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ECONOMICS OF SECONDARY RENEWABLE ENERGY SOURCES*

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Against the background of diminishing traditional energy sources, increasing negative impact on the environment, also due to some energy sectors, as well as the growing threat of extreme increase in the waste on a global scale, SRES have a serious potential to play the role of one of the key methods to achieve a sustainable balance, without any harm to the economic development. In practice, if assumed that the total population of the Earth is 7 billion people, at least 5 million tons of waste is generated on a daily basis (not counting the industrial ones). Of them, circa 2 million tons are non-recyclable, but these could be transformed into energy. Modern technologies offer up to 50% conversion of the source materials into usable free energy—i.e. there is a potential for the generation of approximately 1 million MW/h per day, or at least 300–350 TW/h per annum. This amounts to the whole electricity consumption of 5–10 small developed countries like Bulgaria, Slovenia, etc. The improvement and implementation of the SRES technologies will require significant expenses for scientific research and development. A part of these expenses can be covered by the general provision of incentives for alternative energy sources, another part should be provided by external sources, including funding from the central budgets, grants, as part of public-private partnerships, etc. The offered article examines the economics of the SRES, and all related factors, including their role and place in the energy sector, significance for the protection of the environment and for the achievement of the sustainable development goals (SDGs), adopted within the UN. An attempt is made to develop the existing and to offer new criteria for a more accurate and universal definition of the SRES. The objective of the article is not to claim to be an universal and exhaustive study of all aspects, related to the nature and use of the SRES, but it is rather an attempt to systematize and carry out a comparative analysis of the main problems, related to the SRES, as well as to draw the attention and stir a wider discussion on a topic, which—according to the authors—undeservedly fails to be sufficiently incorporated into the studies and research, related to the alternative energy development. Special attention is drawn to the opportunities provided by waste-to-hydrogen solutions alongside with other waste-to-energy approaches. Authors are also introducing for the first time the notion of “double-green-solution” as a specific feature of the waste-to-energy solutions. The article may be of interest to economists, investors and practitioners.

Keywords: SRES; economics of the SRES; hydrogen energy; alternative energy; green energy; RES; sustainable development goals; inter-fuel competition.

ЭКОНОМИКА ВТОРИЧНО ВОЗОБНОВЛЯЕМЫХ ИСТОЧНИКОВ ЭНЕРГИИ

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На фоне сокращающихся традиционных источников энергии, увеличивающееся негативное влияние на природу, в том числе из-за некоторых секторов энергетики, а также нарастающая угроза экстремального увеличения отходов в глобальном масштабе, вторично возобновляемые источники энергии (ВВИЭ) могут сыграть роль одного из ключевых методов достижения устойчивого баланса, без ущерба экономическому развитию. На практике если допустить, что население Земли составляет 7 млрд человек, то как минимум 5 млн тонн отходов производятся ежедневно (не считая промышленные). Из них около 2 млн не подлежат рециклированию, но из них можно получать энергию. Современные технологии позволяют до 50 % исходного материала конвертировать в бесплатную энергию, то есть в результате можно получать 1 млн МВт/ч ежедневно, или 300–350 ТВ/ч в год. Это равно потреблению электроэнергии 5–10 малых развитых стран, таких как, например, Болгария, Словения и т.д. Дальнейшее улучшение и применение технологий для использования ВВИЭ потребует значительных средств для научных исследований и опытно-конструкторских работ. Часть из них может быть получена за счет льгот для альтернативных источников энергии, другая часть – за счет внешних источников финансирования, в том числе, государственных бюджетов, грантов, как часть государственно-частного партнёрства и т.д. В предлагаемой статье рассматривалась экономика ВВИЭ и связанные с ними факторы, их роль и место в энергетическом секторе, значение для охраны окружающей среды и достижения Целей устойчивого развития (ЦУР), принятых ООН. Предпринята попытка развить существующие и предложить новые критерии для более четкого и универсального определения ВВИЭ, систематизировать и сделать сравнительный анализ основных проблем ВВИЭ, а также привлечь внимание и спровоцировать более широкую дискуссию по данной теме. Отдельное внимание уделено аспектам «отходы-в-энергию», включая возможности, связанные с водородом. Впервые вводиться термин «double-green-solution».

Статья может представлять интерес для широкого круга экономистов, инвесторов и практиков.

Ключевые слова: ВВИЭ; экономика ВВИЭ; водородная энергия; альтернативная энергия; зеленая энергия; ВИЭ; Цели устойчивого развития; МАВИЭ; ООН; Комиссия Брундтланд; межтопливная конкуренция.

