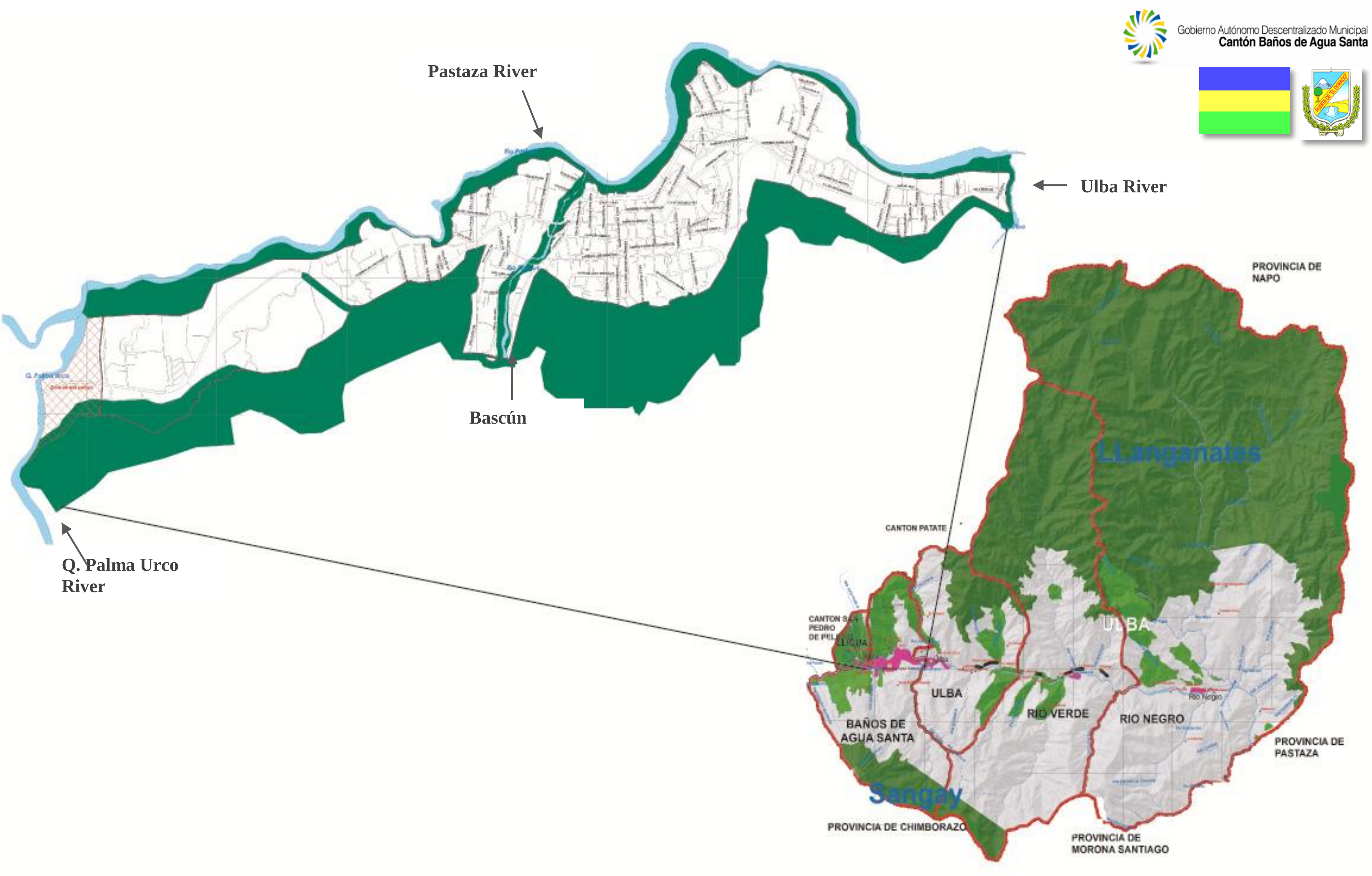
The municipality Baños is an autonomous town located at the latitude 1°23'47.02"S and longitude 78°25'29.00"W, surrounded by mountains, as depicted in Figure 18. Furthermore, Baños is roughly 180 km from the Ecuadorian's capital Quito and 35 km from the Tungurahuan capital Ambato. The total area of the municipality encloses 91.62 km^2, of which almost 9% are protected areas. The altitude of the municipality is about 1 826 m ASL. Additionally, the municipality is divided into 15 official neighbourhoods, each consisting of a few square blocks which have their own representatives and festivities (Municipio Baños web, 2010).

Figure 18: Location of the municipality Baños de Agua Santa
Source: a: Baños web (2013); b: own photography

The climate conditions of this region are characterised by the Equatorial and Andean climate which is tropical humid to semi-humid as well as cold due to the high Andean mountains. The annual average temperature is of 18.2 °C and the annual precipitation accounts to 1 400 mm (AME, 2007, p. 7; Baños web, 2013)

Baños was mainly an agricultural oriented region. However, since the infrastructural development and the construction of the main road to Ambato and Puyo in 1935, Baños has become a significant reference point for national and international tourists as well as for commerce.

To analyse the optimisation potentials of the municipality a regional material flow (RMF) analysis would be conducted in the following chapter.



Map 3: County Baños de Agua Santa and the municipality
Source: Municipality of Baños de Agua Santa, personal communication, 03.2013 (modified by the author)

4 Preliminary RMF analysis

A closer research study on the municipality of Baños is conducted through the application of a RMF analysis which allows a better understanding of the system by examining the current situation, including socioeconomic and environmental aspects. Additionally, a detailed overview of the municipal services related to drinking water, waste water and municipal solid waste as well as a SWOT analysis would be carried out in the next sub-chapters. The objective of this analysis is to uncover untapped potentials of the system's energy and material flows and identify possible social, environmental and economic instabilities of the municipality.

4.1 Current situation of Baños de Agua Santa

4.1.1 Social aspects

a) Demography and Population

According to the Ecuadorian statistic and census institute INEC (2011), the entire county encompasses 20 506 inhabitants (see Table 4), whereas a concentrated population number lives in the municipality Baños and at the rural areas along the Pastaza River.

Table 4: Distribution of the county's population according to their division

Division of the county	Inhabitants (Nr.)	Inhabitants (%)
Lligua	287	1,40
Rio Negro	1 276	6,22
Rio Verde	1 339	6,53
Ulba	2 594	12,65
Baños	15 011	73,21
Total	20 506	100,00

Source: (INEC, 2011)

The annual population growth rate of the county is about 2.44%, whereby since 2001 the population increased by about 21.43%. Additionally, there are a large number of immigrant people who relocated to the county mainly due to employment (65%) and business, but also due to family reunification or studies (PDOT-GADRAS municipal document, 2011, pp. 58, 216).

With respect to the county's population age, the majority of the population is between 15 and 64 years (see Figure 19). The percentage of elder people living in county is small; however it is somewhat more than within the entire country. Elder people live particularly at rural areas.

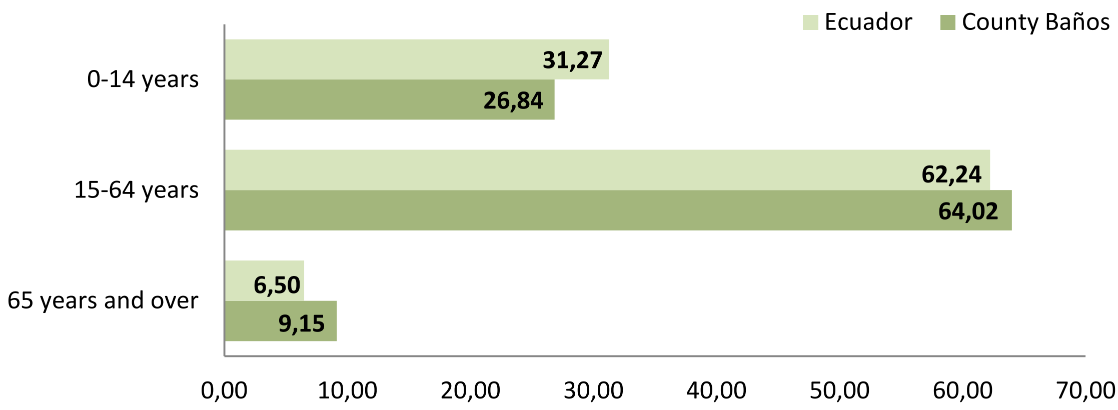


Figure 19: Distribution of the county's population by age
Source: own elaboration based on data from (INEC, 2011)

b) Education

The county has several educational institutions, whereas one third is located at the urban area. Currently 32% of the county's population has visited a primary school, 20 % completed secondary school and 14% obtained a universities degree. Furthermore, a great percentage (around 46%) of the population attends to an educational institution from 26 years upwards. The illiteracy rate is presently around 4% and has been decreasing in the last years (PDOT-GADRAS municipal document, 2011, pp. 235-236).

4.1.2 Economic activities

The county's population is mainly active in the tourism and agricultural sector, as demonstrated in Table 5, whereas the municipality Baños is particularly concentrated on tourism, as well as Rio Verde and Rio Negro. In respect thereof, 62% of the county's economically active population is employed or runs a business in the tourism sector; also the county's economically active population represents almost 50% of the inhabitants.

Table 5: Economic activity of the municipality

	Tourism (%)	Agriculture (%)	Livestock (%)	Commerce (%)	Artisanal work (%)
Lligua	-	70	20	10	-
Baños	**69**	**11**	**-**	**8**	**11**
Ulba	19	65	10	6	-
Rio Verde	65	22	7	5	1
Rio Negro	48	28	8	13	3

Source: (PDOT-GADRAS municipal document, 2011, p. 136)

The following paragraph would provide an overview of the abovementioned economic activities.

a) Tourism

The county Baños de Agua Santa is a well-known and highly promoted touristic destination within the country but internationally. From the 1980s the number of foreign visitors started gradually to increase and therefore the number of hotels, restaurants, bars, and other touristic services. Nowadays, the county receives one million national and international visitors annually, whereof 70% are national tourists who visit the county frequently during weekends, holidays, and festivities and particularly due to pilgrimages and other religious activities. The county has an important and recognized religious tourism for instance during the Holy Week on Eastern, about 6,000 visitors from all over the country come to praise the Virgen del Rosario. The main interest for visiting the county are the following (PDOT-GADRAS municipal document, 2011, pp. 147, 349; AME, 2007, pp. 12-16,147,349):

- Thermal baths: 26%
- Waterfall's route: 24%
- Extreme sport: 19%
- Nightlife: 14%
- Religion: 10%
- Trekking: 7%

The tourism sector of this region has a great variety of touristic activities and services. Those are, among others, rafting, waterfall sightseeing, horseback-riding, hiking, rock climbing, bungee jumping, trout fishing, zoo visiting, as well as ziplining and cable car riding across the Pastaza River canyon. Furthermore, the county amounts 16 different waterfalls along the Ecological Corridor (see Chapter 4.1.3), several viewpoints, recreation areas and ecological trails. Moreover, one of the main attractions are the thermal baths (hot springs) and water park areas, situated within Baños, as reflected in the county's name "Baths of Holy Water". There are three main public thermal baths, namely: *Agua de la Virgen* (English: waters of the Holy Virgin*), Santa Clara* and *El Salado*. Those baths are therapeutic due to their high temperatures (up to 55°C) and mineral compositions. Every month over 26 000 people visit the thermal baths, whereas the number does not include the amount of visitors during holidays and festivities. Additionally, the public baths represent an important income source for the autonomous municipality Baños. In combination to the hot springs, hospitality and wellness industry has been developed as a new touristic trend of Baños, besides the adventurous tourism activities (PDOT-GADRAS municipal document, 2011).

Momentarily, there are 154 different accommodations, of which 14 are hotels (shared rooms), 5 hosterias (private rooms), 112 hostels and 23 pensions. Moreover, Baños has around 51 tour operators, 92 restaurants, 55 small food and drink providers, 17 artisan shops and 31 bars and clubs. The tourism industry of the county has augmented significantly during the period of 2002 to 2011, whereby accommodation and food supply increased by approximately 45% and tour operators by 24% (PDOT-GADRAS municipal document, 2011, pp. 149-152).

To this end, tourism has turned into the backbone of the municipality, not only due to the infrastructure and services, but also due to the parks Llanganates and Sangay and the Ecological Corridor giving to the county an ecological character. Thus, the tourism industry in Baños is promoted as ecotourism, whereat it could be observed that several tourism management strategies and activities are not compatible with this concept.

Furthermore, publications from the municipality show that projects related to the tourism sector are aiming the integration of new tourism strategies such as community tourism, agrotourism, scientific tourism, in order to promote the county worldwide as a biodiverse tourism destination. However, it has been stated that the county has not considered the international awards of biodiversity dedicated to the protected areas as a marketing strategy to promote the county as a sustainable tourism area (PDOT-GADRAS municipal document, 2011).

According to the provincial government of Tungurahua, the tourism industry of Baños faces besides regional potentials also limitation factors due to the following aspects:

Table 6: Restriction issues and potentials of the county's tourism industry

Potentials	Limitation factors
• Presence of specialized products and producers for domestic and international tourism industry, particularly regarding wellness through thermal baths, ecotourism, adventure sports and religious tourism	• Insufficient awareness and commitment of the population to improve the daily tourism environment, particularly concerning urban aesthetics
• Possibility to develop community-based initiatives oriented to segments of social tourism, sciences, ecotourism, enabling the county to connect to more specialized niches of better educational and economic level.	• Low levels of human resource quality , mainly concerning customer service
• Permanent access to the Amazon through the Baños-Puyo route, which demonstrated touristic initiatives along the way and which connects both regions.	• Lack of updated statistical information disables adequate decisions related to tourism
• The presence of the Tungurahua volcano, despite the risks, transforms Baños to a unique touristic place located at the foot of an active volcano.	• Unqualified customers information and assistance service and inappropriate information management related to the volcano activity, reducing common tourism turnout particularly impeding free exploitation of adventure tourism
• The rich cultural variety in terms of gastronomy as well as local and artisanal work enriches the county and broaden tourism offers	• Negative impacts on the environment caused by the infrastructural projects and work for instance the San Francisco and Agoyán, which may cause natural resource deterioration due to overexploitation or lack of policies and actions in order to mitigate or restore the impact.
	• Uncoordinated public institutions, mainly private and local institutions, which could not support tourism activities as there competition between the actors is strong.
	• The rural areas share the greatest biodiversity and ecosystems. However, there is no adequate infrastructure which could attract the tourist to prolong their stay.
	• The commerce has been concentrated at the urban area, without contributing to economical development of rural areas and supporting.

Source: (Provincial Government of Tungurahua web, 2013; PDOT-GADRAS municipal document, 2011)

b) Agriculture and livestock

Historically, the regions along the Pastaza River were one of the most dynamic trade centres between the *Sierra* (highlands) and *Costa* (coast), which introduced progressively a market economy resulting in intensive expropriation of indigenous-owned land and natural resources. In the beginning of the 20th century, the province was characterised by large *haciendas*, dominating the provincial countryside with small population concentration. In respect thereof, in the 1960s the agricultural process expanded due to the agrarian reform and agricultural colonisation policies inducted by the state. To this end, large forest areas were transformed into pasture land and intensive cultivation land. Many communities changed their traditional agricultural practices for instance crop rotation, hunting and fishing by agricultural activities including monoculture practices and livestock. Such development had accentuated cultural effects (Rivera, Ospina Peralta, & Valarezo, 2004, pp. 204-207).

Nowadays, agriculture including humid forestry is one of the largest economic sectors of the county. The total area of the county accounts for 107 014 ha, whereas the forestry represents the largest county's area with 69% (Figure 20). The cultivated area encompasses 8%, on which particularly guava, lulo, soft corn, mandarin, blackberry, wheat, potatoes, onions, tomatoes and tamarillo are cultivated. Additionally, the production of balsa wood was carried out in the 1960s. (Fundación Natura, 2005).

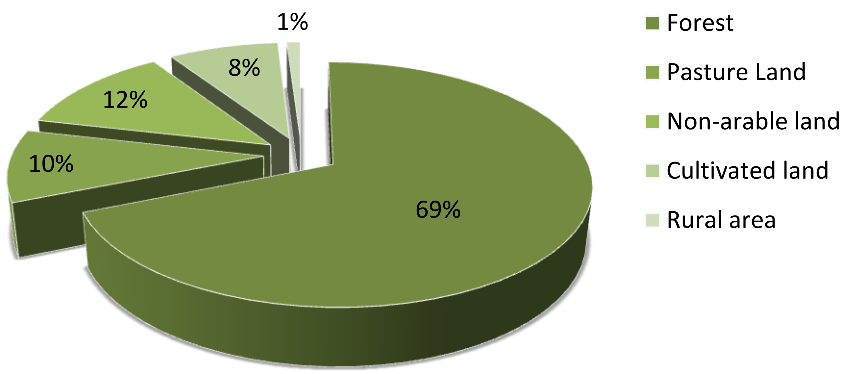


Figure 20: Area distribution of the county
Source: own elaboration based on data from (AME, 2007, p. 12); (SNGR, 2011)

The county's soil composition is characterised by pyroclastic materials and sediments derived from the volcano's activity over centuries. Typically those soils are shallow with different temperature according to the location and altitude. Thus, isothermal temperature of the soil in the north central part of the Pastaza River is between 1-10°C and more to the south the temperature increases to 10-20°C. The average annual precipitation is about 1 400 mm, whereby it varies within the county by diminishing westward in direction to the Amazonian region, where the moisture of the soil changes accordingly (PDOT-GADRAS municipal document, 2011, p. 59).

Vegetables and fruits

Given the soil cultivation potentials at favourable soil fertility, abundant water resources and special microclimate conditions, the county Baños is a traditional agricultural area predominated by a variety of crops, namely (PDOT-GADRAS municipal document, 2011):

- Transitory crops: soft corns, white carrot, potato, *fréjol* (bean), dry corn, potato called papa china, sweet potato, cabbage, vetch (this products are commercialised at the farmer market or utilised for own consumption).
- Permanent crops: blackberry, *naranjilla* (lulo), tamarillo, granadilla, mandarin, babaco, avocado, lemon, *Reina Claudia* (plum), guava, pear, strawberry, kidney tomato (this products are mainly sold at the wholesale market in Ambato or even Pelileo or Puyo).

Corn is the predominant crop in rural areas, occupying 200 ha in the rural areas of Vizcaya, Lligua, Pondoa and Runtún. Within these cultivation area, farmers plant pumpkins, which are fed to swine and cattle. Furthermore, fréjol is cultivated on 42.4 ha, vetch on 20 ha, lulo on 55 ha, tomato on 32.2 ha, tamarillo on 47.45 ha, avocado on 40.46 ha, babaco on 27.46 ha, mandarin on 12.97 ha and blackberry on 9.92 ha. The tamarillo is a plant which is too susceptible to pests, virus and fungi. This fruit is increasingly planted in greenhouses.

The vegetables and fruits are sold per box units. Therefore, during high seasons, 4 000 boxes of each mandarin, kidney tomato and babaco, 2 000 boxes of lulo and 1 000 boxes of tamarillo are sold each week to the wholesale market in Ambato. The livestock farming, on the other hand, is predominated by the production of poultry, swine, bovines, cultured fish (trout and tilapia) and guinea pig (Provincial Governement of Tungurahua, 2011).

The agricultural products are traded on the county’s market or traded to the wholesale market in Ambato in order to distribute it nationwide.

Livestock

According to Cadena Antonio, head of the municipal department for hygiene and agricultural development (see Appendix 9.3), the county count up about 6 000 cattle heads including Holstein and Jersey breeds for milk production. The daily milk production per cattle accounts for 3-8 l. Furthermore, the main poultry industry is the “Avícola Agoyán” accounting about 160 000 laying hens. Other four poultry establishments have together 50 000 to 60 000 laying hens. To the south west of the county, several people are raising, breeding and selling trout to the market or delivering to restaurants or directly on site in combination with fishing activity for tourist.

Regarding swine farming, the county is characterised by a special form of swine breeding called *“traspatio”.* This implies that the breeding of swine managed jointly within families, of which approximately 150 are known.

Farmer families

Approximately 65% of the small farmer families own 1 ha of land, representing only 6% of the agricultural sector area. The remaining agricultural areas belong typically to large farmers. Small farmers still apply some of the traditional agricultural practices. According to Elena Rojas (from a farmer family, personal communication), livestock is fed with organic kitchen residues (5-10 kg per day), sugarcane (0.5 kg), plantain (10 units per animal per day). The manure is collected for the utilisation of the production of organic fertilisers. In her family, manure of 12 swine is collected every second day, approximately 69 kg of pure manure mixed with the sugarcane bagasse. The residues of 100 guinea pigs are collected once a month, approximately 12 canvases which are equivalent to 544.8 kg. Further livestock residues for instance from cattle or horses are not collected as those animals are on the fields. With the collected animal manure, the families prepare organic solid and liquid fertilisers. Solid fertiliser consists of manure, dried leafs, ash of firewood, alfalfa, water, molasses and yeast. On the other hand, liquid fertiliser consists of water, manure from guinea pig, alfalfa, beans leafs, nettle and garlic.

Agrotourism

Furthermore, the agricultural sector supplements the tourism sector of the county through the offers of sports and recreational fisheries as well as gastronomy selling regional products such as fish and pork (Governement of Tungurahua Province, 2011).

Currently the government of the municipality and the province set the objective to support a “clean” agricultural development under the motto: *“Juntos por una producción limpia para una poblaión sana!”* (in English: Together for a clean production, for a healthy population). This implies organic fertilisers and includes the abovementioned aspects in order to strengthen, among others, farmer organisations, market infrastructure, agro-ecotourism and marketing. Therefore, the objective should be fulfilled through the application of three main strategies concerning a) communal participation and organisation, b) Capacity building and technical agricultural assistance and b) promotion of agricultural production and agro-tourism. So far, the municipality of Baños carried out several actions to fulfil the objective, among others, developed 7 types of organic fertilisers based on, inter alia, grass, fruits, compost, in order to introduce those to farmers. Moreover, agroecological products are offered at the trade market *“Plaza 5 de Junio”* of Baños and an agroecological farm is situated at the park are *“Parque de la Familia”* of Baños. (Provincial Governement of Tungurahua, 2011) (Cadena Antonio, personal communication).

