Measuring the Sustainability of Biomass Resources – The Sustainable Biomass Index SBI

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Abstract: - Nowadays world's energy market changed rapidly because of a decrease of unrenewable energy resources together with the growing public environmental awareness. In order to give consideration to this development, the existing renewable energy resources have to be utilized in an efficient sustainable way. Therefore, biomass energy systems, as the only renewable energy system achieving continuous power on a high level, play a significant role. These systems can only be implemented sustainable if the utilized biomass resource is conforming to the sustainability. Hence, we have elaborated the Sustainable Biomass Index SBI to help the planning authorities and energy investment groups to identify the best biomass resource for their requirements. After giving a brief overview of recent possibilities of sustainable measurement, we illustrate the structure and the data content of the SBI. Proximate, the calculation and application of this Index is given.

Key-Words: - Biomass and Bio-energy, Sustainable Development, Biomass Energy Systems, Sustainability Measurement

1 Introduction

Biomass Resources have become a more and more important role in the recent time period in the frame of energy systems. This is based not only on the current growth of public environmental awareness and their outer appearance but also on the fact that the biomass energy is the only renewable energy achieving continuous power as a result of planning and storing the available energy resource [1]. Besides, in case of sustainable behavior the usage of biomass is CO2 neutral and has no bearing on the global warming and climate change [2]. Moreover, in the most countries the integration of biomass as a renewable energy is under constitutional law and has to be embedded in the energy policies. Nevertheless, nowadays the geographical planning of functional energy plants within a biomass energy system is not optimized and partially unstructured [3].

Therefore, there is a need for action regarding planning methods of biomass energy systems. Planning has to be realized on the lowest administrative level on the basis of the bottom-up principle which is embedded in the most countries. Furthermore, the local affairs is a cross-section policy and therefore responsible for the local energy policy, as well [4]. Since the famous Report of the World Commission on Environment and Development in 1987 (Nowadays known as Brundtland Report) [5] the local development authorities and policy maker embedded more and more the sustainability in their laws and decrees. Today, every regional planning in the European Union has to be up to the mark of sustainability [6].

Our proposed method helps to identify the most sustainable biomass resource and, through the possibility of comparisons, the decision making will be supported regarding location, size, and type of biomass energy plants. Firstly, we refer to related works in the area of measuring the Sustainability with different focal points and introduce the Environmental Sustainability Index followed by the presentation of our approach resulting in the Sustainable Biomass Index SBI.

2 Related works

Meanwhile, there are several scientific works in the area of sustainability with almost one equal basis. This basis is the Report *Our common future* from the World Commission on Environment and Development. This Commission was founded in 1983 from the United Nations as an independent authority on long-termed environmentally sound development with the mission to develop a perspective report. The results were published 1987 in the above mentioned report and contains the new mission statement of sustainable development: "Meeting the needs of the present generation without comprising the ability of future generations to meet their needs" [5]. Since then, several constructive works have been elaborated. Some of them deal with the Measurement of Sustainability, as well. There are four important main approaches to mention dependent on:

- External Costs / Externality
  External Costs is defined as costs, which “arises when the social or economic activities of one group of persons have an on another group and when that impact is not fully accounted, or compensated for, by the first group” [7] and are the basis for the integration of the Sustainability in the companies’ balance sheet. Hence, the companies’ assets have to be revised with the external cost value. There are two main works in this area from Atkinson elaborating the Green Added Value [8] and from Huizing and Dekker working on the Net Value Added [9]. The main problem of this approach is the implementation because of difficulties in monetary valuation of the external effects.

- Prevention Costs
  There are several works dealing with the integration of prevention costs in companies’ balance sheet [10][11][12]. These costs are defined as costs for avoiding or revoking ecological strains through the use of technical solutions [13]. Not only is the implementation of all ecological strains a difficulty of this approach but also the fragmentary understanding of sustainability. In order to include the whole sustainable costs, the socio-cultural impacts of the companies’ behavior have to be implemented by reason of the definition of sustainability.

- Efficiency Conception
  With this theory by [14][15][16] the efficiency of the companies’ sustainable behavior can be calculated. Therefore, the added value is set into the relationship of the adherent ecological impacts. These impacts are summarized in an aggregated value of the weighted relative harmfulness of different ecological elements taken out of statistics. Analog to the Prevention Costs, the Efficiency Conception does not consider the socio-cultural effects and is therefore not fully sustainable.