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1. Introduction

The end of last century and the beginning of the 21st, along with many other things, are characterized by several interweaving trends in the area of energy and the environment. These include:

• Progressive decline of the reserves of easily-extractable traditional fossil energy sources

• Increasing investment costs for meeting the ever-growing energy consumption, which is also a direct consequence of the preceding trend

• Increased negative impact on climate and the environment in general, reaching threshold-critical values, as a result of the increasing production and ever wider use of most traditional energy sources. A number of limitations and voluntary measures have been adopted on international and national levels, and various policies, focused on sustainable development, have been introduced

• Increased demand, research and use of alternative energy sources and new energy technologies. As a rule, each and every such technology, at first proves extremely expensive for general implementation, but with time and with the development of the technologies, the investment components of some of these technologies reach acceptable, in terms of the reasonable yield, and their effectiveness and efficiency increase.

As for the last mentioned trend, probably the longest history and achievements are those of the research and implementations of technologies, related to the Renewable Energy Sources (RES), which has become particularly evident in the past 15 years. In this period, the RES managed to take a stable position of their own in the energy sector and started having an increasing influence on a number of political, environmental and other processes on the international, regional, national, local or even household level. There are some suggestions that the group of the **Secondary Renewable Energy Sources (SRES)** should incorporate all the sources, formed as a result of human activity in different sectors including industrial and household liquid and solid waste, other waste, the waste of industrial, agricultural, other enterprises.

There was also a significant development of the technologies and approaches, related, among others, to:

• Energy efficiency and the use of by-products of energy production, such as heat, both at the source and in the transmission grid and the end-user

• “Smart-distribution” of electricity and reducing the losses in energy transportation through the distribution grids

• Accumulation/storage of energy, etc.

• Other technologies, offering “green” or alternative (different from RES, or in general—non-renewable, such as nuclear power, combustion cells etc.) solutions.

The offered article examines for the first time in a complex manner the economics of the SRES, and all related factors, including their role and place in the energy sector, significance for the protection of the environment and for the achievement of the sustainable development goals (SDGs), adopted within the UN. An attempt is made to develop the existing and to offer new criteria for a more accurate and universal definition of the SRES. The objective of the article is not to claim to be an universal and exhaustive study of all aspects, related to the nature and use of the SRES, but it is rather an attempt to systematize and carry out a comparative analysis of the main problems, related to the SRES, as well as to draw the attention and stir a wider discussion on a topic, which—according to the authors—undeservedly fails to be sufficiently incorporated into the studies and research, related to the alternative energy development. Special attention is drawn to the opportunities provided by waste-to-hydrogen solutions alongside with other waste-to-energy approaches. Authors are also introducing for the first time the notion of “double-green-solution” as a specific feature of the waste-to-energy solutions.

Nomenclature	
Abbreviations	
CAPEX/OPEX	Capital expenses / operational expenses
EEA	European Energy Agency
EUROSTAT	European Union Office for Statistics
IAEA	International Atomic Energy Agency
IRENA	International Renewable Energy Agency
PVs	Photovoltaics
LCOE	Levelized Costs of Energy
RES	Renewable Energy Sources
SDG	Sustainable Development Goals
SRES	Secondary Renewable Energy Sources
UN	United Nations
UNDESA	United Nations Department for Economic and Social Affairs
UNGA	United Nations General Assembly
WCED	World Commission on Environment and Development

2. Energy Sector and Sustainable Development

The most significant effort to balance the increasing needs of energy and the severely negative and irreversible impact of the prevailing forms of its generation on the environment is beyond any doubt the ratification of the Concept of Sustainable Development, adopted by the UN General Assembly in 1987.

The concept is based on the work of the World Commission on Environment and Development (WCED), better known as the “Brundtland Commission”, after the name of its chairperson, the former Prime Minister of Norway Gro Harlem Brundtland.

The commission was established within the UN in 1983 on the background of the quick decline in the environment, accompanied by impaired economic and social development.

According to the Commission, "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs; manageable and balanced development of the society, non-destroying its natural foundations and ensuring a continuous progress of civilizationUNGA A/42/427" [1], and WCED 1987 [2] Global Goals and numerous indicators were developed to monitor the implementation of the Concept. Thirty indicators, allocated in three domains of the concept—social, economic and environmental, have been developed and are currently employed in the areas, related to the energy sector. These indicators are related to all types of energy [3] worked out in IAEA, UNDESA, EUROSTAT, EEA, IAEA.