Nonetheless, the agricultural sector faces limitation factors, which are as follows (Governement of Tungurahua Province, 2011, p. 27) (PDOT-GADRAS municipal document, 2011):

- Lack of agricultural production improvements drives to decreases in the active population of this sector due to low profitability
- Poor infrastructure in collection and storage centres for the product distribution
- Poor capacity building, training and technical assistance for agricultural and fishery sector
- Elevated consumption of chemicals
- Presence of intermediaries within the county’s markets and trade fairs
- Topographical irregularities disabling agricultural mechanisation and extensive agricultural cultivation
- Permanent risk due to Tungurahua volcano

- Absence of agricultural studies applicable to the current situation of the county
- Absence of trade fairs in the communities and appropriate commercialisation systems
- Poor availability of networks for agricultural commercialisation
- Unavailability of land-use plans/regulations

Furthermore, the county's agricultural sector has significant impacts to the environment due to the high consumption of artificial fertilisers and pesticides, particularly in cultivations of large farmers. Additionally, the number of greenhouses has augmented noteworthy in the last years contributing to soil degradation due to high chemical applications and intensive cultivation. Furthermore, greenhouses produce plastic residues which are highly contaminated. Each greenhouse is utilised for 8–10 years, whereas the plastic has to be changed every 2-3 years and afterwards, the soil remains infertile. After use, several greenhouses are left behind without any restoration or clean up of the plastic material. In some cases the greenhouses are even burned. In order to reduce the burning of greenhouses, the municipality offers the service of picking up the plastics and dispose them on the landfill.

Furthermore, it has to be mentioned that agricultural practices are similar to monoculture agricultural practices due to concentration of single crops growing at most of the county's agricultural sectors. For instance Cusua mainly cultivates corn, Runtún kidney tomato, tamarillo and babaco. To make the soils fertile, lots of fertilisers are applied. This leads to intensified and extensive cultivation practices with severe impacts on the soil and environment.

c) Commerce

The county amounts three markets, namely as follows (PDOT-GADRAS municipal document, 2011, pp. 142-143):

- *Mercado Central:* is opened every day, provides stands for 120 local people for selling fruits, vegetables, meat, crops and prepared food.
- *Plaza 5 de Junio*: opened twice a week, whereas Sunday is the main market day for selling fruits, vegetables, meat, crops and prepared food. On this market around 200 farmers have their stand, of which 10% are from the county and the remaining part from other municipalities such as Pelileo, Ambato and Pillaro.

- *Heriberto Jácome*: opened on Sunday and is a market particularly for the commerce of potatoes (96%) as well as textiles like clothing and shoes.

d) Artisanal products

The elaboration of artisan products within the county is an ancient practice, whereby products based on balsa wood were one of the most recognised crafts. But the artisans working with traditional balsa wood migrated to other cities, due to the volcanic activity. Nowadays, artisan works are concentrated on ornamental objects including jewellery, key chains, chests wood, acoustic guitars, wooden coffers, coloured maracas, textiles based on cotton, alpaca wood, sheep wood etc. Those articles are mainly offered at the city centre.

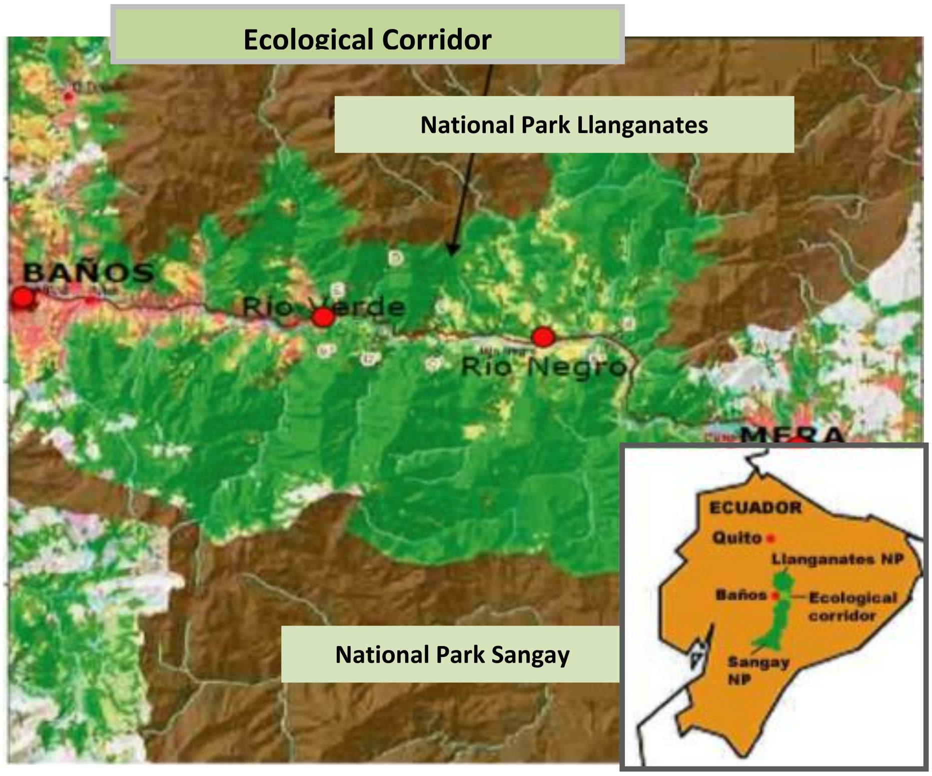
Further artisan products typical from this region are sweet products, among others, *melcocha* (chewable candy made of sugarcane and fruits), *dulce de guayaba* (guava confectionery), *manjar de leche* (cameralised milk), *mermelada de guayaba* (hard jam made of guava). Those products are known nationwide and representative for this region.

4.1.3 Environmental aspects

The county is located between two national parks: Llanganates and Sangay, as mentioned above. The total area of those natural reserves account for 571 765 ha (Sangay) and 219 707 ha (Llanganates). The main objectives are: (AME, 2007, pp. 7-9)

- Protection and conservation of the areas at the Sangay and Tungurahua volcano and their adjacent areas including eastern foothills of the central mountain range of the Andes and the as well as
- Protection of the scenic resources of major recreational value and tourists
- Provision of opportunities for scientific research, environmental education and community development.

The connection of both national parks represent “the Ecological Corridor Llanganates-Sangay” with a surface of 42 052 ha, of which around 60% belongs to the county Baños. Approximately 14% of this area is covered by private properties and the Pastaza River and the remaining area represents the ecological corridor. This corridor, particularly at the Pastaza valley, is the habitat for a wide variety of species in fauna and flora, among others, orchids, birds, bats, as well as mountain tapirs, spectacled bears, pumas and ocelots. Nonetheless, several species are facing the threat of extinction due to anthropogenic disturbances for instance through agricultural practices and other human activities such as deforestation (WWF, 2003).



Map 4: Ecological Corridor in between the national parks Llanganates and Sangay
Source: won elaboration based on (AME 2007, p. 9; WWF, 2003)

Therefore, *Fundación Natura*, an associated organisation of the World Wide Fund for Nature (WWF) of Ecuador, has developed an initiative plan to maintain and protect the rich biodiversity and genetic variability of the species living within the corridor. Activities carried out have been for instance the promotion of ecotourism, environmental awareness and appreciation building among famers and the local people. To this end, WWF organisation declared ecological corridor as “Gift to the Earth” by (WWF, 2003; AME, 2007).

Despite the conservation efforts, there are various threats affecting to the county’s environment. For instance, in the late 1980s poultry farms have been developed along the Pastaza and Ulba River which have contributed to their contaminations. Additionally, several infrastructural activities, such as the construction of the San Francisco Bridge, the road from the county to Puyo (located in the Amazonas) and the tunnel interconnecting to the hydropower central, have affected the environment.

Further, concerns have been acknowledged in relation to the construction of additional hydroelectric power stations which would cause significant environmental impacts (Fundación Natura, 2005).

In respect to the abovementioned environmental concerns, the *Fundación Natura* organisation developed a strategy plan based on ecotourism and environmental protection by formulating several project ideas in cooperation with the municipality and the EcoCiencia organisation. The project ideas incorporate, inter alia: development of a county's curriculum including ecological, social and cultural aspects; capacity building of involved actors in the areas of environment and tourism; investigation, use and management of natural resource and development of environmental institutions (Fundación Natura, 2005).

4.1.4 Hydropower facilities

Given the large water resource availability at the county, there are currently 6 hydropower projects which take advantage from the Pastaza and the Topo River with a total flow of about 467 m3/s (PDOT-GADRAS municipal document, 2011, p. 106).

Approximately 5 km to the east of the county Baños is located the hydroelectric power station Agoyán, the third largest hydroelectric generator of the country. The dam is operated by a state-owned company (Hidroagoyán S.A). Since 2009, this company belongs to the seven business units of national electricity cooperation, namely CELEC E.P[16]. Additionally, Hidroagoyán S.A. administrates the hydropower station *Pucará* and *San Francisco*, both situated in the Tungurahua province, whereas the former is located within the national park Llanganates, 35km from Pillaro village; and the latter is located downwards the Agoyán facility. The hydropower Agoyán has an annual installed capacity of 223 MW (CELEC EP web, 2012).

Current emerging problems related to hydropower projects are: severe environmental and socio-economic impacts, losses of biodiversity and reduction of water disposability. For instance, water from the Topo River was known for its good to excellent water quality, previously utilised for domestic, agriculture, recreation and tourism purposes,

[16] The CELEC E.P. is a public strategically of electricity of Ecuador which was constituted in 2009 by merging the energy companies: Hidroagoyán S.A, Hidropaute S.A., Electroguayas S.A., Termoesmeraldas S.A., Termopichincha S.A. and Transelectric S.A.

which is nowadays affected through the hydropower facility. Furthermore, a great waterfall, called Agoyán, became almost disappeared a result of the construction of the hydroelectric power plant Hydroagoyán, as depicted in Figure 21 (PDOT-GADRAS municipal document, 2011).

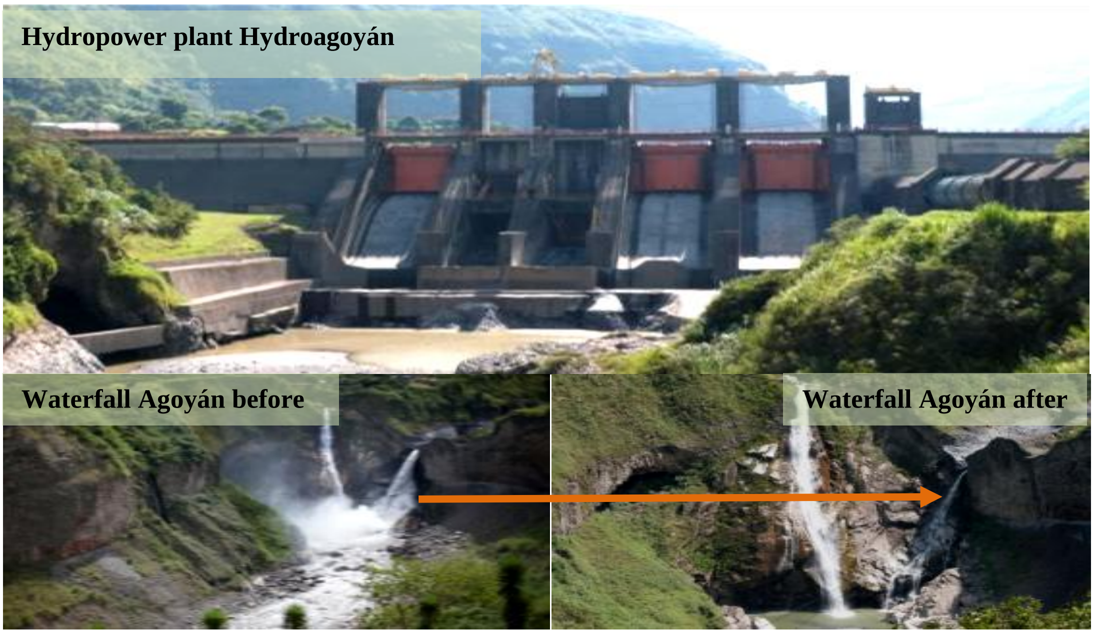


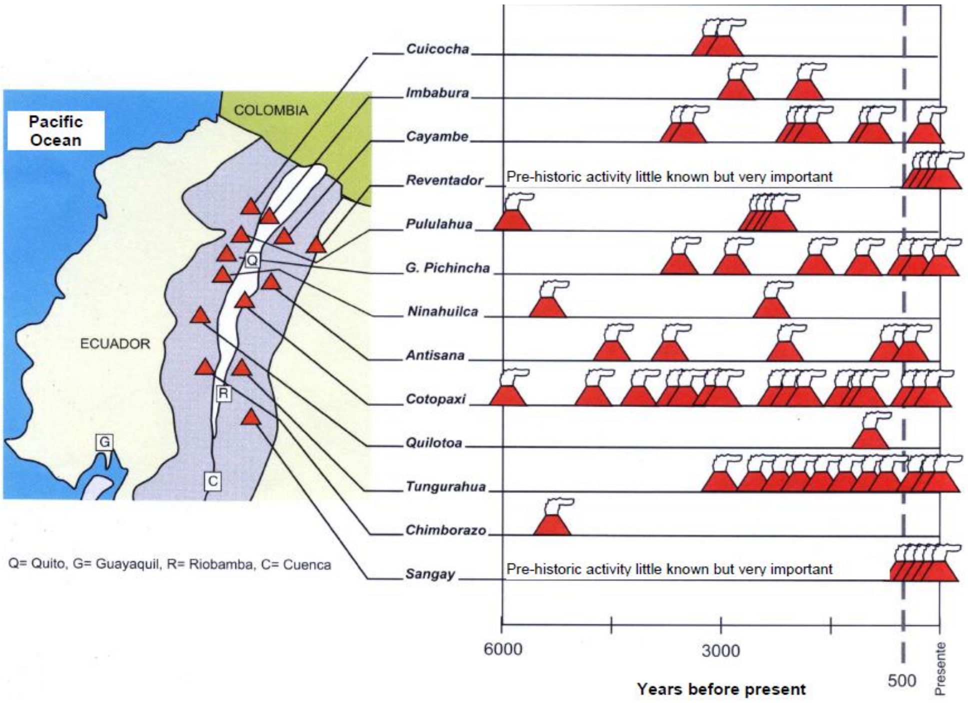
Figure 21: Hydroelectric power plant Agoyán and waterfall Agoyán
Source: own photography

4.1.5 Natural vulnerabilities

The county Baños is exposed to three main significant vulnerabilities: volcanic activity, landslides and seismic acceleration, explained as follows:

a) Volcanic vulnerability

Ecuadorian volcanoes are situated from the north of Quito to the south of Riobamba (Map 5), lying under two tectonic plates (South American plate and Nazca plate) which are compressing against each other and form the mountain chain of the central Andean (in Spanish Sierra). They are more than 4000 m high and the eruptive activity of the majority of them (andesitic cone volcanoes) is explosive with frequent eruptions including pyroclastic flows, extensive ash falls and lahars forming. The explosive reoccurrence is large, ranging from hundreds to thousands of years. Moreover, frequent earthquakes menace areas of the highlands. All over Ecuador, there is no use of geothermal energy for energy generation; however, hot springs are common along the Andean regions of the country (Leonard, Johnston, Williams, Cole, Finnis, & Barnard, 2005) (IGEPN, 2012).



Map 5: Ecuador’s volcanoes and graph of their eruptive history
Source: (Leonard, Johnston, Williams, Cole, Finnis, & Barnard, 2005, p. 3)

Ecuadorian’s active volcanoes are monitored by the Ecuadorian Geophysical Institute of the Polytechnic University (*Instituto Geofísico de la Escuela Politécnica Nacional*: IGEPN), in the capital Quito. IGEPN was founded with governmental and foreign support as well under the assistance of research agencies such as the Institute for Geosciences and National Resources (BGR) and Institute de Recherche por le Développement (IRD).

The Tungurahua volcano (Lat. 1°28’S; Long. 78°27’W) is a harmful and frequently active volcano, of a height of 5023 and 14 km diameter. It is situated on the Eastern Cordillera of the Andes around 33 km from the capital Ambato, of Tungurahua province. The principal drainage sources are the rivers Puela (south and southeast), Chambo (west) and Pastaza (north and northeast) (IGEPN, 2012). Since the last 2300 years, the supply rate of magma has been approximated at ~$1.5x10^6$ m^3 per annum (Hall, Robin, Beate, Mothes, & Monzier, 1999, p. 18).

Since the discovery of the volcano in 1532, 17 different eruptions have been reported, whereby more than half of them are doubtful. The historically documented and approved main eruptions periods have taken place in 1641-1646, 1773-1781, 1886-1888, 1916-1918 and 1999-present. According to this, the volcano has shown activity phases about each century (Hall, Robin, Beate, Mothes, & Monzier, 1999; IGEPN, 2012; Samaniego, Le Pennec, Robin, & Hidalgo, 2010).

The abovementioned eruption periods are defined “as a time interval of several months to years that may comprise successive eruptive phases characterised by alternating eruption styles (e.g. strombolian, vulcanian, etc), which typically last from hours to weeks” (Pennec, et al., 2008, p. 71). Recently, studies have determined that the Tungurahua volcano represents one of the most harmful Ecuadorian volcanoes due to its pyroclastic-, lava- and volcanic debris flows as well as ash falls and lahars, endangering 25 000 residents and damaging their cultivation lands in the surrounding area of the volcanos’ foot.

Present activity

After 80 years, the present activity of the Tungurahua volcano started in 1999 and has since then continuously demonstrated eruptive phases of different alarming levels (low, moderate and strong), mainly of short time length. Those are determined explosions like canons, 7 km high columns and regional ash distribution. The most hazardous explosions are those emitting pyroclastic flows representing a great danger for the populations, particularly in 2006 (July-August), 2008 (February) and 2010 (May). Additionally, according to Arellano, et al. (2008 p. 156) estimated that during the period of 1999-2006 more than 1.91×10^6 t of sulphur dioxide (SO2) emissions have been released to the atmosphere.

For instance, the explosion in August 16th, 2006 is characterised by heavy pyroclastic material deposited on the north-western valley of the Tungurahua volcano (Figure 22 a,c) and release of thick ash into the troposphere (Figure 19 b) with following eruptive breakouts of lava flows two month later. The pyroclastic flows contained andesitic rocks depicted in Figure 22 d) (Samaniego, Le Pennec, Robin, & Hidalgo, 2010). With respect to publication from (NASA, 2006), around 5 000 households have been damaged.

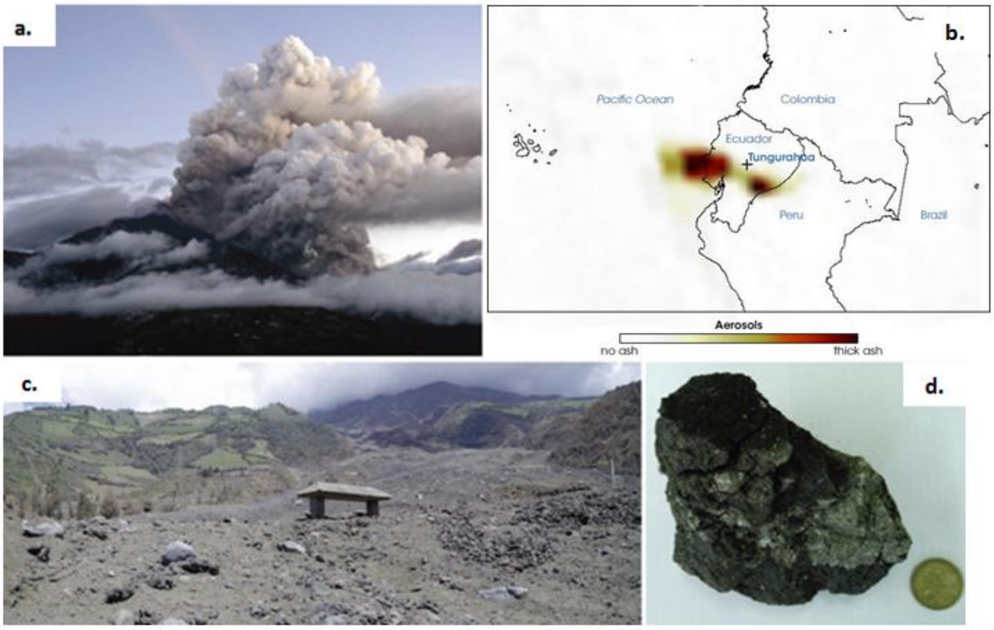


Figure 22: Images of the eruption of the volcano Tungurahua in 2006
Source: a,c,d: Samaniego, Le Pennec, Robin, & Hidalgo (2010, p. 71); b: NASA (2006)

Menaces to the county Baños de Agua Santa and society

Since mid 1989, the Tungurahua volcano is monitored by the IGEPN through the installation of seismological stations and measures concerning ground deformations, geochemistry, lahars, thermal, meteorology as well as other visual and acoustic technologies (IGEPN, 2012). Therefore, IGEPN manages an observatory station located in Guadalupe, 13 km from the volcano Tungurahua. Furthermore, a local civil defence (CD) administration based on volunteers work has been founded in 2001. They have carried out several activities concerning education and risk awareness in schools, evacuation route signs, safety measurements, informative posters etc. Additionally, the CD supervise a network with people which communicate any observed alarming activities and manage siren systems placed in several areas of the town and . But the CD is lacking of financial sources and support.

According to the mentioned studies and the experienced volcanic events, vulnerability of the county Baños de Agua Santa is estimated to be around 10%. The main threats to the communities are earthquake as well as pyroclastic and large lahars flows (see Table 7). The lahars flows, however, have affected mainly the rural areas Lligua, Ulba as well as the Chambo River, tributary to the Pastaza River. Nevertheless, the Pastaza River represents high concentration of villages, infrastructure and economic activities (SNGR, 2011).

Table 7: Lahars and pyroclastic flow risk to the county Baños de Agua Santa

Volcanic threats	Risks	Exposed area (ha)	Percentage (%)
Pyroclastic flows	Major	8089.00	7.59
	Minor	2462.70	2.31
Lahars flows	Major	592.00	0.56
	Minor	309.49	0.29

Source: SNGR, 2011, p. 13, modified and translated by the author

Regarding volcanic threatens; historically eruptive events transferred pyroclastic material and lahars down the valley of Bascún, directly to the urban area Baños, as depicted in Figure 23 a. Scientific evaluation models of recent hazardous explosions, for instance in 2006 (July 14th and August 16–17th), demonstrated volcanic pyroclastic flows covering the western half of the crater flowing down the drainage paths. The magma, whereas, covered mainly the north-western side, as illustrated in Figure 23 b (Samaniego, Le Pennec, Robin, & Hidalgo, 2010).