- Sustainable Added Value
  Apart from the above mentioned approaches this approach is not burden-based. For reason of excluding the monetary weighting it is based on opportunity costs and it is worth-oriented. The weighting of ecological impacts is based on the created economical value. Additionally, the economical and social efficiency is considered resulting in a real sustainable approach [17]. However, this approach can not be used for the measurement of Biomass Resources because of the worth-orientation.

Beside these approaches which are not suitable for the sustainable measurement for biomass resources, the criteria for a sustainable development have to be pointed out in consideration of measuring the sustainability of biomass resources. In the most countries exists a set of sustainability criteria used in their spatial planning. As an example we point out the strategy for a sustainable development from Germany. They emphasize four main coordinates: Generation justice, Quality of life, Social co-operation, and international responsibility. Every coordinate contains different action fields for the sustainable strategy, which are evaluated by using different indicators and goal-worth. The following figure describes exemplary the structure by pointing out the Quality of Life [18].

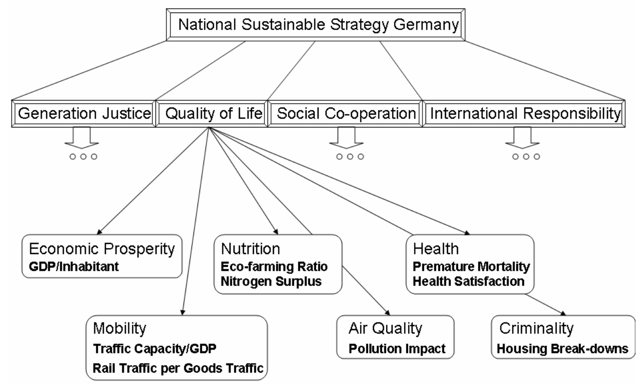

Fig. 1: Quality of Life action fields of the National Sustainable Strategy Germany

There are many diverse criteria-structures elaborated by the different countries. Among others, these criteria are a basis for the proposed Biomass Sustainability Index.

The 2005 Environmental Sustainability Index published by the Yale and Columbia University is a benchmarking-index reflecting the possibility to compare countries with regard to their sustainable behavior. Therefore, five broad categories have been pointed out: Environmental Systems, Reducing Environmental Stresses, Reducing Human Vulnerability to Environmental Stresses, Societal and Institutional Capacity to Respond to Environmental Challenges, and Global Stewardship [19]. This approach is mainly important for planning reasons of the observed countries with the aim of protecting their environment. Consequently, the worst evaluated countries have the ability to change their policies and general conditions in consideration of the best evaluated countries in order to advance their environmental attitude. However, this approach is only a benchmark and has no real impact on the countries’ policies or behavior unless the inhabitants and/or the politician take their environmental position seriously and want to advance it.

3. Measurement of the Biomass Resources' Sustainability

Nowadays, in the field of Renewable Energy mainly the biomass energy is a fast growing market because of the above mentioned facts. Therefore, sustainable planning of this energy integration is a requirement to reach real 'green' energy. Our approach addresses to regions with limited means but large-scaled biomass resources. Their problem is to identify the suitable biomass for energetic use. Hence, a possibility to compare the different regions biomass resources has to be elaborated. Consequently, a sustainable resource consideration should be conducted in order to involve the above mentioned mission statement of the sustainable development.

In order to answer the question on how measuring the sustainability of biomass resources, the related work in the field of sustainable measurement has to be observed and, if possible implemented. Due to the fact that we point out a sustainability index, we have to implement the mission statement of the sustainability in every step of the creation of the index. Therefore, we subdivide the Sustainable Biomass Index into three different operating levels according to the sustainability: the Socio-Cultural Operating Level, the Economical Operating Level, and the Ecological Operating Level. For balancing reasons every Operating Level gets the same weighting.

$$SBI = \frac{OL_{Socio-Cultural} + OL_{Economical} + OL_{Ecological}}{3} \quad (3.1)$$

$$\{OL \in R \mid 0 \leq OL\} \quad (3.2)$$

Following the related work from Section 2 we have to consider the Externalities as well. However, this is not only because of the above mentioned difficulties in the monetary valuation not possible, but also because of the fact, that we observe natural resources and not a company or a region and by reason of no production/change the external effects are incapable of measurement. Analogical, the Prevention Cost Theory is inapplicable because there are no ecological strains of biomass resources. Similar to these theories, the two efficiency oriented approaches, the Efficiency Conception and the Sustainable Added Value are not suitable to calculate the Sustainable Biomass Index because of the incapability of measurement of the natural resource biomass.