The concept, goals and indicators form an integrated system for evaluation and action. Some of the main issues, as discussed below, involve finding a sustainable and perspective balance of mutually exclusive processes and phenomena. It is impossible to even imagine modern world without energy, and progress and the satisfying of the growing needs require more and more energy. The current balance of the methods of its production and their environmental friendliness is regrettably not yet sustainable. Despite the positive trends of restructuring of the current energy, focused on the replacement of the production methods that are the most harmful to the environment (conventionally: from coal and fuel oil to gas) and the increasing share of the "green" energy, in the foreseeable future the traditional sources will continue to prevail. A natural limit is the need of sufficient energy in the developing and underdeveloped countries and regions, which utilize cheaper raw materials and older technologies (attempting to solve their current pressing problems), at the expense of the environment ("postponed" problems).

On this background, further solutions need to be found, on the one hand by optimizing the use of the energy produced (e.g. reducing the consumption of materials, especially of those with poorer environmental characteristics), and on the other—new, global solutions of environmentally-friendly sources and technologies.

The first group are generally solved by a number of energy efficiency measures and solutions. In the second group, worth mentioning are the so called "regenerative" technologies—i.e. the capability of solving already existing or constantly arising environmental issues, by simultaneous generation also of "green" energy, e.g. through proper utilization and processing of organic waste. This, along with the wider implementation of RES and the energy efficiency measures, would significantly contribute to the achievement of a number of Sustainable Development Goals.

Another important aspect, which should be taken into consideration, is the availability of energy resources and their rational use in their distribution. For example, the energy, no matter how cheap or environmentally friendly it may be, depends on the means of its supply and their efficiency. The availability of cheap nuclear energy requires a complex and well developed system of high-voltage transmission grids and is best used to supply major consumers. At the same time, in case of remote or temporary energy use locations – islands, temporary settlements, small users, situated remotely from the main power lines, etc., the use of RES and SRES can prove to be the demanded environmental and beneficial business solution, as opposed to the construction of new electricity grids, nets of small-scare transformer stations, etc.

The use of SRES will further solve to a significant degree the issue of waste utilization, ensuring a multiplication effect of local solutions.

This also applies to liquid fuels. There are a number of examples of locally produced biofuels (based on agricultural waste as the source raw material), mixed with traditional fuels, resulting in serious reduction of the costs, along with the decreased negative impact on the environment.

Placing sustainability as the main vector in the short-term perspective, however, cannot be absolutized, for two main reasons.

The first is related to the enormous costs, impossible to cover in the short-term, required for the global substitution of the traditional energy sources for "green" sources. The second one is that accessible energy is one of the main drivers of development. That is why, as it has already been indicated above, extremely polluting plants in the developing countries cannot be closed at present, without finding energy equivalent green alternatives first.

3. Definitions

So far there is no comprehensive, overall and generally accepted system of classification of the primary and secondary currently used and of the potential new energy sources. There are even certain contradictions between the classifications of primary and secondary sources, within the UN, OECD, IEA and the EU/Eurostat [4].

The definitions in the area of alternative energy, including SRES and RES have not merely scientific, but also a wide practical significance. They form the basis of the general and sectorial statistics, which has important economic and financial implications, and they are key to the formation of tariffs, precise definition of subsidies, etc.

The definition of the SRES is to be developed chiefly, but not entirely, with respect to the RES.

The most complete and reliable, in terms of general acceptance, definition of RES is contained in the Statute of the International Renewable Energy Agency (IRENA), established in 2009 as an international intergovernmental specialized organization in the area of the RES. Art. 3 (Definition) has the following wording: "the term 'renewable energy' means all forms of energy produced from renewable sources in a sustainable manner, which include, inter alia: bioenergy; geothermal energy; hydropower; ocean energy, including inter alia tidal, wave and ocean thermal energy; solar energy; and wind energy [5].

Unofficially this list is often supplemented with the hydrogen technologies.

The RES are usually considered to be divided, based on the type of origin and the primary energy resource etc., as most often, the division line is based on IRENA's definition. The sources, listed therein, are considered *traditional* RES, and all other sources – *non-traditional* RES.

There are also other approaches. For example, V. Bushuevet. al., developing IRENA's definition, go even further, dividing the RES into *organic* (land and water-source biomass) and *non-organic*, including all the other renewable resources [6].

There are further approaches, dividing the RES into traditional and non-traditional, based on whether or not, these have been researched and proven or have an "exotic" nature, such as the use of the energy of lightning bolts, road traffic of vehicles [7].

Of particular interest is the definition, according to which the term "RES" refers to "sources, constantly existing or regularly occurring, under the effect of the solar, geothermal energy, the energy of the orbital movement of the planets in the Solar system, independent from human activity, as well as the energy sources accumulated as a result of human activity and natural reactions" [8].

Such an approach provides a good framework for a wider perception of the definition of RES and their more logical division into types and classes. It offers also a better basis for the understanding of the term *Secondary RES*.