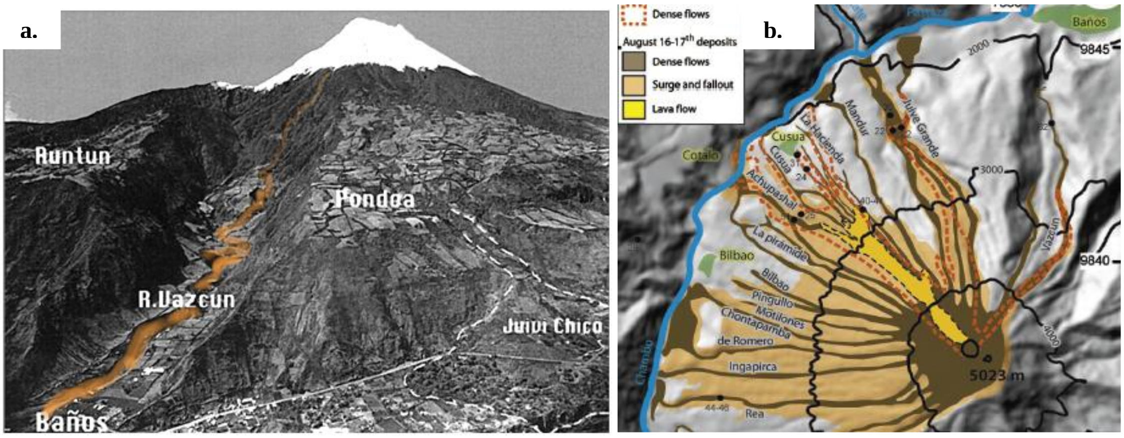


Figure 23: a: Tungurahua volcano seen from north, b: Distribution of volcanic hazardous matter
Source: a: Hall, Robin, Beate, Mothes, & Monzier, 1999, p. 5 (modified); b: Samaniego, Le Pennec, Robin, & Hidalgo, 2010, p. 70

Furthermore, the communities have been affected through extensive agricultural damages and transportation interruptions due to lahars flow. The impacts on local people associated to ash amount, distribution and temperature depends on the wind course, eruption periods and geographic location. For instance, agricultural areas at the foot of the volcano have been covered by 20 cm of ash during the eruptions of 2004, burning and damaging significantly the crops. The Tungurahua volcano is surrounded by farmland and livestock production, mainly cattle and chicken. Particular vulnerabilities of ash fall are as follows (Leonard, Johnston, Williams, Cole, Finnis, & Barnard, 2005):

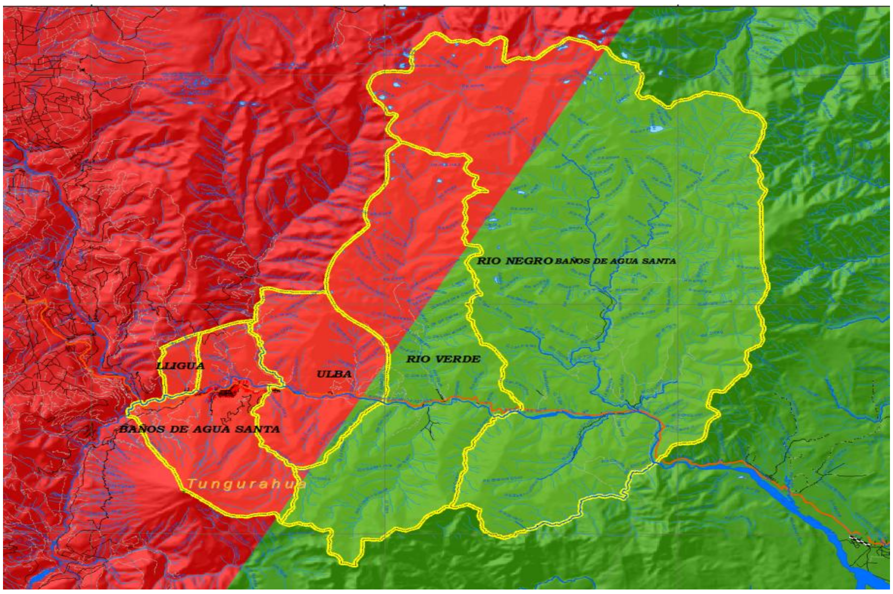
- Price reductions of meat (mainly chicken) up to 50%
- Loan restriction to small land-owners situated in ash affected areas
- Livestock malnourishment and increased death rate (ash intake through feed and respiration)
- Livestock evacuation difficulties
- Fish death of local cultivations in Baños (around 10%)
- Crop destruction up to 50% at Baños and its neighbourhood through ash burning (also 100% crop losses for some farmers)
- Farm breakdown through accumulated ash flows from ongoing volcano explosions
- Income and livelihood loss especially for small farmers and particularly during the evacuation period (already 3 evacuations since 1999)
- Local food reduction and regional economic decline rates

Nevertheless, the land productivity returns after a few months of an ash fall and the ash also increases land fertility. The Ecuadorian livestock association (*Asociación de Ganaderos de la Sierra y el Oriente*: AGSO), measures frequently ash depths and supports the communities with advices, restoration activities and food distribution to the most vulnerable areas during heavy eruptions.

The residents of the county experienced a first evacuation in 1999 against their willingness, having significant consequences on tourism industry and the inhabitants. After some month they inhabitants returned to their houses against permission of the authorities. The population living in Juive Grande, a high risk area, have been relocated to residencies at Rio Blanco, 7 km from Baños. Those residencies were constructed by the MDUVL (PDOT-GADRAS municipal document, 2011).

b) Seismic acceleration

The seismic acceleration is considered to be very high within the county, accounting with 36% at westerns side (incl. Lligua, Ulba and Baños) and 63% of the eastern side (incl. Verde River and Negro River), as depicted in Map 6. The majority of the buildings are exposed to seismic acceleration risks due to the same reasons as mentioned above as they are exposed to landslides (SNGR, 2011, pp. 11,23).



Map 6: Seismic acceleration risks at the county Baños de Agua Santa
Source: (SNGR, 2011, p. 11)

Those threats represent high menaces to the county and its development because they have great impacts to buildings as well as to vital networks such as drinking water, waste drainage systems and water bodies which affect the population of the county. The main water pipe network is composed of seven lines, which are in a relatively poor condition. Additionally, the thermal baths as well as the drinking water treatment plant are located at high risk areas (SNGR, 2011, pp. 26-31).

c) *Landslides*

The county faces high risks of landslides and earth collapses with very high features. Therefore, landslides are a potential threat for the county, as Baños is located at a monotonous terrain with many slopes. Heavy precipitations and unsustainable land use such as deforestation and agricultural practices cause erosions and landslides. Particular risks are given during the rainy season, causing heavy floods. The consequences are high, driving to losses of human lives, agricultural goods and livestock, homes, as well as infrastructural damages. Inhabitants living in the most vulnerable areas were resettled to more secure locations (PDOT-GADRAS municipal document, 2011).

The majority of the buildings within the municipality are exposed to landslides, as demonstrated in Table 8. Most of them are facing medium to high risks levels, particularity in the south east part of the municipality. Reasons therefore are, among others, wall construction materials of the buildings, the age, one-floor-houses and unfavourable topographic places (SNGR, 2011).

Table 8: Landslide risks affecting building

Risk level	%
High risk	19
Medium risk	51
Low risk	29

Source: own elaboration based on data from (SNGR, 2011, p. 21)

For instance, a dangerous landslide area is the gorge of Bascún, starting practically at the volcano's crater (5 033 m ASL) and going down until the Pastaza River (1 800 m ASL). This gorge has a very deep slope, representing high risk for landslides, particularly during the rainy season. In respect thereof, the landslides and increased water flows have caused several damages to households, including the thermal baths, namely *El Salsedo*. Due to those menaces, most affected population were relocated to Rio Negro. Furthermore, the Bascún gorge has a high vulnerability to pyroclastic flows and lahars.

4.1.6 Stakeholder Analysis

The determination and selection of the relevant stakeholders plays an important role in practice-oriented research especially by conducting a field study. Stakeholders are important individuals and groups who directly or indirectly influence the material and energy flows in a system in the sense of decision-making and management. Moreover, according to Wagner & Enzler (2005), it is important to involve stakeholders in order to develop sustainability strategies which find solutions harmonizing the different requirements of the players. Thus, solutions could be developed through better communication opportunities among the potential stakeholders. Additionally, collaboration and communication with stakeholders enable to achieve expectations and "to increase the probability of project success by ensuring that the stakeholders understand the project benefits and risks" (Project Management Institute, 2008, p. 261).

Therefore, potential stakeholders are, among others, governmental authorities, NGOs, other organisations, institutions, enterprises, tourist agencies, creditors and industries.

The main stakeholder group for this study is the municipality, as they are relevant information and data providers of material and energy flows within the municipality.

During the field study and the stay at Baños, constant communications with municipal stakeholders have been carried out. The most relevant stakeholders of this study are as follows:

- Mayor of the municipality: Eng. José Luis Freire Yepez
- Risk Management: Eng. Mayorga Cifuentes Xavier Enrique
- Environmental Chair: Eng. Ramos Gabriela,
- Environmental recovery: Eng. Coca Edwin
- Head of hygiene and agricultural development: Eng. Cadena Antonio
- Head of Drinking Water and Recovery department: Eng. German Vega
- Director of Tourism Department: Eng. Mayorga Enrique

More detailed information of the analysed stakeholders is listed at Appendix 0.

4.2 The Municipality and municipal services

The municipality Baños is an autonomous decentralised government according to Art.270-271, Constitution of the Republic of Ecuador (PDOT-GADRAS municipal document, 2011). To this end, the municipality generates its own financial resources and take part in the central state revenues (minimum 15% of the permanent and maximum 5% of the non-permanent revenues, excluding public debts) which are in conformity with the principles of subsidiary, solidarity and equity. Within the municipal departments around 246 people are employed, of which 27% are women and 20% have a higher education level (PDOT-GADRAS municipal document, 2011, pp. 266-267).

The current mayor of the municipality determined three main strategic objectives embodied in the County's Development Plan, which are defined as follows (SNGR, 2011):

- Development of the tourism, services and agriculture which represent the main economic drivers
- Enhancement of educational and health service quality
- Enhancement of basic services and equipment of recreational areas

Baños is an exemplary municipality compared to other municipalities of the country, with regard to own income generation of about $532,689, whereas 62% comes from the municipal thermal baths. This income makes up to 40% of the total municipal budget.

Moreover the basic municipal services include wastewater (WW) disposal, municipal solid waste (MSW) collection, and access to drinking water. These services are explained in the following sub-chapters.

4.2.1 Drinking water

Baños de Agua Santa is blessed by a large number of water river flows arising from the eastern range of the National park Llanganates and Sangay, whereas the main rivers are: Bascún, Pastaza, Ulba, Rio Verde and Rio Negro. Due to the county's topography there are also waterfalls, creeks, streams and frills as well as outcrops of thermal waters. Thereof, the municipality accounts for several drinking water sources along the country, whereas the municipality Baños provides the households with tap water from two main sources (PDOT-GADRAS municipal document, 2011).

Approximately 82-85% of the county's population, mainly in urban areas, have access to drinking water provided through the public network of the municipality. The remaining population obtain drinking water from rivers, streams and ditches According to German Vega, head of municipal drinking water and recovery department and publication from PDOT-GADRAS municipal document /2011), the population's water consumption in the county, particularly within the municipality Baños, amounts for 180–200 l per capita per day. In this respect, the high water consumption rate surpasses those of most developed countries and represents one of the top water consumers worldwide. Momentary, the price per m^3 tap water is by US$ 1.20.

Main concerns regarding public drinking water is the poor water quality due to contamination of the water by pyroclastic flows and other volcanic materials at the catchment area and other contaminations through agricultural practices. The drinking water network system is exposed to landslides and seismic acceleration as well as to volcanic events such as lahars and pyroclastic flows). For instance 40 m of volcanic materials have been detected at the water catchment area, according to German Vega (personal communication, see Appendix 9.3). Furthermore, the water has a high content of iron (Fe) and magnesium (Ma) related to its volcanic origin. Through the waste treatment plant, those minerals are being reduced (SNGR, 2011, pp. 26-31.

In respect thereof, the poor water quality is directly related to the most frequently emerging diseases affecting the health of the population. According to the National Institute of Statistics and Censuses INEC (2010), around 37% of the population in the county drink water directly from the tap.

However, in order to improve the tap water's quality, the municipality has carried out a US$ 8 million project the construction of a new drinking water treatment plant located at a village called *El Porvenir*, around 40 km from Baños, near Ulba. The new plant has the capacity for 100% and is considered to be an emergency plant in case the current water capturing system would be destroyed through the volcano activity (see Appendix 165). The project would be running until February 2014, whereby 80 % of the project is already realised (German Vega, municipality, personal communication) (PDOT-GADRAS municipal document, 2011).

Nonetheless, this service represents a financial deficit for the municipality, whose expenses (US$35,515) exceed the revenues (US$17,852) by 50%. (AME, 2007, p. 13).

4.2.2 Waste Water

Regarding WW disposal of the county, almost 62% of the households are connected to a public sewers system, whereas according to INEC publications, 79% of the county's households have connections to those systems. However, momentarily 100% of the WW of all connected households to the public sewer systems is discharged untreated to the Pastaza River, as demonstrated at the two WW "waterfalls" shown in Figure 24. From that, there are 13 active sewage discharges directly in the Pastaza River. The remaining county uses septic tanks, cesspools, and latrine or discharge it directly to the nearest water bodies. Thus, there is any WWT system employed in the municipality and the whole county.

Figure 24: Untreated WW discharge into the Pastaza River
Source: own photography (March, 2013)

In respect thereof, the Pastaza River is highly contaminated. Thus, the high contamination of this river is inducted through WW discharges from upper river flows from large cities like Latacunga, Salcedo, Ambato and Pillaro. For instance, besides domestic, industrial and hospital WW discharge into the river, residues from agricultural practices as fertilisers and high toxic pesticides run into the water bodies. To this effect, the section of the Pastaza River running through Baños is highly polluted. Nonetheless, sportive tourism activities, among others, rafting and kayaking are carried out on that river, putting in risk human health.

According to German Vega (see Appendix 9.3), the sewer drainage system of the municipality is 50 years old. It is characterised by round centrifuged reinforced concrete pipe systems, which are in very poor conditions. Furthermore, the sewer drainage system is a combined system without separation of rainwater and waste water. A few years ago the municipality planned the implementation of a separated drainage system, however it was not realised. But recently, the proposal was retaken and new proposals would be presented in August this year. The investment amount is estimated to be US$20 million, whereby proceedings for a governmental loan subsidised by half, are continuing.

Conforming to studies published by the municipality, about 1.07 million m^3 WW is discharged annually from the public sewer of Baños system to the Pastaza River. The domestic pollution load of the municipality Baños, defined by the biochemical oxygen demand (BOD5) indicator, is about 233 t BOD_5 per annum and household. Further contamination loads compared to other provincial cities are, as indicated in Table 9.

Table 9: Domestic contamination load at Tungurahua Province

Municipalities	Discharge (million m^3/a)	BOD_5 (t/a)	Solids (t/a)	Carbon (t/a)	Nitrogen (t/a)	Ammonia nitrogen (t/a)	Phosphorous (t/a)
Ambato	17.5	3096	11185	2486	2417	504	32
Baños	**1.07**	**233**	**670**	**149**	**37**	**23**	**7**
Cevallos	0.36	81	234	52	13	8	3
Mocha	0.29	67	194	43	11	7	2
Patate	0.52	122	352	78	20	12	4
Pelileo	2.26	521	1501	334	83	52	17
Pillaro	1.57	370	1067	237	59	37	12
Quero	0.78	184	531	118	29	18	6
Tisaleo	0.44	105	301	67	17	10	3
Total	24.62	4779	16035	3594	2686	671	86

Source: (PDOT-GADRAS municipal document, 2011, p. 110)

The high domestic pollution loads to river bodies is causing severe damages to the environment, human health and productive activities.

4.2.3 Municipal Solid Waste

Municipal solid waste (MSW) collection services include: administration, street sweeping, collection and transportation of MSW to the landfill, MSW treatment, final disposal and hospital (hazardous) waste responsibility. The waste MSW collection service is principally concentrated in the in the municipality of Baños, where 100% of the generated MSW is collected seven days a week. The collection frequency of the rural areas is two times a week, covering 90% of the households with the collection service. Furthermore, the municipal expenses for this service are about US$ 496 482, accounting for 86.7% of the total expenses (MSW management document, 2011).

The municipality Baños disposes of two collection cars with a capacity of 7 t each (see Figure 25). The collectors are operated seven days a week, twice a day and travel 25 km per day each vehicle. Furthermore, the municipality employs 20 workers, including three chauffeurs, people responsible for the collection and clean up (sweeping) of the municipality’s streets.

Figure 25: MSW collection vehicles
Source: own photography

Since tourism industry and urban growth, MSW augmented drastically in the municipality. Therefore, 16 t of waste are generated in the average per day, amounting 112 t per week. The daily collection waste amount fluctuates on tourism seasons and holidays (Antonio Cadena, personal communication, 2013)

Table 10: Daily and weekly MSW collection amount (average)

Municipal services		
Municipal personal	20	
Collection vehicles	2	
Weekly MSW generation	112	t
Hospital waste	0.039	t
Distance to landfill from Baños	7.43	km

Source: own elaboration based on data from Antonio Cadena
(personal communication, 2013; MSW management document, 2011)

There is no particular separation of the MSW employed, until recently in May 2013. For the first time the municipality introduced the separation of MSW at the collection site through the distribution of two different coloured plastic bags to the inhabitants of the county. To this end, the organic fraction would be collected in green bags and the remaining solid waste in black bags. Most of the organic fraction is collected within the municipality, because in rural areas a great part is utilized for compost, animal feeding or organic fertiliser. Apart from the recent separation of the organic fraction, there is no other classification of waste at the collection sites (Edwin Coca, personal communication, 2013).

Although the organic fraction is collected separately, most of it is disposed together with the remaining solid waste fractions in the sanitary landfill of the municipality. Thus, the final disposal of the entire MSW represents solid waste fractions mixed up on the municipal sanitary landfill area. The sanitary landfill is located about 5 km from Baños in direction to Ambato, at the foothills of the Tungurahua volcano, about 2057 m

ASL (see Figure 26). The total landfill area composes 4 ha, of which 2 ha are utilised for MSW disposal divided into 3 landfill cells. However, only 1 ha is controlled (MSW management document, 2011).

According to PDOT-GADRAS municipal document (2011), the MSW disposal areas dispose of leachate drainage channels, geo (water proofing) membrane on the bottom, covered with a 10 cm thick clay layer, digester for leachate treatment and subsequent discharge to the river; gas drainage systems consisting of wood from eucalyptus trees, a perimeter drainage system to divert rainwater. Furthermore, 2 landfill cells are prepared for hazardous waste including hospital waste and batteries. The entire sanitary landfill has a technical lifetime estimated for 30 years.

Figure 26: Municipal sanitary landfill (location and current situation)
Source: a: own elaboration based on Google earth; b, c: own photography

According to personal communication with Antonio Cadena (May, 2013) and MSW management document (2011), the MSW is composed as follows:

Table 11: Composition of the MSW of Baños

Waste fractions	Municipal data 2011
Organics	60,00%
Paper	8,00%
Cardboard	9,00%
Plastics	6,50%
Metals	1,75%
Glass (scrab)	1,00%
Hazardous (hospital)	1,00%
Others	12,75%
	100,00%

Source: (MSW management document of Baños, 2011).

The category “other residues” include, among others, textiles, toilet paper, sanitary towel and nappies. In respect to the organic fraction, about 40% is bargasse coming from processing sugarcane into juice, alcoholic drinks or food within artisanal businesses of the municipality. Furthermore, the plastic contend of the MSW, includes high contaminated plastics coming from the greenhouse utilisation in the agricultural sector. Nonetheless, the plastic content decreased in the recent years due to the high market demand for plastic bottles. This has the effect, that households separate plastic bottles from other wastes, in order to sell them to artisanal businesses within the municipality or in Ambato. The bottles are reutilised for sugarcane juice and alcohol drinks. The trade price is about US$ 0.50–0.60 per kg of plastic bottles, whereas in Ambato trades pay US$ 0.74 per kg. Even schools are ordering their students to collect bottles and bring them to school for selling them. Additionally, the municipality implanted four large collection containers in form of a large bottle around the city. Before, this business became lucrative for inhabitants; the plastic bottles were collected by waste picker families at the landfill, who earned around US$ 160 per lorry plastic bottles each 15 days. Nowadays, they need around one month to fill a lorry. Those families are informal workers of the waste sector whose livelihood is separation, collect and sell valuable waste materials from at the landfill side. At the moment there are seven waste picker families. Moreover, metals and similar materials are collected also by informal workers, who pay according to the size a certain amount to households.

The municipality does not account with large industries, however, hazardous waste is generated in hospitals, clinics, pharmacies and laboratories. The dangerous and partially toxic wastes are collected separately and disposed at the same municipal sanitary landfill, on a specific landfill cell (and not two as published by the (PDOT-GADRAS municipal document, 2011) particularly prepared for this kind of wastes. As depicted in Figure 27, hazardous waste landfill is a pool shaped basin, laid out with a plastic foil on the bottom on which the waste is deposited on an area of 30 m^2. Thus, the waste is exposed to the environment without any cover. The only treatment method is the fumigation of chemicals to kill bacteria and viruses as well as the daily coverage of the landfill with a soil layer.

Figure 27: a) Landfill area for hazardous waste; b) visible syringes at the landfill
Source: own photography

As mentioned before, the municipality Baños faces separation issues at the collection site, leading to unsorted MSW deposits at the municipal sanitary landfill. This issue is related to poor MSW collection and disposal management as well as waste regulation enforcement. Furthermore, the mixing up waste fractions is related to habits and unconsciousness of environmental impacts in former times, where waste was disposed untreated and without any separation to wild dump sides or to the Pastaza River. But, since the municipality Baños offers the collection service of MSW, less waste is disposed illegally on natural landscapes. Nonetheless, a small percentage of the inhabitants still have the habit to burn and bury their waste or to through it down the mountain valleys, rivers, even sewage drainage systems and channels. Furthermore, a great number of inhabitants don’t have sufficient knowledge about waste separation and classification and are lacking of motivation to do so. This behaviour is observed since the recent introduction of organic waste separation by the municipality. Most of the green bags contain mixed up solid waste.

Regardless of the separation and classification issues at households, the municipality managed to separate a small percentage of the organic fraction within the municipal sanitary landfill in order to generate humus, which is utilised on public green areas, depicted in Figure 28 below. Approximately 0.5 t are produced each month (MSW management document, 2011).