Hence, we concentrate on the criteria of the Sustainability and modify them in consideration of applying to biomass resources. Therefore, we point out three different levels of sustainable Measurement of Biomass Resources: The three Operating Levels (Socio-Cultural Level, Economical Level, and Ecological Level) their parameter values (Parameter Level) and their indicators (Indicator Level). The command structure of these Levels is visualized in the following figure.

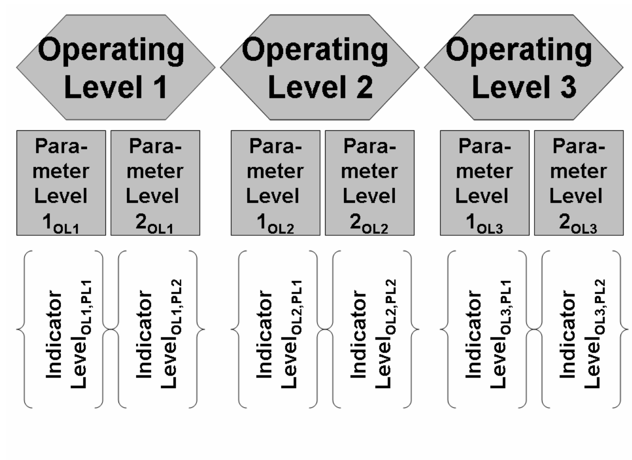

Fig. 2: Level Structure of the Sustainability of biomass resources

3.1 Operating Level 1: The Socio-Cultural Measurement

In order to measure these aspects it is a requirement to define the meaning of socio-cultural. Essentially, this first Operating Level consists of two terms: social and cultural. Due to the fact that these aspects are intertwined they have to be measured combined. The social component describes the surrounding area of the observed inhabitants including their employment activities and their leisure activities. Furthermore, the cruising radius is very important. Additionally, the cultural component covers the course of action and measures the behavior.

For the purpose of measuring these aspects we have to point out the different parameters according to Fig. 2. Intrinsically, the elaborated parameter should be Quality of Life because of the overarching character; all different possible indicators are integrated within this parameter. Nevertheless, we have to subdivide this parameter for measuring reasons. There are two resulting parameters: the first deals with indicators created out of statistics and the second parameter is based on indicators realized by interviews of the inhabitants of the observed region.

Therefore, we termed these parameters Quality of Life – Strong Criteria and Quality of Life – Soft Criteria. The strong criteria are indicated by the population figure, the regions gross domestic product, the traffic performance, the ecologic cultivation, the contaminant loads, the early mortality rate, and the crime rate change. All of these criteria are taken out of the National Sustainable Strategy Germany and are modified to get in the context of biomass resources. Accordingly, the following indicators should be considered in the measurement:

- Economic change of prosperity
  - ⇨ GDP/Inhabitant
- Mobility
  - ⇨ Traffic Performance/GDP
- Nutrition
  - ⇨ Ecological cultivation/cultivation
  - ⇨ Nitrogen surplus
- Air Quality
  - ⇨ Contaminant loads
- Physical health
  - ⇨ Early mortality rate
- Crime rate change

All of these values have to be taken out of statistics or, in case of no suitable statistics, have to be collected within the frame of studies. Due to collect the data for possible changes of these indicators as a result of biomass usage, scenario analysis have to be implemented. Available data from other regions can be instrumental in creating such scenarios.

The measurement of the soft criteria must be different from the strong criteria because of nonexistence in available statistics. The soft criteria are related to the inhabitants' life and how a change in biomass resource would alter the regular course of life. Therefore, questionnaires must be created and used in representative interviews in order to measure these changes. Mainly, three impacts of change in biomass resources have to be measured:

- o Recreational activity
- o Everyday life
- o Public acceptance

By virtue of the special circumstances and the different initial situations, these questionnaires have to be specific to the interviewed region.

Finally, the following figure visualized the above mentioned parameters and indicators.