Figure 28: Municipal humus production with organic fraction
Source: own photography

Besides the separation issues and it's mixed up deposition, there are other concerns related to the municipal sanitary landfill management. The entrance to the sanitary landfill is opened and uncontrolled, whereby during the field study it could be observed that dead animals, probably from poultry industry or slaughterhouses were deposited at the landfill. Additionally, the landfill is an open-air landfill, exposing landfill gases to the environment. However, it has been stated that there are plans to close the open-air landfill through levelling, compaction, stabilization, creation of terraces and restoring the vegetation.

Moreover, the daily maintenance of the landfill consists of covering the MSW with a layer of soil and compressing it with heavy machinery. It also includes, as required, fumigation of chemicals in order to reduce bacteria and virus.

Furthermore, the landfill area is located at a high risk area, at the foot of the Tungurahua volcano and on the top of a gorge of the Pastaza River, affected by the volcano's activity and landslide accidents down to the river. Exposed to this risk, one year ago, a great amount of MSW fell down to the Pastaza River causing disturbances to the downwards located hydropower station Agoyán.

During the field study at the sanitary landfill, it could be identified that several of the before mentioned elements were not available. For instance, not all landfill cells are provided with a geo (water proofing) membrane system on the bottom and no leachate drainage collection systems have been installed (according to Edwin Coca) neither a digester for leachate treatment. Nonetheless, there is a methane gas collection systems based on wooden pipes, whereby most of them are burned and destroyed through the direct solar radiation. In addition, the hazardous waste disposal area consisted only of one landfill cell and not two as stated on the landfill information document.

All the mentioned issues contribute heavily to environmental burden, emission pollution and human health risks. Thos are inter alia:

- Emissions realised to the atmosphere (i.e. methane through open-air landfills)
- Risk of infections due to bacteria and virus creation (i.e. no pre-and post-treatment of MSW, open-air landfills)
- Heavy health risk exposures due to untreated hazardous waste disposal on open-air landfill
- Soil, groundwater and river contaminations due to chemicals and leachates (i.e. through fumigation, toxic materials) etc.
- Landscape degradation
- Permanent landfill risk exposure to landslides, volcano activity and earthquakes

Similar to drinking water and WW disposal service, the MSW collection service shows a financial deficit, whose expenses (US$145,096) exceed the revenues (US$37,404) by almost 74% (AME, 2007, p. 13).

4.3 SWOT analysis of the municipality

On Table 12: SWOT Analysis from a general point of viewTable 12 a SWOT analysis is presented to provide a general and summarised overview of the strengths, weaknesses, opportunities and threats currently present in Baños. The mentioned points on the table enable the identification improvements aspects.

Table 12: SWOT Analysis from a general point of view

SWOT / Aspects	Strengths	Weaknesses	Opportunities	Threats
Environment	• Creation of the national parks Llanganate and Sangay • Declaration of the ecological corridor as "Gift to the Earth" by the WWF • International support	• No particular environmental and natural resource management system available • Weak enforcements and knowledge of environmental laws or regulations • Lack of environmental standards	• Funding agencies for environmental protection projects • International support for environmental protection programmes in the national parks • Focus on ecological corridor in order to improve environmental conditions of this area	• Environmental pollution and contamination • Poor knowledge of the population about native plants and animals • Lack of environmental awareness by the population • Lack of compensation activities related to destruction of natural reserves due to road construction or hydropower projects
Social, cultural	• Safe county with low criminality rate • Each village and rural area are organised in communities or organisations which strengthen the social and communal life, as well as their interests	• Occasional instances of traditional indigenous justice. In Ecuador, there is a legal and enforcement vacuum between the legal system and indigenous traditional systems, which often involve public physical punishment.	• Not recognised	• Not recognised
Tourism	• Well-known and highly promoted touristic destination area nationwide • High presence of national tourism (70%) contributing to a stable tourism-based economy • Municipalities identity through thermal baths and artisanal/regional products • Diversified tourism services and activities such as adventure, wellness, nature and religious tourism • Well-developed tourism infrastructure within the municipality	• Concentration of tourism activities at the centre of the municipality representing a crowded area with additional traffic • Incompatibility with ecotourism concept and its performance • Insufficient improvement commitment of the people working on tourism sector • Poor quality of public transportation to main cities (informality)	• Untapped tourist attractions. • Potential for ecotourism and sustainable tourism development through the presence natural resources, biodiversity of flora, fauna, landscapes, waterfalls, caves, rivers, national parks and ecological corridor • Exemplary tourist destination place of the nation • Increase of hospitality and wellness tourism though thermal baths, massages etc.	• Lack of diversified investment in the tourism sector • Lack ecological paths and infrastructure to tourist attractions • Total emigration of artisans working with balsa wood • High competition • Tourist sport activities at the polluted Pastaza River

SWOT / Aspects	Strengths	Weaknesses	Opportunities	Threats
	• Easy accessibility of the county and favourable geographical location bordering with the Amazonian region • The Tungurahua volcano makes Baños to a unique touristic place located at the foot of an active **volcano.**		• Local gastronomy increases the local identity	
Agriculture	• Fertile soils for agricultural cultivations • Subtropical fruit production due to the favourable climate conditions	• Low support for local and regional product distribution • Large variety of fruits and vegetables including subtropical fruits, but tendency to develop monoculture agricultural practices with concentration on a few singly crops. • High consumption of chemicals • Absence of regulations • Increasing trend of greenhouses utilisation (high chemical applications)	• Potentials for organic and sustainable farming • Labelling of organic products and promotion • Agro-ecotourism	• Lack of capacity building and technical assistance to improve agricultural production. • Low knowledge disposability about alternative and sustainable agricultural practices • Lacking of agricultural production improvements • Pastaza River contamination due to of poultry and other livestock industries along the river • Abandoning of traditional agricultural practices due to low profitability • Perish of traditional, small farming families • High local environmental impacts through artificial fertilisers and pesticides
Drinking Water	• Not recognised	• Lacking access to public drinking water at rural areas	• Not recognised	• The existing water system is under-maintained and aged • Water catchment is located at a high risk area exposed to volcano eruptions and pyroclastic flows

SWOT / Aspects	Strengths	Weaknesses	Opportunities	Threats
				• Poor water quality due to inadequate water treatment • Contribution to human health risks • Per capita drinking water consumption too high (180-200l)
WW	• Not recognised	• The existing sewer drainage system is under-maintained and aged	• Preventing of further collapse by the use of the new water system. • Utilisation of NPK minerals contained in WW	• No WW treatment system available • WW discharge to the Pastaza River without any pre-treatment leading to high river contaminations • Insufficient network connection to households
MSW	• Municipal collection system available • Statics disposability of MSW composition	• Uncontrolled access to the landfill • No energetic utilisation of MSW • Any recycling system on site • Financial deficits of the municipality • Limited time lifetime of landfill area • Plastic residues of greenhouses are disposed at the landfill • Landscape degradation	• Utilisation of the methane gas generation • High content of organic fraction • Production of organic fertiliser • High content of sugarcane bagasse	• Atmospheric pollution and gas realises through open-air landfill • Environmental pollution due to disposal of mixed waste composition on the landfill and chemical applications • Lack of leachate and gas collection and treatment system leading to environmental contamination • Inappropriate landfill conditions and management • Risk of infections due to bacteria and virus creation (i.e. no pre-and post- treatment of MSW, open-air landfills)

SWOT / Aspects	Strengths	Weaknesses	Opportunities	Threats
				• High environmental threats and human health risks due to current conditions of hazardous waste landfill • Landfill location at high risk area, slide risks of waste into the river
Municipality structure	• Absence of research institutes and research initiatives	• Lack of qualified technical personnel • Poor legal and regulatory framework adapted to the county's conditions	• Capacity building of environmental conservation, sustainable agriculture and tourism, etc.	• Lack of distribution of responsibilities for supervision, permissions, enforcements, communication etc. • Deficit of capacity building or competent service in different economic sectors or interrelation with population
Natural vulnerabilities	• prevention through cantonal emergency 0perations Committee	• Poor management strategies to reduce risk of landslides in populated areas	• Risk-prevention measurements availability	• Volcano vulnerability through eruptions and pyroclastic material flows • Landslides • Floods during rainy season • Lacking of risk management

Source: own elaboration in line with field study, personal observations, interviews with stakeholders and research based on studies (AME, 2007; SNGR, 2011; PDOT-GADRAS municipal document, 2011)

5 Development of a tailored sustainability strategy

The sustainability strategy envisioned for Baños focuses on enhancing key municipal basic services (waste and waste water management) and further developing sustainable tourism, organic farming and risk-prevention management. The waste management proposal would be a key project of the strategy among the other proposed projects. To this effect, Baños improves the current socio-economic and environmental situation, while creating added-values and new business opportunities for the municipality.

Likewise, the strategy intends to position the municipality of Baños as an example of “green” development nationwide. Therefore, Baños could become the first green oriented municipality of Ecuador.

To this respect, a variety of potentials are untapped in the material and energy flows of Baños. For instance, MSW flows can be sorted out, recycled and used for energy and fertilisation purposes. Waste waters could be treated by means of constructed wetlands (reed-bed filter system). Moreover, in order to boost tourism, certain organisational measures could be taken in the touristic areas, for instance, creating pedestrian areas in the Baños centre, providing regular transportation to the touristic areas, among others. Additionally, through the production of organic fertiliser based on digestate, farmers could be supported by development of sustainable agriculture. Those mentioned projects intend to build up to such a sustainability strategy, as illustrated in Figure 29.

To this end, the proposed sustainability strategy composed of several projects, are mostly interlinked one another and influence the in-and output flows of material and energy flows and creates value out of them within the municipality. This is explained in the following sub-chapters.

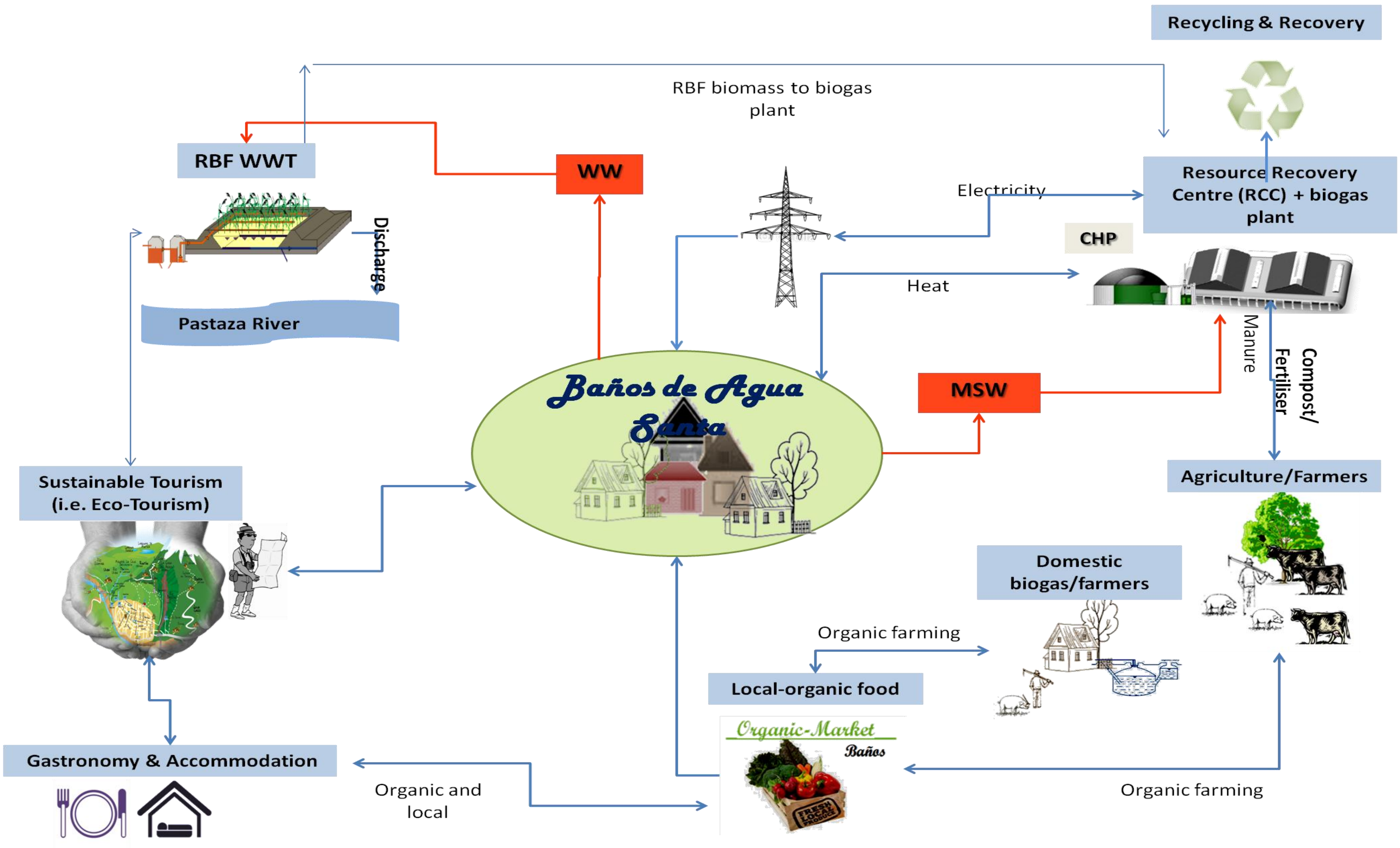


Figure 29: Tailored sustainability strategy for Baños de Agua Santa
Source: own elaboration

5.1 MSW separation and treatment scheme

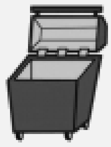
Although the municipality employed the separation of organic waste from remaining waste on household level in May this year, no clear strategy has been developed. Moreover, collected MSW is dumped into the landfill (mixed together with the organic fraction) without any pre-treatment, classification or recycling. Therefore, it is essential to develop a separation scheme on household level according to “wet” and “dry” and on the landfill through the implementation of a resource recovery centre (RRC) in order to recover valuable materials for energy generation or recycling. To this end, a biogas plant would supply regional electrical and thermal energy to the municipality as well as high qualitative fertiliser for agricultural purposes. This strategy would provide formal job opportunities for kerbside pickers and other residents, reducing environmental burden and health risks through significant reduction of waste disposal to the landfill, emissions and leachate generation, as explained in the following sub-chapters.

5.1.1 MSW separation scheme at household level

A simple separation scheme would be advisable in order to facilitate treatment of MSW fractions. For instance, at the household level “wet” waste and “dry” waste could be collected separately. Wet waste would include all organic residues and soiled paper; while dry waste would include everything else (recyclables and inert materials) (see Table 13). Such an approach has been successfully implemented in various Latin American cities such as Curitiba, in Brazil (Keuhn, 2007; Gruber, 2011).

To achieve so, the municipality would have to provide separate household bins or larger containers (e.g. per block). Moreover, the involvement of informal kerbside pickers would be essential in such a scheme, and the municipality would dramatically reduce the volumes to be collected. Furthermore, the separation at the collection place enables a first and essential separation of the MSW through the participation of the residents.

Table 13: Waste separation scheme of domestic households

Container	**WET WASTE** **Green container** 	**DRY WASTE** **Black container** 
Waste separation category	Organic waste	Recyclable and inert material (non-digestible waste)
Classification examples	• Fruits and vegetables (seeds, peelings, cores, rotten, etc.) • Peelings of eggs, nuts etc. • Meat, fish, poultry (bones, fat, etc.) • Cereals (grains, bread, oats, rice etc.) • Tee, coffee • Solid paper (toilet paper, paper towels) • Garden and yard waste (branches, grass, leaves etc.) • Ornament plants • Others: food left over from food (rotten bread, cheese etc.) • Waste wood without lacquer or paint • Sugarcane bargasse • Used straw for animals • Disposable diapers, sanitary napkins, cotton	• Metals • Plastics light • Plastics heavy • PET • Wood waste painted, lacquered • Glass • Cardboards

Source: own elaboration based on regional products and in line with (Westmordland-Albert, 2009)

Furthermore, in order to successfully enforce a MSW separation strategy on household level, it is particularly important to stress on educational programmes principally for children, but also for adults through information streams in the local radio and television channel or collective gatherings (reunions) as a common communication/information policy of the municipality to their residents. To this effect, children and adults should be taught about the importance of recycling MSW and how they could contribute and be involved in the separation of different waste fractions.

Stressing more on educational programmes for children, this should include theoretical and practical applications. For instance, theoretically the children should be informed about the impacts of waste to the environment (i.e. emissions to the air, contamination of soil, groundwater etc.), in particular the accumulation of untreated waste at landfills and wild dump sides. Furthermore, they should become an overall understanding from a "cradle to grave" perspective in order to increase the awareness of primary resource requirements such as trees, water and energy utilisation for paper production. Examples could be given by demonstrating that paper saving and recycling reduces deforestation impacts or that plastic, glass and metal waste have a long decomposition time at the landfills which should better be reduced, reused or recycled (according to the concept of 3R's). In the sense of reducing waste, children should become aware of products which generate huge quantities of waste or have a stronger impact on the environment, whose consumption should better be reduced or avoided.

Practically, children could, among other ideas, take part on an excursion to the landfill area, develop projects activities to reduce waste at school, create waste reduction and recycling handbooks, create own recycled material, develop posters with waste information to distribute in the municipality, plant trees in order to increase responsibility etc. In order to increase the effectives of the educational programmes, each school should be provided with waste collection bins in different colours for waste separation. Furthermore, competition programmes between schools could be implemented in order to increase the children motivation and prise their actions. In respect thereof, several organizations and governments who provide waste educational materials for school children.

By applying a successful MSW separation strategy on household level, the municipality would be able to collect the separated wet and dry fractions and transfer them to the second MSW separation level at the resource recovery centre on the sanitary landfill side, which is explained in the following sub-chapter.

5.1.2 Resource recovery centre at the landfill site

The collected MSW is transferred to the sanitary landfill area and deposited in the resource recovery centre (RRC), where a second separation takes place (manually and mechanically) through mechanical-biological treatment (MBT) processes. The mentioned RRC would be implemented next to the landfill area, where the waste collectors deliver the collected MSW. Therefore, the mechanical treatment process implies the separation of the following MSW streams with its respective utilisation purposes:

- *Organic material*: energy generation and organic soil conditioner (compost, fertiliser) through the implementation of a biogas plant
- *Recyclable material*: Plastic, metal, paper, glass and cardboard for recycling and material reuse
- *Non-recyclables material*: stabilization process for disposal at the sanitary landfill or alternatively utilisation as fuel for incineration purposes under environmental friendly conditions

The biological treatment processes, on the other hand, involves anaerobic fermentation of the organic fraction through the implementation of a biogas plant. This biological treatment is more favourable because simultaneously biogas (~60%) and compost (~ 20%) can be generated compared to MBT aerobic conditions where only compost (~50%) is generated and no energy is recovered (Martínez-Gómez, IMAT lectures, 2013).

In respect thereof, the RRC features a large hall, where municipal collection trucks could enter and deliver the collected wet and dry MSM fractions. Therefore, the RRC would be divided into two main treatment areas including a third area for compost production as follows:

a) *Mechanical treatment*
    - Reception area
        - Reception of collected MSW form the county Baños
        - Preparation of MSW for separation
    - Separation area
        - Manual separation (bulky material)
        - Mechanical separation through rotary drum (<80 mm and >80mm)
        - Manual separation (recyclables: paper, metal, plastic, glass, PET)

b) *Biological treatment area*
    - Biogas plant area
        - Anaerobic digestion
        - Biogas generation

- Renewable energy generation (CHP plant or refinery)

c) *Compost area*

  - Composting
  - Mixture and storage
  - Point of sale

d) *Hazardous waste area*

  - Reception of hazardous waste
  - Treatment of hazardous waste

Firstly, the dry waste fraction is prepared for the mechanical treatment by initially sorting out manually bulky materials such as tires, carpets, which would be stored in a special container for voluminous waste. Furthermore the remaining dry waste fraction is transferred manually or with a front loader to the transport band in the RRC, as depicted in Figure 30 .

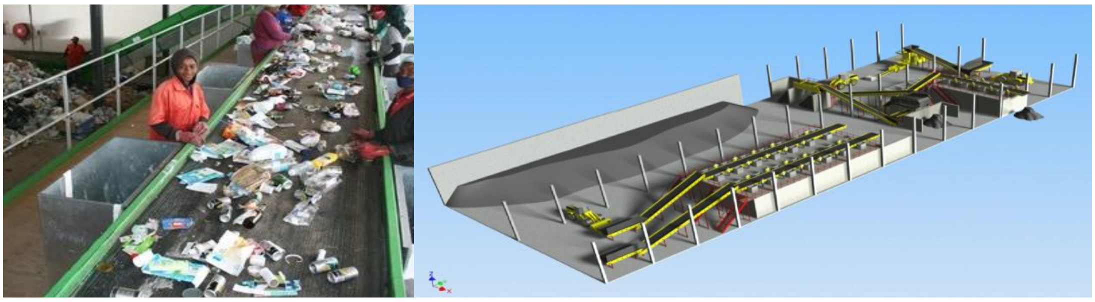


Figure 30: a) MSW transport band; b) waste recycling hall design of Kigali project
Source: (Kehrer, IMAT lectures, 2013)

At the transport band disturbance materials are sorted out manually before the waste is processed mechanically through a trommel (rotary drum performed with 80 mm wholes) which has the ability to separate small fractions under 80mm falling through the wholes and fractions larger than 80 mm passing to the end of the trommel (see Figure 31). The larger fractions (>80 mm) are further separated manually into the recyclable materials (paper, plastic, metal, PET), whereas ferrous materials are sorted out by magnets (Martínez-Gómez, IMAT lectures, 2013).

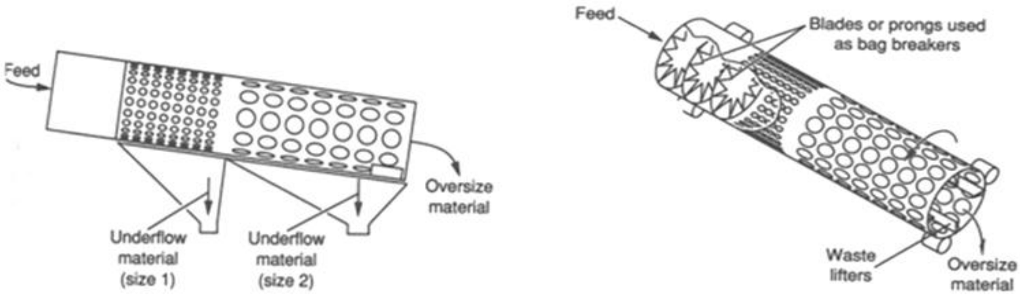


Figure 31: Rotary drum for waste separation (<80 mm and >80mm)
Source: IMAT MSW lecture, Speck, (2013)

Secondly, the delivered wet waste fraction (organic waste) has to be pre-treated by separating the fermentable components from the non-fermentable (stones, plastics, sand, etc.). The fermentable components represent the input materials for the biogas plant which is utilised for the generation of energy and soil conditioner.

Thirdly, an additional area to the RRC would be required for processing compost from the digestate (output product of the biogas plant), to store it and to prepare it for sell. Therefore, the already existing area for humus production at the landfill area (see Figure 28), could be utilised for this purpose.

Furthermore, there are three additional essential aspects of sanitary landfill requirements, leachate treatment and hazardous waste regulations have to be considering within the sanitary landfill management, indicated as follows:

- Sanitary landfill requirements: Layout of the present landfill according to the sanitary landfill requirements in order to avoid severe impacts to the environment, although the ultimate goal is reduction of the MSW disposal on the landfill area through the RRC to a maximum. A proper sanitary landfill management implies the application of synthetic membrane systems on the bottom of the landfill cells in combination with a compacted clay layer, leachate drainage collection systems at the bottom of the landfill, storm water drainage system to control water runoff, reasonable methane collection system and gas measurements (vertical gas wells, not wooden pipes in order to avoid damages through direct solar radiation), coverage of the landfill, leachate treatment system and groundwater monitoring system. Furthermore, the older landfill cell should be covered with a mineral layer (UNEP, 2012). Additionally, it should be considered that the current landfill cell is located at slope side to the Pastaza River. This should be stabilised in order to avoid future accidents of waste landslides to the river.

- Landfill leachate treatment: at the landfill area has to be treated in order to prevent that the leachate seed into the soil and get into the groundwater or Pastaza River. Therefore, the collected leachate could led through a pipe system to a reed bed filter (natural system), which could treat and purify this liquid substance.
- Hazardous waste regulations: pre-treatment of hazardous waste according to national sanitary requirements before disposing it into the hazardous waste landfill.

MSW separation on household level and the respective treatment at the RRC under the consideration of anaerobic processes would bring the following benefits to the municipality:

- Reduction of the MSW on the landfill and the impacts to the environment (leachate, emissions, etc)
- Generation of renewable energies in form of biogas
- Formal employment of kerbside pickers and creation of new jobs for residents
- Reduction of GHG emissions
- Production of soil conditioner (compost, fertiliser) which enables the close the natural nutrient cycle by applying it back to the soil
- Economical added value through revenues from recyclable materials, energy generation and compost sail
- Development of self-sufficient biogas plant with heat and electricity for the RRC
- Cooperation with the waste picker families and improving their living conditions
- Creation of employment
- Participation of the residents by separating wet and dry waste at households
- Educational measurements through
- Reduction of MSW on the landfills and therefore reduction of capital and operation expenses for waste treatment
- Contributes to resource recycling and preservation

5.1.3 Renewable energy from municipal organic food waste

The biological degradation of waste in order is a highly favoured alternative technique for processing organic food waste (food waste) compared to incineration or landfilling. Incineration usually implies expensive technologies and flue gas generation. On the other hand landfilling is the worst management technique (even if it is well designed and managed) due to large space requirements and costly measures to avoid leaching and GHG emissions.

To this effect, it is recommendable for the municipality Baños to consider anaerobic fermentation of the collected wet waste (organic fraction) through the application of a biogas plant. Therefore, the municipality would be able to generate biogas (CH4) with efficiency rates from 50-75% depending on digestion processes of the feedstock (i.e. domestic food waste, energy crops, manure and agricultural products), as depicted in Appendix 9.7.

Typically, agricultural biomass and garden waste needs to be pre-processed (e.g. cut or shredded) and/or mixed with other input materials like manure, in order to overcome certain drawbacks (like for instance a high lignin content or too high dry content) and yield better gas outputs (Nijaguna, 2002). However, the primary feedstock material in this case is food waste (domestic organic waste), which is collected separately by the municipality in and transported to the RRC and pre-treated by sorting out the fermentable materials, as explained above.

a) Digester and digestion process

Subsequently, after the separation and pre-treatment process, the fermentable organic food waste matter is fed into the digester (also called fermenter) of a biogas plant, as depicted in Figure 32. The anaerobic digestion process or organic matter occurs always in a closed digester in order to capture the methane gas. The inside of a digester is composed of a mixing zone for mixing of the fermentable matter with the water and to keep a constant temperature for the biodegradation, a sludge zone, a fluid zone and a biogas capturing zone.

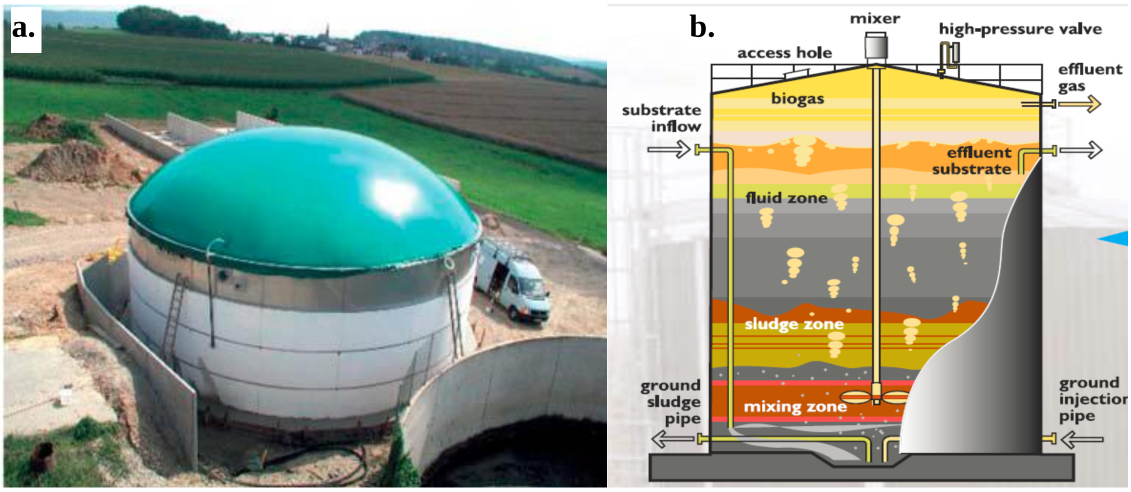


Figure 32: a) Digester of a biogas plant with steal container; b) Components inside a digester
Source: a: (FNR, 2004, p. 59); b: (BPEX, 2012, p. 2)

The retention time is of 60 days through a mesophilic digestion at 25-45°C or 15-20 days through thermophilic digestion at 50-60°C which requires continues energy input. Therefore, thermophilic digestion is more favourable due high temperatures which destroy pathogenic bacteria (BPEX, 2012, p. 2).

The digestion process differentiates between wet and dry fermentation. Therefore, wet fermentation refers to TS content in feedstocks <15% and above this level it is considered as dry fermentation. Additionally, biogas plant could involve one single feedstock or a mixture of different feedstocks called co-digestion.

b) *Energy generation potentials from CH4*

The generated CH4 gas (bio gas) is equivalent to natural gas of which electricity, heat or vehicle fuel could be generated. The energetic benefit of $1m^3$ biogas is about 9.97 kWh at a CH4 conversion efficiency of 60%. Therefore, the calorific value is comparable to 0.6 l of oil (FNR, web). When biogas is utilised to fuel combustion engines such as the combined heat power plant (CHP plant), then electric and heat energy could be produced simultaneously, as depicted in Figure 33. The CHP plant is worldwide recognised as an energy efficient technology, which provides the opportunity to generate decentralised power.

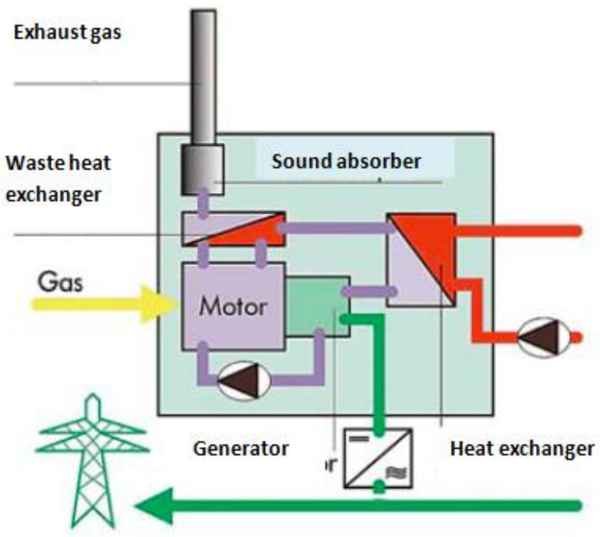


Figure 33: Components of a CHP plant for combined electricity and heat generation
Source: (FNR, 2004, p. 127)

The generated electricity could be sold to the national grid or utilised on site. The thermal power is used to heat the digester (~7-10%) and the remaining heat energy could be sold for instance to nearby hotels to heat the swimming-pools. On the other hand, biogas could be refined and fed into a gas grid/network to fuel boilers and heaters or to fuel vehicles (biomethane fuel).

According to calculations on data of the MSW in Baños, the biological degradation of the municipal food waste holds the potential to generate 2.7 million m^3 biogas (CH4), of which 5.8 million kWh electrical and 4.2 million kWh of thermal energy can be generated through the application of CHP technology. To this effect and according to the fixed renewable electricity prices (US$ 0.11/kWh) based on biogas with a installed capacity of under 5 MW, as depicted in Table 14

Table 14: Biogas yield and energy generation through CHP

Energy generation from biogas (CHP)		
Biogas yield	2,698,080.00	m³
Electricity generation	5,786.117.00	kWh el.
Installed electrical capacity	0.73	MW el.
Heat generation	4,190,192.00	kWh th.
Installed heat capacity	0.53	MWth.

Source: own elaboration based parameters in Appendix 9.8.4

However, the feedstock input for the biogas plant could be increased in order to extend the electricity generation potential. Importantly to consider are two additional feedstocks potentially applicable for the fermentation process in the biogas plant:

- Feedstock from manure and slurry from cattle, poultry and swine, which are available in Baños due to livestock farming. Through the integration of this feedstock in the biogas plant concept for the municipality, two additional benefits would be created, besides biogas and renewable energy generation. On the one hand, the livestock's slurry and manure would reduce the contamination impacts to the Pastaza River, as most of the livestock farmers are located along the river and wash out the livestock waste to the river, particularly poultry farming. On the other hand, through cooperation initiative with those agricultural farmers, the feedstock input for the biogas plant would be secured, while the farmers obtain back high qualitative organic fertiliser from the digestate. This would furthermore, would support farmers to utilise organic fertiliser instead of spreading crude fertiliser to the fields, as they do so.
- Feedstock from wetland plants (i.e. water hyacinth) utilised in WW treatment plants. In case the municipality implements a reed bed filter (RBF) WW treatment system (introduced sustainability strategy in Chapter 5.2). Through the RBF system, nutrients are absorbed from the contaminated water and transformed into biomass, while the water is purified and the biomass is concurrently applied in the biogas plant for energy and fertiliser generation.

The anaerobic digestion of the organic waste fraction implies the following benefits for Baños:

- Fossil fuel reduction utilisation through renewable methane gas (biogas) generation
- Alternative processing of organic matter and simultaneously avoiding the disposal on landfills
- Natural nutrient rich fertiliser production from the digestate for agricultural use
- Close nutrient cycle through returning digestate to the fields
- GHG emission reduction
- Environmental impact reduction on landfill area
- Substitution of currently available synthetic fertilisers with high qualitative (nutrient rich, no health risks, low odours, clean) organic fertilisers/compost
- Development of a new organic product which is competitive on the county's market

The production of non-conventional renewable power is progressively increasing target of the Ecuadorian government which has initiated several projects in order to reduce the dependency of petroleum. Through the operation of a biogas plant for power generation for the municipality would develop Baños to an exemplary place for the whole nation. By the application of an CHP plant from the biogas it would also be possible to generate thermal energy (heat) which would partly utilised for heating the digester.

5.1.4 Organic fertiliser from digestate

Furthermore, the sludge at the bottom of the biogas plant, known as digestate, is a by-product of CH4 production in the biogas plant. This liquid mixture is to consider having excellent fertiliser properties suitable for organic farming, private garden and public local flower beds and green spaces, horticultural applications, land restoration or turf establishments. The digestate has less than 5% TS, a depicted in Figure 34 a). The components of this substance are liquor (without solid matter) and fibre (solid matter), as demonstrated in Figure 34 b. and c. (Rigby & Smith, 2011; WRAP, 2012).

Figure 34: Forms of digestate; a) whole, b) liquor and c) fibre
Source: (WRAP, 2012, p. 4)

The content of nutrients supplied to the biogas plant as feedstocks, are equal to those nutrients in the digestate. The only difference is that after the digestion process in the biogas plant, nutrients are better absorbed by plants as for instance nitrogen is converted to ammonia. Through the provision of the digestate (fertiliser) back to the soil, the nutrient cycle would be closed, like in natural nitrogen-cycle. Furthermore, the odour of the digestate is less intensive compared to manure and is also a better soil conditioner due to the nutrients and pH values. Furthermore, the anaerobic digestion enables the reduction of pathogen contents in the digestate. Nonetheless, if the digestate is based on food waste and left over (fish, meat etc.) such as in the case of Baños, the substance should be pasteurised in order to use it (FNR, 2013; Lukehurst, Frost, & Al Seadi, 2011).

The digestate is applicable directly on the soil without further treatment. Digestate based on food waste has a high content (~80%) of nitrogen (N). However, digestate could be separated into solid and liquid fertiliser which represents two output flows. The separation process is carried out through dewatering technologies either mechanically (e.g. belt press, sieve drum, screw press and decanter centrifuge) or non-mechanically (e.g. geo-textile tubes for sedimentation or filtration). Therefore, the solid fraction should be further treated to compost or stored adequately to avoid CH4 emissions to the air. This solid fertiliser is rich in phosphorous. The liquid fraction is a nitrogen and potassium rich fertiliser which could be applied on the soil or returned to the biogas plant (Lukehurst, Frost, & Al Seadi, 2011, pp. 20-21; Makádi, Tomócsik, & Orosz, 2012; Lukehurst, Frost, & Al Seadi, 2011, pp. 12-13)

The mean values of the physicochemical properties of fresh food waste digestate are listed on Table 15.

Table 15: Physicochemical properties of food waste digestate

Physicochemical properties	Value	
Volatile solids (VS)	69	%
pH	8.4	
TS (wet fermentation in digenster)	12	%
TS (decanter centrifuge)	22.3	%
TS (screw press)	12.9	%
TS (belt press)	8.7	%
N	3.0	kg
Phosphate	0.5	kg
Potash	2.0	kg

Source: (FNR, 2004, p. 23; Rigby & Smith, 2011, S. 36-40; WRAP, 2012, p. 5)

The high VS content of food waste represent good properties of the digestate as soil conditioner to improve the soil structure. This content is typically higher by digestate based on food waste feedstock. Furthermore, the application of a decanter centrifuge system reaches high dewatering levels of about 22.3% compared to screw and belt press. Although the decanter centrifuge system is efficient and enables higher P content in the solid fraction, it involves high capital and operation costs. To this effect, it is recommendable to apply screw press technology, which is efficient, reliable (Lukehurst, Frost, & Al Seadi, 2011).

In respect thereof, the separation of digestate into two fertiliser fractions and the respective preparation for market conditions, represent a value added, as this new business opportunity is a revenue source for the municipality Baños, illustrated in Appendix 9.8.6.

Therefore, resulting benefits from digestate utilisation form anaerobic food waste digestion are as follows:

- Reduction of fossil fuel based fertilisers (mineral fertilisers) through the substitution with organic fertilisers from digestate
- Production of high qualitative organic fertiliser
- New revenue source for the municipality

5.1.5 Potential revenues from MSW separation scheme

Regarding the economic point of view, through the separation of MSW into the recyclable fractions and the generation energy through the fermentation of organic matter in a biogas plant, the municipality would generate a potential revenue source, amounting minimum US$ 24.5 million (with decanter centrifuge technology) or US$ 24.8 million (with screw press technology) per year, as illustrated in Table 16. A more detailed revenue calculation is listed in Appendix 9.8.3 and 9.8.6 .

Table 16: Potential revenues from MSW separation strategy (summarised)

Potential MSW revenues		
Household collection rates	68,575.91	US$/a
Recycling	2,627,562.00	US$/a
Electricity generation	639.365,91	US$/a
Fertiliser and composting		
Fertiliser and composting (decanter centrifuge)	21,211.900.00	US$/a
Fertiliser and composting (screw press)	21.491.670,00	US$/a
Total revenue recycling (with decanter centrifuge)	**24.547.403,67**	**US$/a**
Total revenue recycling (with screw press)	**24.827.173,36**	**US$/a**

Source: own elaboration according to market prices of the Tungurahua province and personal communication with the municipality

5.1.6 GHG emission reduction potential

In this respect, the generation of renewable energy, recyclable materials as well as organic soil conditioner, has positive effect on the environment and on the mitigation of GHG emissions associated to final disposal of MSW in the landfill.

In order to calculate the potential GHG emission reductions that would occur if the suggested MSW management strategy is implemented, the United Nations Intergovernmental Panel on Climate Change (IPCC) guidelines, methodologies and default values for emissions accounting were used (UNFCCC, CDM Methodologies Booklet, 2012). The "Tool to determine methane emissions avoided from disposal of waste at a solid waste disposal site" of the UNFCCC/CCNUCC (2008) is used in Kyoto Protocol's Clean Development Mechanism (CDM) projects worldwide, to calculate baseline, project and avoided emissions from waste-related project activities.

Baseline emissions refer to the status quo, that is to say, disposal of MSW at the landfill, including MSW transportation. Project emissions include anaerobic digestion of the organic fraction, including production of electricity and heat by means of CHP; recycling of the other usable fractions, and finally disposal at the landfill of the unusable "burnable" fractions. GHG emissions from waste management are calculated as a balance between emitting practices (i.e. landfilling, transportation, sorting/shredding, stabilisation for Refuse-Derived Fuel production, incineration without energy recovery) and non-emitting/offsetting practices (i.e. anaerobic digestion + CHP, incineration with energy recovery, etc). The avoidable emissions are presented in Table 17.

Table 17: MSW project GHG emission avoidance

Process	tCO2eq per year	
	Baseline	Project
Transportation to landfill	52	52
Landfilling	4 279	191
Composting	2	0
Sorting, recycling	N/A	0
Anaerobic digestion and CHP	N/A	-6 423
TOTAL	4 334	-6 180
Avoidance	**-1 846**	

Source: own elaboration, using the calculation tool presented in (Avadí, 2010)

The complete MSW management scheme could be proposed as a CDM project, or carried out independently and the emissions avoided traded in voluntary carbon markets. Voluntary carbon markets involve companies, individuals, and other entities that wish to offset GHG emissions and which are not subject to mandatory limitations (such as the Kyoto Protocol/CDM and the European Union Emission Trading System (EU-ETS)). These voluntary markets are small compared with regulatory ones, yet they are expected to grow and become substantial (Peters-Stanley & Hamilton, 2012).

5.2 Reed bed filter waste water treatment

An initial solution for the deficiency in WWT could be the installation of reed bed filter (RBF) basins, also known as constructed wetlands, as depicted in Figure 35. This natural treatment system could be installed next to the two main discharges into the Pastaza River (Figure 24) or at the south west of the municipality. There is plenty of space in the riverbanks as to deploy such installation (required ~4-5 m^2 per population equivalent (PE)).

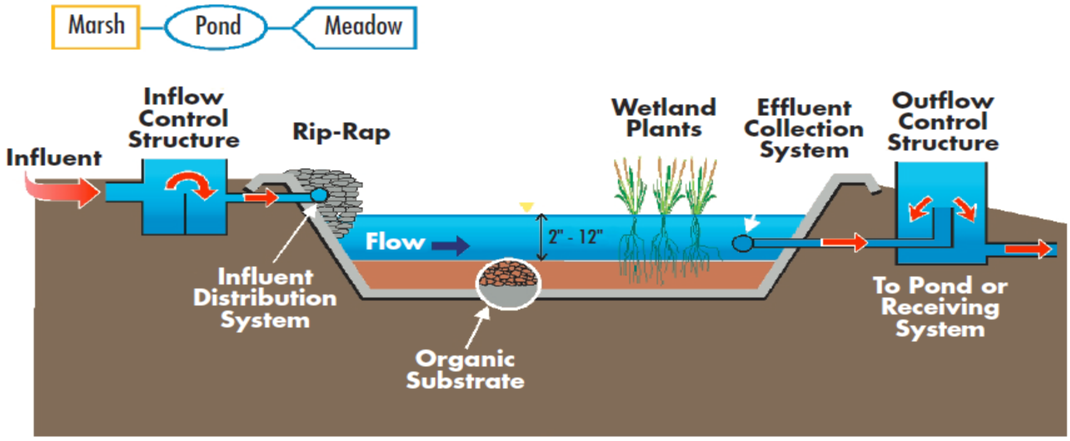


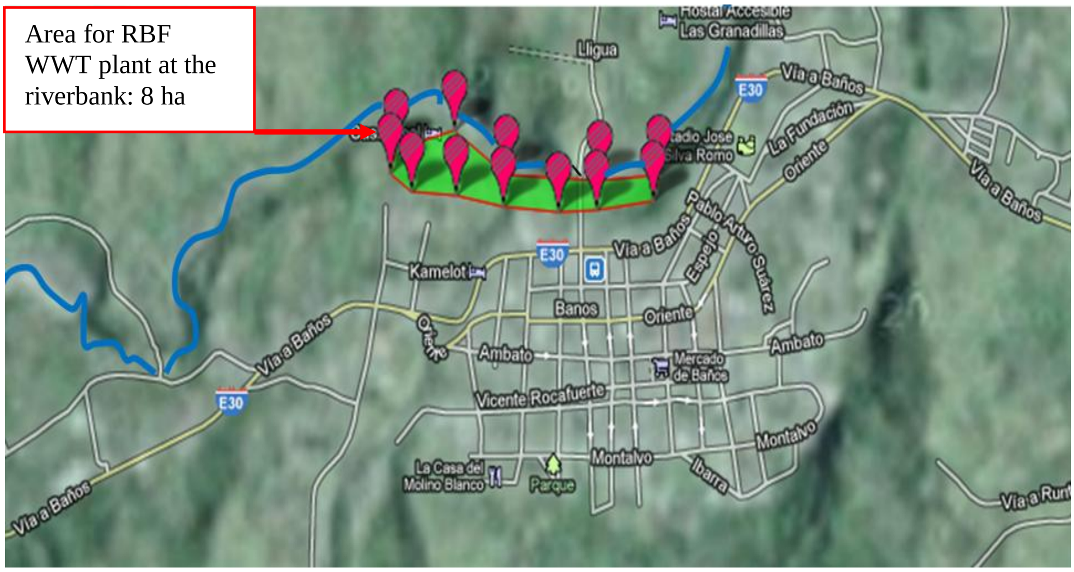
Figure 35: Reed bed filter WWT system
Source: (BSA, 2001, p. 2)

RBF WWT plants are nowadays recognized as an essential natural system in order to treat contaminated liquid and solid WW (e.g. domestic WW, leachate from landfills or compost, pre-treated industrial WW, hazardous WW) through natural biological and chemical reactions carried out by plants, microorganisms, soil and sunlight. The treated water could be discharged into the Pastaza River or be reutilized as irrigation water. The load of the water contaminants, indicated in Table 9, for instance BOD levels, nutrients, organic matter and suspended solids, could be reduced effectively by up to 98%. This technology has been implemented in several countries, for instance France (Honfleur, 3 000-5 000 m3/day plant), Spain, Netherlands, Taiwan etc. and widely tested, concluding that natural WW treatment systems are effective and provide various benefits (WWG, 2013).