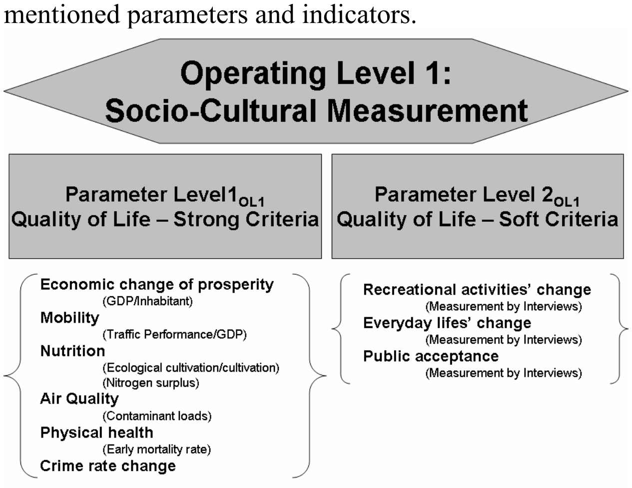

Fig. 3: Socio-Cultural Measurement of biomass resources

3.2 Operating Level 2: The Economical Measurement

In contrast to the Socio-Cultural Measurement, the Economical Measurement is based on cost[1] and revenue of biomass resources. These elements represent the economical parameter level.

The Cost Analysis as the first parameter consists of at least two indicators: Newly growing biomass cost and the valuation of biomass. In order to measure sustainability these two indictors have to be considered combined. To be economic efficient, the growing cost should always be less then the valuation of biomass. If the costs are higher, outer acquisition will be the best choice.

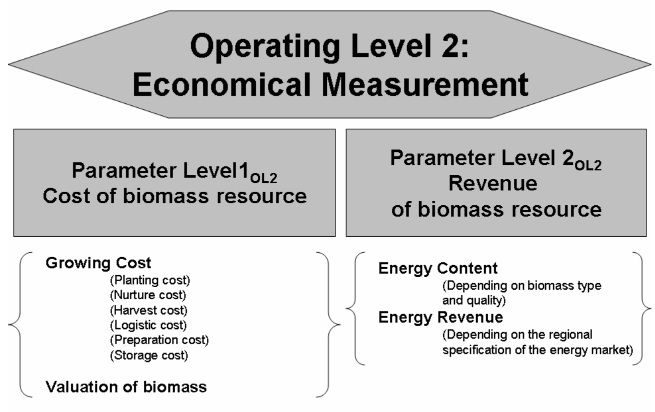

Fig. 4: Economical Measurement of biomass resources

3.3 Operating Level 3: The Ecological Measurement

In order to fulfill the sustainability criteria the ecological level has to be considered in addition to socio-cultural and economical measurements.

The most important factor regarding the ecological sustainability is that the utilized biomass has to be substituted by newly grown biomass. Only this behavior permits the usage of biomass in consideration of sustainability and CO2 neutrality.

Mainly, the Ecological Measurement of the biomass resources is subdivided into two parameter level: the Resource oriented Measurement and the Ecological Biomass Impacts. The Resource oriented aspect is about the Generation Justice and therefore very important for the sustainability. In order to calculate a certain value utilized and newly grown biomass has to be considered. For the specification of this newly grown biomass the second parameter, Ecological Biomass Impacts, includes the diversity of species (plants as well as animals), the climate protection, and the air quality. According to the above mentioned paragraphs, the following figure describes the structure or the third Operating Level.

[1] No consideration of profit because of nonprofit approach (Biomass Resources)

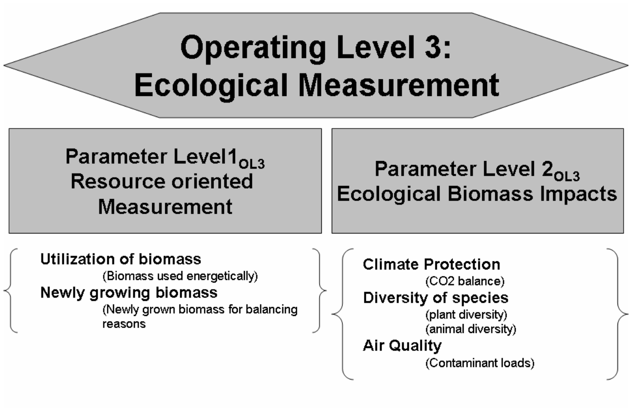

Fig. 5: Ecological Measurement of biomass resources

4. The Sustainable Biomass Index

The above described Operating Level, Parameter Level, and Indicators are the basis for the calculation of a specific Sustainable Biomass Index SBI for each biomass/region. Mainly, for the planning authorities and investment groups the best sustainable biomass for an energetic use can be identified.