The treatment process incorporates primary, secondary and tertiary treatment. Primary treatment includes screening and sedimentation processes of the crude WW in order settle solid matter. Therefore a septic tank is need with a size of $5m^2/m^3$ daily flow. Therefore, solid matter settles at the bottom of the tank, where it is stabilised through anaerobic digestion. Secondary treatment further removes BOD and SS levels in a settling pond and the tertiary treatment, as a final treatment, for nutrient reduction in a basin/lagoon and accomplish with discharge requirements to the river (ITRC, 2003).

In respect thereof, a RBF WWT systems for the municipality Baños requires an area of 60 044 m^2 (equivalent to 6 ha) for WWT. To this end, it is essential to consider the volume of the RBF. The annual discharge load is considered to be 1.07 million m^3 (see Table 9), which is equivalent to a daily discharge load of almost 3 000 m^3. The riverbank along the Pastaza for instance provides an area of about 8 ha for the installations of the RBF WWT plant, as depicted in Map 7. Optional, the treatment plant could be installed at the south east side of the municipality, as shown in Map 8.

- *Option 1: RBF at the riverbank of the Pastaza*



Map 7: RBF for WWT at the riverbank of Pastaza River
Source: own elaboration with the help of Google Maps Area Calculator Tool

- *Option 2: RFB at the south end of the municipality*

Map 8: RBF for WWT at south end of the municipality
Source: own elaboration with the help of Google Maps Area Calculator Tool

To this effect, those natural treatment plants are environmental friendly systems, because no chemicals are applied, as the water purification process occurs through natural aerobic and anaerobic processes. Furthermore, RBF have lower maintenance and operation costs, particularly in terms of energy input, as no energy or very little is required for the treatment process, particularly in the case of Baños where the gravity of the riverbank could be used instead of pumps.

To this effect, reed filter WW treatment plant would bring the following benefits to the municipality:

- More cost effective due to lower lifetime, capital, operational costs (i.e. energy, no chemical utilisation) and maintenance costs compared to conventional WW treatment plants
- Decentralised WW treatment technology close to the resident's area which is sustainable
- Fulfilment of discharge requirements and is reliable
- Educational opportunities
- WW is not exposed to the surface and therefore no odours are created, no mosquitoes are attracted and no contact with sewage could occur

- Creation of a natural ecosystem which provide habitat for wild species and biological communities and supports wetland preservation
- Stabilisation of the nutrients, organic matter, sediments in the water in order to provide clean and qualitative water which could be discharged into the Pastaza River
- Provide biomass for further use in biogas plant
- Reduction of water contamination of the Pastaza River
- Low cost WWT through low maintenance and operation of RBF costs
- Enhancement of aesthetics though natural system
- Sequestration of GHG emissions through avoided or reduced utilisation of fossil fuels

However, the design of the RBF has to consider ecological risk assessment in order to avoid potential negative effects. Additionally, it is essential to consider several aspects related to the installation, among others, the topography, soil conditions, WW infiltration possibility to the groundwater, exact contaminant concentrations of the municipality's WW as well as biological conditions (ITRC, 2003).

5.3 Sustainable tourism

The protection of natural reserves, national parks and biodiverse areas, has become increasingly important for nowadays travellers which are disposing to pay more for its preservation. Therefore, tourism industry which integrates environmental protection into their management strategy is considered to be an innovative industry with improved values. To this end, ecological friendly and sustainable tourism management is a new marketing idea and future trend with two essential results: creation of new business opportunities and protection of the environment.

From this point of view, the municipality Baños has a great potential to become a attractive place for ecotourism due to its unique location between two national parks (Llanganates and Sangay), along the Ecological Corridor Llanganates Sangay and at the border to the Amazon region which represent a rich biodiversity with numerous ecological areas.

Although the county has already implemented the concept of ecotourism into their management strategies, the performance of it faces essential issues due to the fact that the objective of this concept has been misled. Therefore, the terminology ecotourism is mainly utilised for promotion purposes without considering the compatibility with environmental friendly performance and nature conservation.

In respect thereof, the municipality has to recognise this issue, direct the tourism department to the ecotourism requirements and circulate a broader understanding of ecotourism to the active population in the tourism sector. This implies a close cooperation with the environmental conservation department in order to clearly define the compatibility of tourism with the surrounding environment. Thus, all tourism services and activities should be in conformity with the objectives of ecotourism.

The ultimate objective is to achieve sustainable tourism development through ecological aspects. Small projects such as the creation of a pedestrian downtown, an eco-adventure trail along the Ecological-Corridor as well as enforcement of agrotourism in connection with organic farming could provide direction to sustainable tourism with revenue opportunities, as described in the following sub-chapters.

5.3.1 Pedestrian downtown

Baños downtown is a small area of 3 urban blocks, along the Ambato Street to the Basilica. Currently, its narrow streets are open to traffic. It would be possible to close the main streets for traffic and turn them into pedestrian areas. Such initiative would increase trade and service providing in the area by enhancing the tourists' experience. Moreover, the measure would not affect regular activities in a negative way, because Baños downtown is very small and thus all affected areas would be easily accessible by walking (infrastructure for reduced mobility citizens is already implemented).

The proposed pedestrian placement of the municipality is concentrated on the centre of city (see Map 10), where most of the touristic attractions, commerce's and artisans are located.

- *Option 1: Pedestrian downtown including 2 blocks of the Ambato street*

Map 9: Pedestrian downtown option 1
Source: own elaboration based on map of (Baños web, 2013)

- *Option 2:Pedestrian downtown including 3 blocks of the Ambato street*

Map 10: Pedestrian downtown option 2
Source: own elaboration based on map of (Baños web, 2013)

The pedestrian area of the municipality impedes the passage of vehicles and simultaneously reduces the traffic within the centre. In order transform the centre into a pedestrian area several aspects have been considered. The pedestrian route does not imply any impact to the municipality, as it does not represent a priority area for transportations such as for schools, hospitals, parks and supermarkets. Additionally, it does not contradict with the traffic flow and it is easy accessible.

Several benefits of pedestrian downtown are given, as follows:

- Considering environmental aspects, the pedestrian area would not be impacted by traffic, noise of vehicles and automobile exhaust gases. Additionally, the presence of a vehicle free area supports the ecological promotion of the municipality and the county.
- In respect to tourism, a pedestrian area creates a more calm and attractive atmosphere where visitors could take a walk, visit the artisan shops, rest at the relaxing spots at the fountain or a banked under a tree, get in contact with residents, listen to life bands, observe artisans working etc. The creation of this positive atmosphere could make visitors prolong their stay at the county.
- Regarding residents living and working at the pedestrian area, they would benefit from a less noisy area and better business opportunities. For instance coffee shops, restaurants or ice-cream parlours could put chairs and tables in front of their business and provide the service of outdoors eating and drinking. Furthermore, this area would only take up three blocks of the main street Ambato, which is not considered as an accessibility impact.
- In terms of aesthetics, Baños would become a more attractive place nationwide, as it provides a pedestrian area similar to a plaza.

Furthermore, several design ideas of how pedestrian downtown could be transformed into a attractive place for visitors and residents including fountains or large round benches at the crossroads, trees implantations, flowerbeds and outdoor cafes/restaurants, as depicted on Figure 36.

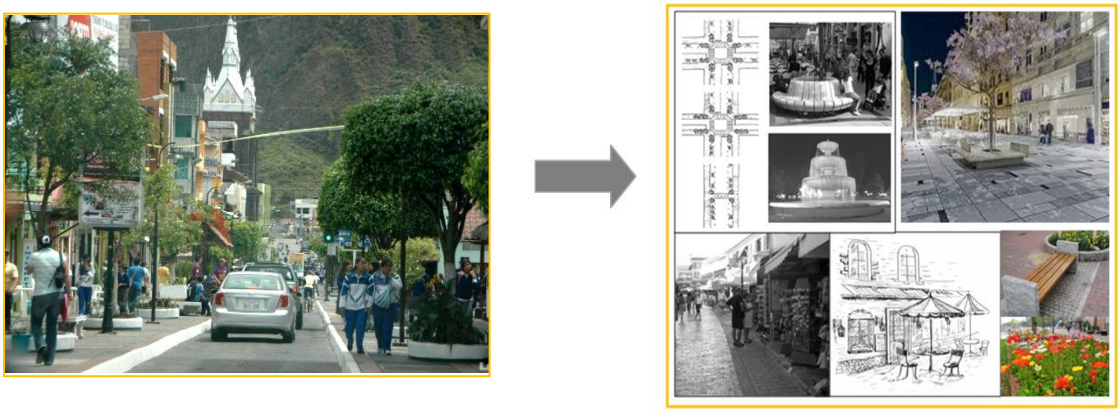


Figure 36: Design ideas for the pedestrian area
Source: own elaboration (various pictures from the internet)

5.3.2 Eco-Adventure trail along the Ecological Corridor

One of the most visited routes of the county is the route along the waterfalls (called *"Ruta de las Cascadas"*) in direction to the last small village of the county *Rio Negro*. This route is represents an exclusive area surrounded by many impressive waterfalls, which conduct to the Amazon region of Ecuador. Additionally, the uniqueness of this route is given by its location along the biodiverse Ecological Corridor embedded by the two national parks, Llanganates and Sangay. Furthermore, along this route many touristic activities take place such as canyoning, kayaking, bunging jumping, rafting, trout fishing, rock climbing and mountain biking. All this activities have awakened the interest of national tourist to visit the county; however the potential of improving the image and uniqueness of this route has not been explored yet.

Main issues related to the promotion of this route as an eco-touristic place, is that there is no eco-tourism on side. The waterfalls are accessible by mountain bike along the public main road, leading to the Amazon region, which is a very busy road with frequently traffic of large vehicles for goods transportation. This makes the route highly dangerous for visitors and residents travelling by mountain bike or walking. Furthermore, the essence and association of an Ecological Corridor gets lost, due to exhaust from vehicles, noise from traffic, pollution and deterioration of the natural environment. Therefore, negative impressions are transmitted to the visitors and the principles of the conservation of the Ecological Corridor are not considered. However, to enhance the environmental conditions of this area and simultaneously converting this route into a famous touristic attraction place, could bring divers benefits for the county's visitors, residents, environmental conservation and native species.

To this end, the hidden potentials have to be uncovered particularly considering the aspect of tourism as a key driver for environmental conservation. In respect thereof, the following strategies could significantly contribute to a better eco-tourism management under the motto „Adventure trail for bicycle and pedestrians along the Ecological Corridor". The objective would be the development of a recreation area in the middle of biodiverse area.

In order to improve the human safety, a separated trail from the main road should be developed, which is prohibited for vehicles and only accessible for mountain bikers and walkers. The construction of this trail represents and eco-adventure trail, specifically designed for bicycle and pedestrians, where visitors can enjoy the natural environment, the observation of the waterfalls. Moreover, for the construction of the trail, it would be feasible to include an already a partially existing trail, which has not been used for this purpose. The concept of an eco-adventure trail along the Ecological Corridor is depicted in Figure 37.

Figure 37: Eco-Adventure trail along the Ecological Corridor
Source: own elaboration base on Google earth and own photography

To this effect, the trail would provide, among others, the following possibilities:

- Bird observatory standpoints
- Waterfall observatory standpoints
- Access to ecological hiking trails
- Eco-Adventure tourism activities
- Local products and gastronomy (organic)

Furthermore, the trail would create the opportunity to replant native species, which have been deteriorated due to the road construction or not carefully handled over the years. According to Elena Rojas (personal communication, May 2013), native plants of this region are, among others, poroto, nogal, motilón, goma, colca, sambuel, ganayuro, niguas, quinillo and ciruelo. Those native species have positive effects the biodiversity of this region. It is most likely that the conservation of native species would bring bag native animals to the Ecological Corridor. At Rio Verde, exist already a similar idea, where an open air botanic garden has been implemented. However, this idea could be considered along the whole eco-adventure trail.

Additionally, an educational function should be integrated in the eco-adventure trail strategy in order to inform all visitors about native animals and vegetation. Therefore, nicely designed signs could be implemented along the train, indicating the names of the waterfalls, flora species, explaining biodiversity and ecosystems, awaken awareness about the importance of environmental conservation etc. Moreover, it could include information signs for children.

In order to promote the eco-adventure trail nationwide as well as internationally, especial eco-events could be realised. Those events should attract visitors to come to the county and participate. For instance competitions could take place such as eco-trail races, flower or bird photography etc.

Further, the residents living or working along the ecological corridor and running businesses in the tourism sector such as restaurants, trout fishing, canyoning etc, would benefits from trail, as more tourists would be attracted to visit the county. Therefore, the promotion of local gastronomy and local products should be enhanced by offering local food to visitors.

In conclusion, the eco-adventure trail brings economic, environmental and social benefits for the county and the residents. The implementation of this trail would support the concept of eco-tourism and provide optimisation potentials in direction to sustainable tourism management. Moreover, residents would equally benefits from a recreation area, where they can spend with their families on weekends for example.

5.4 Organic farming in direction for sustainable agriculture

Given the soil cultivation potentials at favourable soil fertility, abundant water resources and special microclimate conditions, the county's agricultural practices would be desirable for sustainable agriculture. This would support the small farmers, which represent the majority, about 65% of the county's farmers. Therefore, farmers should reconsider their traditional agricultural practices for instance crop rotation and intercropping. This could be sustained through organic farming by to the availability of organic fertilisers and compost produced by the fermentation process of a domestically biogas plant for small farmers at remote areas. Additionally, organic farming could be connected to tourism through agritourism concept. Both projects are explained in the following sub-chapters. However, exploring a detailed direction to sustainable agriculture exceeds the scope of this proposal.

5.4.1 Agritourism and organic farming

Agritourism is a concept which has been developed in the recent years, as a new marketing strategy combining agricultural based activities and education with tourism sector, in order to enhance business opportunities of agricultural producers (Ag MRC, 2013). To this effect, agritourism could support directions to sustainable tourism, however to provide this it is essential to stabilise the agricultural sector conducting it to a sustainable development.

In Baños, awareness of this potential has already been awakening, but there is still a large gap between the concept idea and the enforcement as well as its connection to sustainable agricultural development. Therefore, within this scope, strategic ideas would be listed in order to reinforce this development.

To this effect, Baños has a wide range of agricultural products as well as several activities related to agritourism such as sports and recreational fishing, farms and haciendas offering accommodation. However, the offer of an agritouristic experience for visitors has to be broadening in order to develop a tailored concept which is, among others, as follows:

- Application of organic farming for educational purposes and for the promotion of healthier lifestyle
- Support of organic farming through traditional agricultural practices such as intercropping and crop rotation and application of organic fertilisers purchased from the municipal or from own domestic biogas plant’s liquid substrate.
- Sales of organic products at a market’s section or directly at the production place
- Providing accommodation to visitors in a family’s agricultural farm or at camping side
- Offer of agricultural working activities to visitors to enable an inside into regional organic vegetable and fruit production as well as self harvesting activities
- Enabling visitors to learn about farmers way of living and daily challenges
- Sales of agricultural and organic products from small farmers to the municipality’s restaurants, cafés and accommodations in order to promote organic farming and healthy food intake
- Offer of organic and regional food at local restaurants along the eco-adventure trail (see 5.3.2) in order to interconnect ecotourism, agritourism and sustainable tourism

According to the abovementioned project ideas, which integrate the two main economic sectors of the Baños: agriculture and tourism. Through the combination of both sectors, optimisation potentials for improving socio-economic and environmental situation of Baños are given. For instance, farmers at rural areas would enhance their business opportunities, find new income sources and follow traditional and sustainable agricultural practices, while visitors could be educated about organic food production and the local gastronomy and accommodation providers would be able to promote ecotourism in combination with healthy and organic food. In order to reinforce agritourism and organic farming it is recommendable to provide educational support and capacity building for farmers at their communities.

5.4.2 Domestic and centralised biogas plants

Domestic biogas reactors in the rural swine-producing and agricultural areas would yield both biogas for domestic use (kitchen stoves and water heating and digestate for soil fertilisation. This technology is currently high promoted in Asia and Africa, particularly for cooking purposes. According INEC (2010), about 91% of the household's kitchen stoves in Ecuador are running with gas. The remaining households use for example wood. In the county of Baños several small agricultural families live in remote areas and don't have easy access to main streets. To this end, it is convenient for them to install a domestic biogas plant in order to produce their own cooking gas. Furthermore, this would support and reinforce the county's agritourism and organic food production.

Common small agricultural families in Baños collect daily manure from their livestock typically about 35 kg from swine and 18 kg from guinea pig (see Chapter 4.1.2). The average daily fermentation slurry is about 60 kg of which around 12% is organic matter. Furthermore, an average size of a biogas plant for households has a volume of about 10.4 m3 with a retention time of 80 days. Taking into consideration these assumptions and calculation methodology from (Sasse, 2001, p. 16) the daily digester loading (R) would be 0.69 kg/m3/day, as demonstrated below:

$$R = (12*60) / (100*10.4) = 0.69 \text{ kg/m3/day}$$

The feedstock for the small scale biogas plants could be slurry or manure from livestock farming as well as organic kitchen waste. In India for instance, farmers have even attached heir toilet latrines to the bio digester. The most common domestic biogas plant is the solid dome type made out of bricks, as depicted in Figure 38.

Figure 38: Design of solid dome type domestic biogas plant
Source: a: (Sasse, 2001, p. 13); b, c: (Blank, Brockmann, Burian, Foerster, & Kapor, 2009, pp. 14-15)

This variant is favourable due to its "high-safety level, relatively easy construction, high production capacity and long lifetime" (Blank, Brockmann, Burian, Foerster, & Kapor, 2009, p. 14). The size of the digester could be between 4-20 m^3. Those types of domestic digesters have a lifetime up to 20 years. The digestate of these small-scale plants represents a nutrient rich fertiliser which is applicable on the fields instead of mineral fertilisers.

The investment costs depend on material costs and workload prices at Baños. However, average costs of projects in Asia amount about US$ 49 per installed m^3. Therefore, the investments for an average sized biogas plant are depicted in Table 18.

Table 18: Domestic biogas plant investment cost

Average investment cost for a medium sized domestic biogas plant		
Average costs	49	m3/US$
Average size of the biogas plant	10.4	m3
Total average costs	514	US$
Average support cost	104	US$
Total average costs (incl. support)	**616**	**US$**

Source: (Blank, Brockmann, Burian, Foerster, & Kapor, 2009, p. 20), converted into US$

The high investment cost compared to the income of small farmers, would rather neglect the idea of a domestic biogas plant installations. However, through the registration this project under the CDM PoA biogas programme (GHG emission reductions based on fossil fuels through CERs purchase) could make significant contributions to the investment costs. To this effect, the requirements of the programme have to be taken into consideration which implies a joint project of several domestic biogas plant installations with a maximum of 5 t CO2 equivalent per unit (Blank, Brockmann, Burian, Foerster, & Kapor, 2009, p. 29)

The benefits arising from domestic biogas plants for farms at remote areas are, among others:

- Own renewable biogas generation on side based on kitchen, manure and human waste
- Reduction of environmental impacts and health risks coming from firewood burning
- Economical savings for the farmer's families through reduced expenses for fuel

- Hygienic organic and human waste treatment and generation of soil fertiliser
- Local contribution to GHG emission reductions
- Reduction of workload for farmers in Baños who are used to prepare their own organic fertiliser or compost by hand

In order to make the farmers aware of domestic biogas plants and their benefits, the farmer's communities could start initiatives informing about the opportunities of this technology. Therefore, small projects among the communities could be started in order to facilitate the implementation and construction of the biogas plants.

5.5 Risk –prevention management

For an overall safety and risk-prevention management within Baños, vulnerabilities in this region should be integrated in the sustainability strategy in order to improve the situation of the municipality. One of the natural vulnerabilities which could be partially reduced is landslides. As mentioned in Chapter 4.1.5, landslides represent high risk at some areas of the municipality including along the main street arriving from Ambato. Whenever a landslide occurs, the street has to be closed and the traffic is stopped impacting trade, commerce and tourism flow. In order to impede these circumstances and improve safety measurements it is recommendable to implement landslide prevention measures, explained as follows.

Landslide classification and prevention is a complex engineering area of research and application. Countries such as Japan and China have developed various measures and strategies to remediate and prevent landslides (Fujisawa, Higuchi, Koda, & Harada, 2007; Kwong, Wang, Lee, & Law, 2004), often including mechanical measures such as drainage and concrete structures. FAO suggests a hierarchy of prevention measures, as shown in Figure 39.

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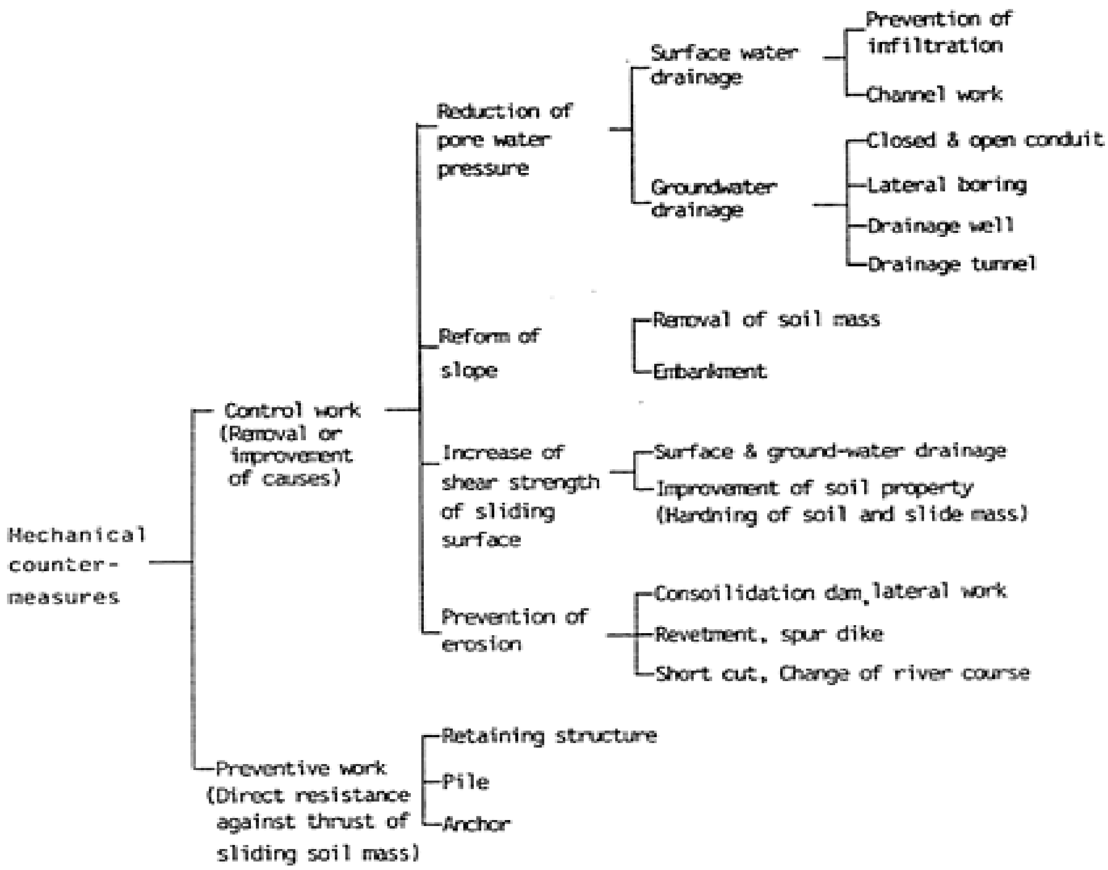
Figure 39: Hierarchy of landslide mechanical prevention measures



Source: (FAO, 1988)

In urban areas, long-lasting, immediate and resistant solutions are required, featuring for instance concrete walls and anchors, drainage channels, slope covering or even slope reforming (involving important soil movement). Nonetheless, such landscape-modifying measures would destroy the Baños rural landscape, and therefore other solutions would be preferable.

For instance, in road-sides and landslide-prone areas (not in critical risk) at the edges of urban areas, a system of anchors and metallic wire mesh netting would be advisable, This strategy/technology is widely used worldwide for slope stabilisation (e.g. (Muhunthan, et al., 2005; Lukkarila, Hunyadi, & Gates, 2009). Wire meshing even allows for shrub vegetation to grow and contribute to stabilising the terrain. In the long term, forestation and reforestation of risk areas would contribute to stabilising those areas.

Figure 40: Examples of wire mesh netting for slope stabilisation
Source: own elaboration (internet images)

6 Regional added values from sustainability strategy

The abovementioned tailored sustainability strategy based on RMFM concept creates essential socio-economic and environmental added values for Baños. Those values are potentials persisting in the region which until now have not been exploited for the benefit of the municipality. In this respect, the following sub-chapters would reveal the untapped added values resulting from the developed sustainability strategy.

6.1 Socio-economic contributions

The proposed waste management strategy would undoubtedly impact positively on the socio-economic dynamics of the county: job generation and job maintenance, formalisation of kerbside pickers and families currently sorting MSW at the landfill site, energy savings for the municipality and creation of added value products (fertiliser/compost) for farmer families implementing household biogas digesters, organic soil ameliorator/fertiliser for local farmers from the centralised biogas digester; among others. The reed bed filter project would improve the water quality of the Pastaza River, while the landslide reduction measures would stabilise dangerous areas and secure permanent access to the municipality.

Those measures, together with the sustainable tourism proposed projects, would contribute to more tourists visiting the county, and thus stimulate the local economy. An important aspect of sustainable tourism is that it contributes to local community development (economic and social well-being, capacity building, enhancement of soft skills, improvement of the self-perception of a community, better quality of life, etc) and environmental education and awareness, among other positive outcomes. As a business strategy, the sustainable touristic projects would boost local community development.

6.2 Environmental contributions

The waste management projects proposed would contribute to emission reductions and other forms of environmental protection: improved water quality, reforestation/afforestation and slope stabilisation, reduction of leakage and contamination of mountain defiles, etc. All environmental-improving measures could be promoted by the municipality as a programme of actions, and thus promote Baños as a green destination managed by a green municipality.

The MSW strategy is the key waste management project among those proposed. In general, anaerobic digestion is preferable to aerobic digestion (composting), because in the latter no energy carriers can be recovered, and ammonia is released to the atmosphere (such release lowers the N and K content of the resulting compost, and contributes to acidification and eutrophication). The CHP would generate renewable energy to complement the local energy production, and eventually outlets for the produced heat will be found. Another alternative could be to use the produced biogas to fuel part of the municipal vehicle fleet (as an additional option); a measure that would not only reduce emissions but could be used as a demonstration of the municipality's green attitude.

7 Conclusions and directions for further research

Baños, the "Golden Gate", is a unique touristic destination in the Andean region of Ecuador, which receives one million tourists each year, particularly national visitors from all over the country. Nonetheless, within the scope of this study and through the application of a preliminary RMFM analysis, it could be identified that the municipality faces socio-economic instabilities and environmental issues, despite the efforts of promoting the county as an eco-touristic place. The present issues are visible and would have severe impacts in near future, by influencing the living conditions and well-being of the residents, weaken economic welfare and further degrading the local environment.

However, through the step-by-step methodological approach of RMFM by considering its dimensional application opportunities related to sustainable development, several untapped optimisation potentials could be identified within Baños. Those potentials are interlinked with one another and influence the input and output flows of materials and energy of the county. That is why such potentials were integrated into a single sustainability strategy. According to the demonstration of the strategy on Figure 29, there is a close connection with the Circular Economy concept.

Therefore, the proposed sustainability strategy would bring a series of benefits to Baños. The MSW separation scheme at the household level and at the RRC enables the recovery of valuable materials, providing formal job opportunities for kerbside pickers and other residents; reducing environmental burdens through significant reduction of waste disposal to the landfill and emission releases to the atmosphere, as well as enhancing the energetic recovery of the organic waste fraction through integration of a biogas plant providing regional electrical and thermal energy, together with organic fertilisers for agricultural purposes. Additionally, domestic biogas plants in remote farmer areas provide the opportunity for on-site biogas generation for cooking and water heating. Moreover, WWT through RBF systems would reduce the contamination load to the Pastaza River, along the Ecological Corridor, improving habitat conditions for native species and reducing health risks to the residents and tourists. The produced biomass from RBF also qualifies as feedstock for the centralised biogas plant. Furthermore, strategies such as the pedestrian downtown or eco-adventure trail, combined with regular participatory events, increase the attractiveness of tourism to

Baños regarding recreation purposes, thus contributing to environmental conservation in combination with touristic services.

Nonetheless, the implementation of the proposed strategy faces challenges such as the change from conventional thinking into a more sustainable thinking. That is how, in the opinion of the author of this study, more efforts should be put into educational programmes integrated in the different aspects of the strategy, particularly regarding the eco-adventure trail, separation schemes and material recovery initiatives (e.g. in schools, technical visits to the RRC, etc.). Additionally, those programmes would establish social responsibilities and strengthen municipal authority as well as stakeholders, which are the key drives for changing the current system into a more sustainable one.

Further directions for the research presented here should focus on detailed engineering for the projects, financing strategies and tools, and a communications and public relations (PR) strategy for the municipality. Such PR strategy would communicate in a coherent manner the underlying sustainability strategy and related projects. It moreover would be useful to stimulate tourism and improve awareness and education on sustainability issues and solutions. Additionally, further renewable energy generation potentials (photovoltaic panels, wind energy and geothermal energy) and energy efficiency models (LED street lighting) could be included into the sustainability strategy. For instance, the Ecuadorian government is currently initiating research studies focused on wind potentials, which have demonstrated that the region of Baños is favourable for this kind of energy generation.

Finally, it could be highlighted that Baños presents a unique place with a great potential to become the first “green” municipality in Ecuador, serving as an exemplary place for further sustainable development projects in the country. A particular driver is the local authority, but also the Ecuadorian government which is currently directing its policies in direction to renewable energies and social improvements activities.

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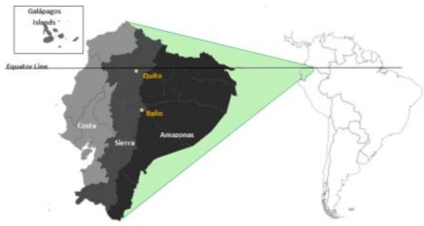
9 Appendix

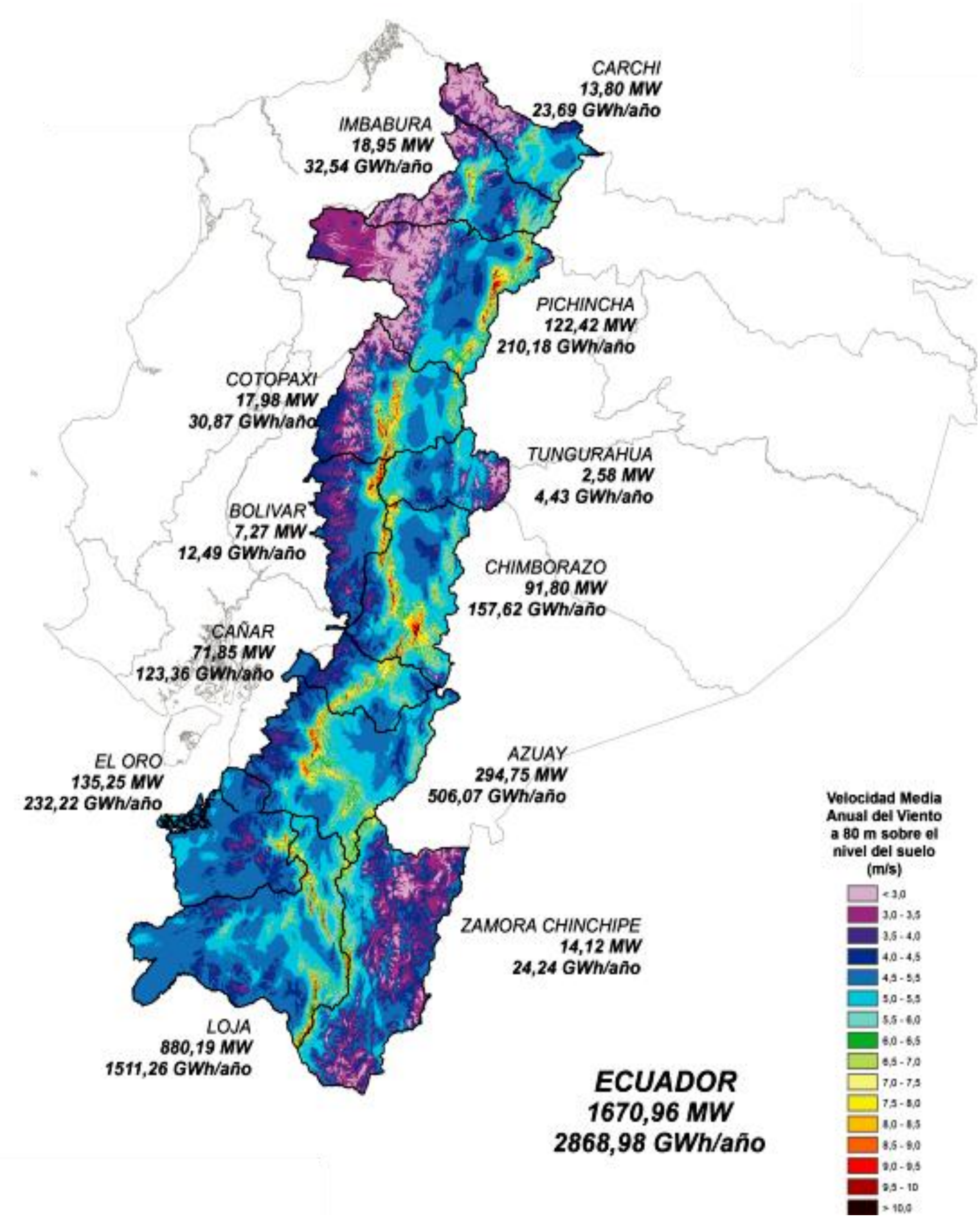
9.1 Ecuador at a glance

Table 19: Ecuador at a glance

Facts of the Republic of Ecuador	
Country's location and flag	 
Country Profile	Republic of Ecuador (Spanish: República del Ecuador)
Area	283 561 km^2
Capital	Quito
Inhabitants	15,480,881
Language	Spanish (official), indigenous (Quechua, Shuar)
Ethnic groups	71.9% Mestizo (mixed Amerindian and white), 7.4% Montubio, 7.2% Afroecuadorian, 7% Amerindia, 6.1% white, 0.4% other
Religion	Roman Catholic 95%
Literacy rate	93.2%
Natural resources	Petroleum, hydropower, fish, timber
GDP (purchasing power parity)	US$ 134.7 billion
Growth rate	4%
Population below poverty line	27.3%
Total External debt	23.3% of the GDP rate
Inflation rate	5.3%
Unemployment	4.1%
Unemployment young age (15-24)	14.1%

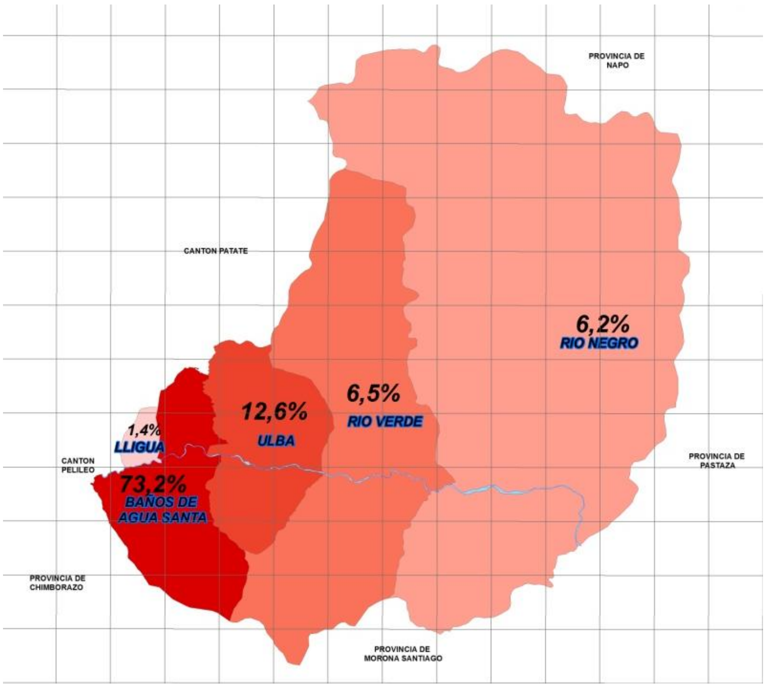
Source: own elaboration based on (INEC, 2011; CIA, 2013)

9.2 Ecuador's wind energy potential



Map 11: Ecuadorian wind energy potential
Source: (MEER, 2013, p. 11)

9.3 Population map of the municipality Baños de Agua Santa



Map 12: Population map of the municipality Baños de Agua Santa
Source: Municipality of Baños de Agua Santa, personal communication, 03.2013

9.4 Questionnaire for the authorities

Estrategia sostenible para la municipalidad de Baños de Agua Santa en base a la gestión regional de flujos de materiales y energías (GFME)

Análisis detallado de datos

Para el desarrollo estratégico sostenible de la municipalidad autónoma de Baños de Agua Santa, adaptado a las condiciones actuales, se requiere un análisis amplio del cantón incluyendo el área socio-económica, social y ambiental. Los resultados serán evaluados de acuerdo a la metodología de la gestión regional de flujos de materiales y energías (GFME) a fin de reconocer potenciales de optimización que estimulen el crecimiento sostenible del cantón como ejemplo para toda la nación.

1) Socio-Economía

Socio-Economía del cantón y la municipalidad de Baños de Agua Santa	
Número de habitantes del cantón	
Número de habitantes Baños	
Número de habitantes Lligua	
Número de habitantes Ulba	
Número de habitantes Rio Verde	
Número de habitantes Rio Negro	
Número de viviendas/hogares	
Porcentaje de pobreza (que no pueden satisfacer sus necesidades básicas)	
Porcentaje de analfabetismo	
Enfermedades comunes de la población	
Número de hospitales	
Servicios médicos	
Número de escuelas	
Número de colegios	
Mercados (nombres)	
Negocios principales	

2) Residuos sólidos

Datos específicos sobre residuos sólidos del cantón y la municipalidad	
a) Residuos sólidos	
• Cantidad anual total de residuos sólidos	
• Cantidad orgánica semanal de los mercados (por mercado)	
• Fracciones de reciclaje (si existe)	
• Cantidad/porcentaje anual de la fracción orgánica	
• Cantidad/porcentaje anual de la fracción plásticos	
• Cantidad/porcentaje anual de la fracción papel y cartón	
• Cantidad/porcentaje anual de la fracción metales	
• Cantidad/porcentaje anual de la fracción vidrios	
• Cantidad/porcentaje anual de la fracción plásticos de invernadero	
• Cantidad de residuos de la caña por semana/mes/año	
b) Manejo de residuos sólidos por la municipalidad	
• Servicios de la municipalidad con respecto a los residuos sólidos	
• Estrategia municipal de colección de residuos	
• Número de carros colectores	

• Número de empleos municipales en la colección de residuos	
• Recorrido de colección de residuos	
• ¿Qué lugares son excluidos de la colección de residuos?	
• Días de colección de residuos sólidos	
• ¿Si se separa, qué se hace con las fracciones separadas/recicladas?	
• ¿Existe una separación de residuos en los hogares/comerciantes?	
• ¿Hay producción de humus/compostaje? ¿En qué cantidades por año?	
• Gastos anuales del municipio (¿Qué incluye?)	
• Ingresos anuales del municipio (¿Qué incluye?)	
c) Residuos peligrosos/tóxicos	
• ¿Qué se considera como residuos peligroso/tóxicos?	
• Origen de los residuos peligrosos/tóxicos	
• Cantidad/porcentaje anual de residuos peligrosos/tóxicos	
• Manejo de residuos hospitalarios (leyes, ordenes)	
• Cantidad anual de residuos hospitalarios	
• Manejo de residuos de gallinerías (leyes, ordenes)	
• Cantidad anual de residuos de gallinerías	
• ¿Dónde se botan los residuos peligrosos/tóxicos?	
d) Relleno sanitario	
• Número de rellenos sanitarios	
• Número de rellenos sanitarios en utilización	
• ¿Qué fracciones de residuos sólidos son botados al relleno?	
• ¿Existe una separación/reciclaje en el área de rellenos?	
• Distancia del relleno sanitario desde la municipalidad de Baños	
• Costo de terrenos para el uso como relleno sanitario	
• Tipos de tratamientos en los rellenos	
• Mantenimiento de los rellenos	
• ¿Existe algún tipo de recolección de gas metano?	
e) Otros	
• Número/Suposición de personas trabajando en el reciclaje que no son empleados por la municipalidad	
• Voluntarios trabajando en la separación/reciclaje	

3) Aguas residuales/aguas servidas

Datos específicos sobre las aguas residuales del cantón	
a) Manejo de la aguas residuales por la municipalidad	
• Servicios de la municipalidad con respecto a las aguas residuales	
• Estrategia municipal de las aguas servidas	
• Porcentaje/Número de viviendas conectadas a la red de aguas residuales	
• Tratamiento de las aguas residuales	
• Tipo de tratamiento	
• Desagüe final de las aguas residuales	
• Costos anuales del municipio para el desagüe y manteniendo de la infraestructura	
• Ingresos anuales del municipio para el manejo de las aguas residuales	
b) Otros	
• Cantidad de aguas residuales por día/mes/año	
• Contenido químico de las aguas residuales	
• ¿Existen estudios sobre las aguas residuales?	

4) Agua Potable

Datos específicos sobre las aguas residuales del cantón	
a) Manejo del aguas potable por la municipalidad	

• Servicios de la municipalidad con respecto a las aguas residuales	
• Origen del agua potable	
• Tratamiento del agua potable	
• Estrategia municipal para el manejo del agua potable	
• Costos anuales del municipio para la disponibilidad de agua potable y manteniendo de la infraestructura	
• Ingresos anuales del municipio para el manejo de las aguas residuales	
• Porcentaje/Número de viviendas conectadas que reciben agua potable	
• ¿Quién controla la calidad del agua potable?	
b) Otros	
• ¿Existen estudios sobre las aguas residuales?	
• Análisis químico del agua potable	

5) Turismo

Datos especifico sobre el sector de turismo del cantón	
a) Turistas/Visitantes	
• Número de turistas/visitantes en el año	
• Número de turistas/visitantes por mes (concentraciones)	
• Número/porcentaje anual de turistas/visitantes nacionales	
• Número/porcentaje anual de turistas/visitantes internacionales	
• Promedio de días de estadía	
b) *Población activa*	
• Número/Porcentaje de la población activa en turismo	
• Número de residencias en Baños (hoteles, hostales, hosterías, posadas)	
• Número de restaurantes	
• Número de baños termales y piscinas en Baños	
• Número de bares y discotecas	
• Número de tiendas de caña y melcocha	
• Número de tiendas artesanales	
c) *Actividades turísticas*	
• Número de operadoras turísticas (agencias)	
• ¿Cuáles son las ofertas/actividades turísticas en el cantón?	
• ¿En qué lugares del cantón se ejercen las actividades?	
d) Transporte e infraestructura turística	
• Número de buses recorriendo el cantón	
• Número de taxis	
• Otros medios de transporte turístico	
• Número de cooperativas camionetas	
• Costos anuales para el mantenimiento de las carreteras turísticas	

6) Agricultura y forestal

Datos específicos sobre el sector agrícola y forestal	
a) Productos agrícolas y ganado	
• ¿Qué productos agrícolas se producen en el cantón, en qué meses?	
• ¿Qué productos son para la exportación internacional?	
• ¿Qué productos son para el mercado nacional?	
• Cantidad anual/mensual de productos domésticos para el cantón	
• ¿Qué tipo de agricultura se lleva en el cantón?	
• Tipo de ganado en el cantón	
• Número/Porcentaje de ganado	
• Cantidad de la producción de humus (¿de qué se hace el humus?)	
b) *0tros*	
• Área agrícola del cantón en ha o km^2	

• Área forestal del cantón en ha o km^2	
• Población activa en la agricultura/ganado	
• Número/cantidad de mataderos (gallinas, cerdos, vacas etc.)	
• Promedio del área común del campesino en ha/km^2 o m^2	
• Catastro/Censo sobre la agricultura en el cantón	

7) Consumo de Energía

Datos específicos sobre el consumo de energía	
a) Energía	
• Fuente principal de energía del cantón (gas, electricidad)	
• Porcentaje/Número de viviendas conectadas a la red	
• Consumo de energía eléctrica por mes/año	
• Producción de energía autónoma	
• Porcentaje de energía importa al cantón de la red nacional	
• ¿Existen fuentes de energía renovable?	
• ¿Existen proyectos de energía renovable?	