Therefore, the SBI calculation is based on equation 3.1. Each Parameter Level PL is weighted 50% of the Operating Level OL, which is described in the following equation:

$$OL_i = (PL1_{OL_i} + PL2_{OL_i})/2 \tag{4.1}$$

The different Parameter Level has to be calculated according to the specific indicators. A sustainable minimal value per indicator has to be pointed out according to the specific region.

$PL1_{OL1}$ includes 6 indicators. Because of double-usage of the indicator Air Quality in OL1 and OL3 it is only weighted 50 % of the other indicator from $PL1_{OL1}$. This results in the following equation[2]:

$$PL1_{OL1} = \frac{2(Ecop + M + N + Ph + Crc) + AQ}{11} \tag{4.2}$$

The indicator value is based on the nowadays situation. This value is defined as 100% and the variance by reason of biomass usage has to be added / subtracted. Typically this value is around 1. The higher the value is, the higher is the SBI. The calculation is based on the indicators of figure 3.

Very similar to $PL1_{OL1}$ is $PL2_{OL1}$. The only difference is the type of data collection, because it is about soft criteria collected through interviews. Possible changes have to be measured negative (less than 100%) or positive (higher than 100%) dependent on the interviewed inhabitants of the observed region resulting in the value of $PL2_{OL1}$ described in equation 4.3.

$$PL2_{OL1} = \frac{Rac + Elc + Pa}{3} \tag{4.3}$$

$PL1_{OL2}$ has to be calculated on the basis of the ratio from Growing Cost and Valuation of biomass. The Growing Cost is calculated according to [3]. The valuation of biomass is dependent on the market situation of the specific region. Accordingly, the $PL1_{OL2}$ value is calculated through the following equation 4.4.

$$PL1_{OL2} = \frac{Vob}{GC} \tag{4.4}$$

The second parameter of Operating Level 2 is about the revenue of biomass resources. The biomass resource efficiency is calculated here. Therefore, the average energy revenue per biomass and the average energy content per biomass are the basis for the calculation.

$$PL2_{OL2} = \frac{\dfrac{\frac{EC}{biomass}}{\frac{\varnothing EC}{biomass}} + \dfrac{\frac{ER}{biomass}}{\frac{\varnothing ER}{biomass}}}{2} \tag{4.5}$$

The Resource oriented Measurement from the third operating level is calculated with the data from the utilization and newly grown biomass in case of an energetic use. According to equation 4.4 the ration of the used indicators Utilization of biomass and Newly growing biomass is very important visualized in the following equation:

$$PL1_{OL3} = \frac{Ngb}{Uob} \tag{4.6}$$

$PL2_{OL3}$ is again based on possible changes of the indicators in case of energetically biomass usage. Climate Protection, Diversity of species, and Air Quality are the observed indicators. According to $PL1_{OL1}$ the Air Quality has to be weighted only 50% of the other indicators described in the following equation:

$$PL2_{OL3} = \frac{2(CP + Dos) + AQ}{5} \tag{4.7}$$

Finally, equations 4.2 to 4.7 have to be implemented in valuation of the SBI. The outcome of the calculation of this index gives the planning authorities or investment groups a possibility to compare different regions in order

[2] The abbreviations are according to the initials of the used indicators.

to generate sustainable biomass energy. The higher the value of SBI is, the more sustainable is the usage of the biomass. Generally, a biomass resource with a value larger than 1 (100%) can be called sustainable according to the definition of the sustainability [5]. Consequently, the SBI is equated as follows:

$$SBI = \frac{PI1_{OI1} + PI2_{OI1} + PI1_{OI2} + PI2_{OI2} + PI1_{OI3} + PI2_{OI3}}{6} \quad (4.8)$$

5. Conclusion

Within this paper, we have shown that related works about measurement of sustainability exists and are functional for regions or companies. The difficulty of the measurement of sustainability of biomass resources, which should be a requirement for planning of biomass energy systems, is about the observation of a natural resource being a non-commercial matter. Therefore, we decided to analyze the biomass resource threefold socio-cultural, economical, and ecological according to the definition of the sustainability. The fundament of this calculation is the consideration of the recent situation and the possible changes if the biomass will be used energetically.

With the use of the SBI planning authorities as well as huge investment groups, who wants to invest in sustainable biomass energy systems are able to compare different biomass resources within a region in order to identify the best sustainable location of the biomass energy plants. Additionally, best type and size of the planned energy plants can be identified.

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