8) Contactos requeridos

- Productores del cantón
- Instituciones (agropecuarias, agrícolas)
- Manejadores de Vertederos
- Gestión de Aguas Residuales
- Gestión de Residuos Sólidos
- Gestión de Turismos (Cámara de Turismo, Dirección Ecoturismo)
- Gestión Agrícola
- Gestión de Energía

9) Más información requerida

- Estadísticas/estudios/censos hechos por el gobierno, estudiantes (trabajos universitarios, tesis) o la municipalidad sobre el cantón, el ecoturismo, biodiversidad y ecología del cantón, socio-economía, vulnerabilidades, seguridad del cantón, residuos sólidos, aguas residuales etc.
- Proyectos actuales o en planeación para el futuro relacionados con turismo, manejo medio ambiental, manejo de aguas residuales, manejo de residuos sólidos, manejo de energías renovables
- ¿Cómo se define el término ecoturismo en el cantón? ¿Cuáles son las características? ¿Qué actividades eco- turístico se ofrece en Baños?
- ¿Qué acciones/actividades son llevadas a cabo para proteger y conservar el medio ambiente y la biodiversidad del cantón?

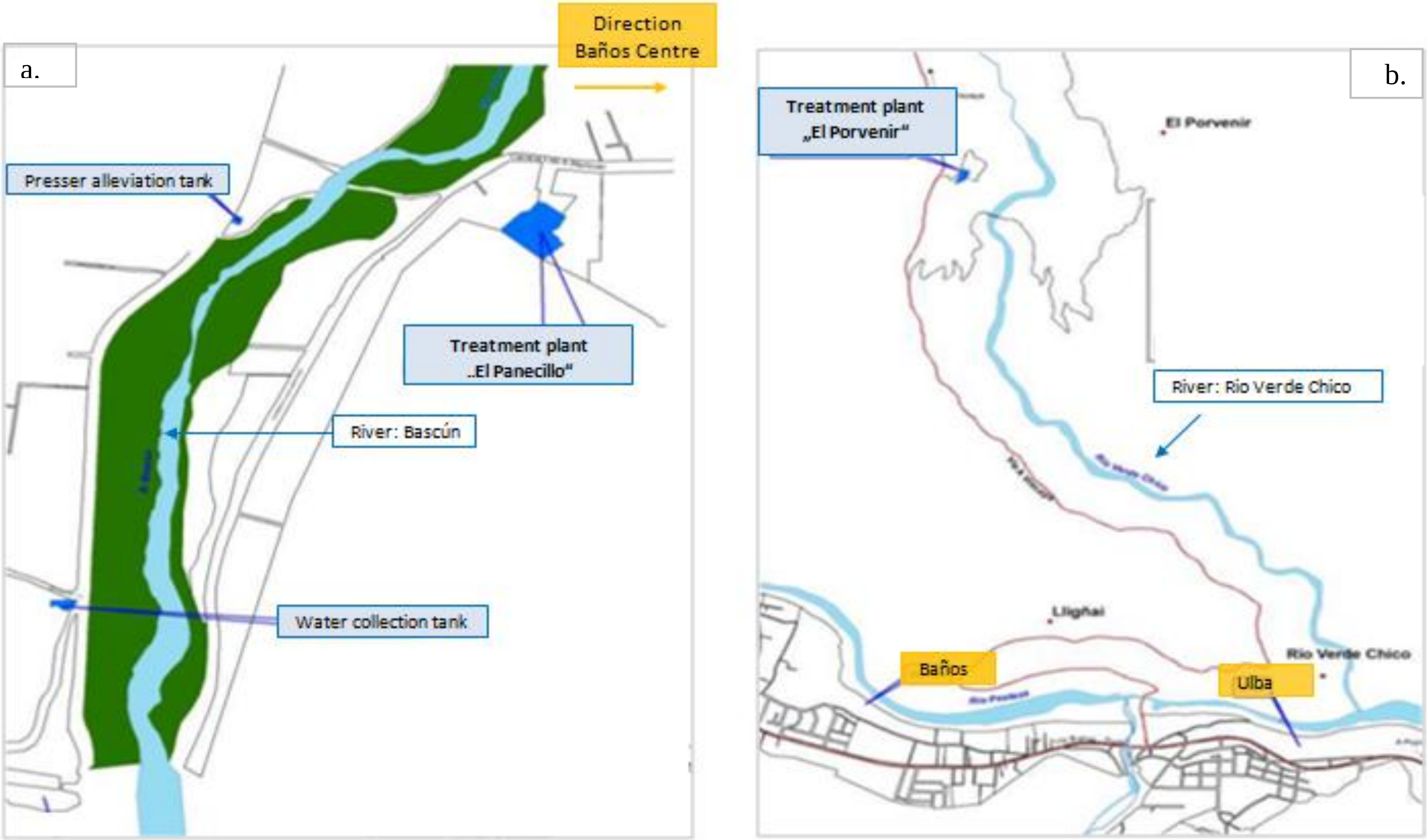
9.5 Stakeholder list

Table 20: Stakeholder list

Title	Surname	Name	Position	Position (Spanish)	Phone	E-Mail
Municipal Stakeholders						
Ing.	José Luis	Freire Yepez	Mayor	Alcalde	(03) 274 33 03	jose.freire@banos.gob.ec munibanos@hotmail.com
Tglo.	Mayorga Cifuentes	Xavier Enrique			09 992 36 4 29	xavier.mayorga@banos.gob.ec
Ing.	Ramos	Grabriela	Environment Chair	Jefa de Ambiente	09 998 50 7 21 (03) 2740 496	gabriela.ramos@banos.gob.ec
Ing.	Coca	Edwin	Inspector of hygiene department	Inspector de higiene	09 841 201 86	educoba13@hotmail.es
Ing.	Cadena	Antonio	Head of hygiene and agricultural development	Jefe de higiene y desarrollo agropecuario	09 847 98 733	toocadena5@yahoo.com
Ing.	German	Vega	Head of drinking water and recovery department	Jefe de Agua Potable y saneamiento	09 396 51 51	wilgerve@yahoo.es
Ing.	Mayorga	Enrique	Director of Tourism Department	Director de Tourism	(03) 2740	

Source: own elaboration

9.6 WWT treatment plants



Map 13: a) Current drinking WTP; b) Emergency WTP project
Source: (PDOT-GADRAS municipal document, 2011, pp. 224-225), modified and translated by the author

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9.7 Biogas yield potentials

Table 21: Biogas yields of different input materials for anaerobic digestion

Substrate	TS (%)	o.TS (%)	Biogas yield (Nm^3/t substrate)	CH4 yield (Nm3/t substrate)	CH4 yield (%)
Slurry – cattle	10	80	25	14	
Slurry– swine	6	80	28	17	
Manure – cattle	25	80	80	44	65
Manure – poultry	40	75	140	90	60
Manure – pig					67
Corn silage	33	95	200	106	
Grass silage	35	90	620	320	70
Grain seeds	87	97	180	98	
Sugarbeets	23	90	130	72	
Fodder beet	16	90	90	50	
Garden waste	12	87	175	105	
Molasses	85	87.5	315	229	
Sugarcane bargasse					
Fats	5	90	1000	31	
Food waste (domestic)	**40**	**50**	**640**	**74**	**50**

Source: (FNR, 2004, pp. 76-83, 174)

9.8 Calculation for biogas plant concept

9.8.1 MSW of Baños de Agua Santa

Table 22: MSW generation and composition in Baños

Waste generation and composition in Baños

1) Waste generation and composition of Baños

Inhabitants	20.506,00	
Average waste per day	16,00	t
Total MSW per week	112,00	t
Total MSW per a	**40.880,00**	**t**
waste generated / person/day	0,78	kg
waste generated / person/a	1,99	t

MSW fractions	Municipal data 2011	
organics	60,00	%
paper	8,00	%
cardboard	9,00	%
plastics	6,50	%
metals	1,75	%
glass (scrab)	1,00	%
hazardous (hospital)	1,00	%
Others	12,75	%
	100,00	%

2) Total waste generation in Baños per year in t

MSW fractions	mass t/a	mass kg/a
organics	24.528,00	24.528.000
paper	3.270,40	3.270.400
cardboard	3.679,20	3.679.200
plastics	2.657,20	2.657.200
metals	715,40	715.400
glass	408,80	408.800
hazardous (hospital)	408,80	408.800
other (textiles, toilet paper, nankins etc.)	5.212,20	5.212.200
SUM	40.880,00	40.880.000

Source: own elaboration based on data from municipal document, 2011
and personal communication with Antonio Cadena

9.8.2 Parameters

Table 23: Parameters for biogas plant

Parameters for electricity and heat generation from biogas		
1 t Biowastes	100-120	m^3
1 m3 Biogas	5,0-7,5	kWh/m^3
CHP Efficiency	1,5-3	kWh/m^3
CHP Efficiency	85 total%	
CHP efficiency el.	30-45	kWhel
CHP efficiency th.	35-60	kWhth
Own heat consumption	7-10%	%
Operation hours	90%	%
Energy equivalents		
Calorific value equivalent to oil	9,97	kWh/m^3
Oil equivalent	0,6	l/m^3
Calorific value equivalent to gas	10	kWh/m3
Total solid content		
Food waste	40%	TS
Wet fermentation (digestate)	12%	TS
Dry fermentation (digestate)	15%	TS

Source: own elaboration in line with (FNR, 2004, pp. 23,30,174; FNR, 2013)

9.8.3 Pricing list

Table 24: Prices

Energy price for non-renewable energies		
Grid electricity < 110 (Sierra)	0,04	US $/kWh
Grid electricity < 500 (Sierra)	0,085	US $/kWh
Grid electricity >2000 kwh (Sierra)1	0,67	US $/kWh
Gasoline extra	0,39	US$/l

Gasoline super			0,53	US$/l
Diesel price			0,27	US$/l
Liquefied petroleum gas (LPG)			1,60	US$/15kg tank
Electricity prices for renewable energies				
Renewable energy source	**Continental Territory**		**Galápagos Territory**	
Wind	0,09	US$/kWh	0,10	US$/kWh
Photovoltaic	0,40	US$/kWh	0,44	US$/kWh
Biomass and bio-gas < 5MW	0,11	US$/kWh	0,12	US$/kWh
Biomass and bio-gas > 5MW	0,10	US$/kWh	0,11	US$/kWh
Geothermal	0,13	US$/kWh	0,15	US$/kWh
Hydropower (up to 10MW)	0,07	US$/kWh	-	
Hydropower plants (10-30MW)	0,07	US$/kWh	-	
Hydropower plants (30-50MW)	0,06	US$/kWh	-	
Recycling prices (according to Reciclar Ltda. Ambato)				
Ferrous Metals				
cerro			0,23	US$/kg
Copper			4,85	US$/kg
Aluminium			0,88	US$/kg
Bronze			2,64	US$/kg
Plastics				
Plastic average			0,7	US$/kg
Plastics bottles small			0,6	US$/kg
Plastic bottles (1 gallon)			0,2	US$/kg/bottle
Plastics PET			0,79	US$/kg
Paper				
Newspaper			0,01	US$/kg
Mixed paper			0,10	US$/kg
white paper			0,13	US$/kg
Cardboard			0,08	US$/kg
Organic fertiliser market price (biol)			10	US$/40kg

Source: own elaboration

9.8.4 Biogas yield and energy generation capacity for biogas plant

Table 25: Biogas yield and energy generation capacity

Biogas yield				
Total organic waste generation			24.528,00	t/a
hours in one year			8.750,00	h
Parameters				
	Scenario 1	Scenario 2	Scenario 3	units
Biogas yield (fresh matter)	100,00	110,00	120,00	m³/t
Electricity potential of biogas	5,00	6,25	7,50	kWh/m³
CHP efficiency (electricity)	30,00%	37,50%	45,00%	
Thermal potential of biogas	1,50	2,25	3,00	kWh/m³
CHP efficiency (heat)	35,00%	47,50%	60,00%	

Losses CHP (own electricity consumption)	7,00%	8,50%	10,00%	
Losses CHP (own heat consumption)	30,00%	38,00%	45,00%	
Operational time of CHP unit	85,00%	90,00%	95,00%	
Gas and energy potential				
Biogas yield	2.452.800	2.698.080	2.943.360	m³
Electricity potential of biogas	12.264.000	16.863.000	22.075.200	kwh
Thermal potential of biogas	5.518.800	14.228.156	29.801.520	kwh
Energy generation (brutto)				
generated electricity	3.679.200	6.323.625	9.933.840	$kWh_{el.}$
generated heat	1.931.580	6.758.374	17.880.912	$kWh_{th.}$
CHP losses				
Electrical energy	257.544	537.508	993.384	$kWh_{el.}$
Thermal energy	579.474	2.568.182	8.046.410	$kWh_{th.}$
Energy generation (net)				
Electrical energy	3.421.656	5.786.117	8.940.456	$kWh_{el.}$
Thermal energy	1.352.106	4.190.192	9.834.502	$kWh_{th.}$
Installed electrical and thermal energy of the CHP unit				
Operational time of CHP unit	7.438	7.875	8.313	h/a
Installed electrical power	0,460	0,735	1,076	$MW_{el.}$/a
Installed thermal power	0,182	0,532	1,183	$MW_{th.}$/a

Source: own elaboration based on parameters of FNR, 2004, pp. 23,30,174; FNR, 2013

9.8.5 Fertiliser and compost generation capacity

Table 26: Fertiliser generation potential (decanter centrifuge)

Fertiliser generation (decanter centrifuge)				
Feedstock input (food waste)	40%	TS	24.528	t/a
Water input	0%	TS	57.232	t/a
Substrate in biogas plant	12%	TS	81.760	t/a
Loses	20%	of TS		
Mass reduction	1,1	kg/m3 biogas	7.353	
Digestate total	10%	TS	74.407	t/a
Solid fertiliser (decanter centrifuge)	22,30%	TS	9.152	t/a
Liquid fertiliser	<10%	TS	65.255	t/a

Source: own elaboration based on data from (FNR, 2004; DeBruyn & Hilborn, 2007, p. 5)

Table 27: Fertiliser generation potential (screw press)

Fertiliser generation (Screw press)				
Feedstock input (food waste)	40%	TS	24.528	t/a
Water input	0%	TS	57.232	
Substrate in biogas plant	12%	TS	81.760	t/a
Loses	20%	of TS		
Mass reduction	1,1	kg/m3 biogas	7.353	
Digestate total	10%	TS	74.407	t/a
Solid fertiliser	12,90%	TS	2.158	t/a
Liquid fertiliser	<10%	TS	72.249	t/a

Source: own elaboration based on data from (FNR, 2004; DeBruyn & Hilborn, 2007, p. 5)

9.8.6 Potential revenue generation with MSW separation scheme

Table 28: Potential revenues from biogas plant (Scenario 2)

Revenues of the municipality		
Municipality revenues		
Household rate revenues	**68.575,91**	**US$/a**
Revenues from MSW recycling, biogas, fertiliser production		
Potential MSW revenues from recycling		
	revenues	
Paper mixed (US$0.10/kg)	327.040,00	US$/a
Plastic (US$0.7/kg)	1.860.040,00	US$/a
cardboard (US$0.08/kg)	275.940,00	US$/a
metals (US$0.23/kg)	164.542,00	US$/a
Total revenue recycling	**2.627.562,00**	**US$/a**
Potential MSW revenues from biogas		
	Scenario 2	
Electrical energy (US$ 11/kWhel)	**639.365,91**	**US$/a**
Potential MSW revenues from fertilizer (decanter centrifuge technology)		
Organic liquid fertiliser	65.255	t/a
Organic fertiliser market price (biol) (US$0,29 /kg)	290	US$/t
Revenue (liquid fertiliser)	18.923.890	US$
Organic solid fertiliser	9.152	t/a
Compost price (US$/10 40kg)	250	US$/t
Revenue compost (solid fertiliser)	2.288.010	US$
Total revenue (decanter centrifuge)	**21.211.900**	**US$/a**

Potential MSW revenues from fertilizer (screw press technology)		
Organic liquid fertiliser	72.249	t/a
Organic fertiliser market price (biol) (US$0,29 /kg)	290,00	US$/t
Revenue (liquid fertiliser)	20.952.220	US$
Organic solid fertiliser	2.158	t/a
Compost price (US$/10 40kg)	250	US$/t
Revenue compost (solid fertiliser)	539.450	US$
Total revenue (screw press)	**21.491.670**	**US$/a**
Total revenue (decanter centrifuge)	24.547.403,67	US$/a
Total revenue (screw press)	24.827.173,36	US$/a

Source: own elaboration based on data given in and (Novillo, 2010)

9.9 Physicochemical and microbiological properties of digestate from food waste feedstock

Table 29: Physicochemical properties of digestate produced from food waste feedstock

	pH	DS (%)	Specific Gravity (g ml^{-1})	Volatile solids (%)	VFAs	Total neutralising value (%fw as CaO)	Conductivity (µS/cm 20°C)	BOD (mg l^{-1})	COD (mg l^{-1})	Stability (L kg^{-1} VS)
n	2	6	2	2	awaiting data	2	2	2	2	2
Mean	8.4	4.5	0.95	69.0		26.1	7490	8769	43887	142
Min	8.3	2.7	0.94	68.3		23.1	6940	6437	34067	72
Max	8.4	6.8	0.96	69.6		29.1	8040	11100	53707	212
SD	0.1	1.5	0.01	0.9		4.2	777.8	3297	13888	99
Percentile										
25	8.3	3.5	0.95	68.6		24.6	7215	7603	38977	107
50	8.4	4.7	0.95	69.0		26.1	7490	8769	43887	142
75	8.4	5.0	0.96	69.3		27.6	7765	9934	48797	177
Interquartile range	0.0	1.4	0.01	0.6		3.0	550	2332	9820	70.0

Data supplied by WRAP (each value from duplicate measurements) and anonymous AD plant

Source: (Rigby & Smith, 2011, S. 36)

Table 30: Nitrogen content and C:N ration of digestate produced from food waste feedstock

		Total N (%)	Organic N (%)	NH_4-N (%)	Readily available N (%)†	Readily available N (% total N)	C:N ratio
n		6	6	4	6	6.0	2
Mean		15.0	5.7	10.5	9.3	61.9	1.5
Minimum		11.9	1.6	5.5	5.5	38.7	1.4
Maximum		20.5	10.0	16.0	16.0	86.8	1.6
Standard Deviation		3.19	3.14	4.33	3.87	3.87	0.10
Percentiles	25	12.7	3.6	9.0	6.6	45.0	1.5
	50	14.3	5.7	10.2	8.7	61.7	1.5
	75	16.0	7.7	11.8	10.3	77.5	1.5
Inter-quartile range		3.3	4.1	2.8	3.7	10.3	0.1

Data supplied by WRAP (each value from duplicate measurements) and Anonymous AD plant
†NH_4-N+NO_3-N by KCl extraction

Source: (Rigby & Smith, 2011, S. 37)

Table 31: Nutrient content (other than nitrogen) of digestate produced from food waste

	Total P (%)	Water Soluble P (%)	Total K (%)	Water Soluble K (%)	Total Ca (%)	Water Soluble Ca (%)	Total Mg (%)	Water Soluble Mg (%)	Total S (%)	Water Soluble S (%)	Water Soluble Na (%)	Water Soluble Cl(%)
n	6	2	6	6	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00
Mean	0.7	0.1	4.7	1.9	0.34	0.10	0.19	0.01	0.33	0.07	3.09	2.32
Minimum	0.3	0.0	1.4	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Maximum	2.0	0.2	9.3	5.7	1.70	0.48	0.69	0.04	0.57	0.22	4.80	8.00
Standard Deviation	0.66	0.10	2.65	2.31	0.68	0.19	0.28	0.02	0.21	0.10	1.74	3.65
Percentiles												
25	0.3	0.0	3.5	0.0	0.00	0.00	0.02	0.00	0.23	0.00	2.78	0.00
50	0.5	0.1	4.7	1.3	0.00	0.00	0.05	0.00	0.37	0.00	3.16	0.00
75	0.6	0.1	5.1	2.8	0.24	0.11	0.28	0.01	0.47	0.14	4.35	4.43
Inter-quartile range	0.3	0.1	1.6	2.8	0.24	0.11	0.26	0.01	0.24	0.14	1.57	4.43

Data supplied by WRAP (each value from duplicate measurements) and anonymous AD plant

Source: (Rigby & Smith, 2011, S. 39)

Table 32: Dry solids and NPK content of separated digestate fibre and liquor estimated

	DS in fibre (%)	Total N in fibre (%DS)	Total P in fibre (%DS)	Total K in fibre (%DS)	DS in liquor (%)	Total N in liquor (%DS)	Total P in liquor (%DS)	Total K in liquor (%DS)
Majority food waste								
Belt press	8.7	9.6	0.31	2.1	2.8	8.3	0.97	2.7
Screw press (median values)	12.9	9.8	0.28	1.2	3.0	6.8	0.84	0.9
Decanter centrifuge (mean)	22.3	19.0	0.82	0.9	2.4	3.7	0.36	1.0
Contains animal slurry								
Belt press	9.5	9.6	0.4	1.6	3.0	7.7	1.3	2.0
Screw press (median values)	14.0	9.9	0.4	0.9	3.3	6.3	1.1	0.7
Decanter centrifuge (mean)	24.3	19.1	1.1	0.7	2.6	3.4	0.5	0.7

Source: (Rigby & Smith, 2011, S. 40)