The SRES category often includes a number of sources, which do not fall under the IRENA's definition, while at the same time it excludes sources, based on other natural phenomena (lightning bolts, non-geothermal heat from volcanic activity etc.), *intermittent* such as methane from coal chambers or turf, which is considered to be rather a *slowly renewable source of energy*.

There are some suggestions that the group of the SRES should also incorporate all the sources, formed "as a result of human activity (heat from industrial and household liquid waste, ventilation emissions, solid household and other waste, the waste of industrial, agricultural or other enterprises" [9].

This approach clearly has its benefits, but it includes in one and the same group both the results of the use of any energy sources (incl. heat from industrial and household waste, ventilation emissions etc.), and some specific sources (solid and other household and other waste), waste from industrial and other enterprises.

Another interesting approach is that, used by the Bulgarian Regulator – the Energy and Water Regulatory Commission (EWRC), which—for the purpose of providing incentives for the implementation of RES through feed-in purchase tariffs of the generated energy, created and periodically updates a table of rates, covering both traditional RES, and some sources, based on the utilization of waste, and takes into consideration the use of by-products, such as heat (co-generation). This list, unfortunately, is of entirely applied nature, but should nevertheless be taken into consideration, as one of the possible models for developing a proper definition.

3.1. Bases for authors' own definition

We believe that a universal definition of the SRES can be developed, based on a package of key criteria, including *the secondary nature* of the energy source in combination with its *renewable* nature and the absolute or relative *inexhaustibility*. This would automatically incorporate or cover the most widely used definitions of SRES, i.e.—defined based on whether or not these are the result of the use of solid household and other waste, waste from industrial, agricultural and other enterprises or activities. As for the energy from heat or ventilation emissions, there probably should be a distinction between the nature of the primary source, in terms of its being renewable or not, etc. Regarding the hydrogen, leading should be the source of origin and the need to utilization of technology to convert it.

4. Comparative analysis of the RES and SRES

Along with the clear benefits of the RES, their use is not always neutral, especially in terms of their impact on the environment. In some cases, there may even be harm, the remedying of which requires significant investments.

For example, solar energy is used either directly for heating of special panels, in order to accumulate heat or transform it into electricity through photovoltaic systems (PVs). Sometimes both technologies are combined, the heating being an extra product of the process.

The efficiency of photovoltaics is constantly increasing, due to the implementation of new crystalline structures and technologies. There have already been successful examples of the utilization of heliothermal technologies, where the solar energy is focused and used to drive steam generators.

At the same time the technologies for utilization of the solar energy have certain shortcomings.

First of all, this is the limitation in the time of use during the day and the location. Even the most state-of-the-art panels cannot operate during night-time, and the energy accumulation equipment has not reached the necessary technological level, making it possible to avoid the issues, related to the dispatching and maintenance of the energy balance and the loading of the electricity transmission grid.

Apart from that, vast spaces are required to host the solar parks (a panel generating 1 KW/h has an area of approximately 10 m^2.), as the land underneath will be fully shaded, causing all the relevant consequences for the microorganisms in the soil and the flora, and these effects have not been fully studied yet.

There are numerous extensive comparisons of the sources of energy with their pros and cons, and therefore we will not discuss them in detail [10].

On the other hand, there is the example of the SRES and in particular—the waste utilization. Waste, in its own right, also has an inexhaustible potential—for example, statistically, the average person generates approximately 0,5–1,5 kg household waste daily. This means that as a category, this can be considered a renewable source. Furthermore, the increasing accumulation of various wastes poses a direct threat to the environment and human health. For example, merely the plastic waste pollution of the oceans has already started having a perceptible negative impact on its flora and fauna, apart from the other forms of pollution.

The proper waste utilization may not only significantly reduce, but in some cases, even completely eliminate the harm, while obtaining significant amounts of useful energy and products at the same time. And the investments per KW/h of output are already comparable to similar indicators of the RES.

In this way, the wider implementation of the technologies for the use of SRES would not only contribute to generating green energy, but would also play a significant role in the prevention of the pollution of the environment and climate change.

The waste-to-energy sector has already occupied a separate niche in the respective sectors of economy and municipal government. It constantly competes with the recycling sector. In a number of cases recycling is preferred to the destruction of waste, which—as a rule—is still carried out through incineration, where the energy balance is often negative. At the same time, even ordinary solid household waste is not 100% recyclable.

Another important difference between the RES and SRES, is that the utilization of certain technologies for organic waste processing can produce not only electricity, heat and mechanical energy, but also a number of liquid and gaseous energy resources. These can be stored for subsequent use, directly or as a raw material/precursors in the chemical industry.

5. Technologies for turning waste into energy

Currently, various thermal facilities, burning/incinerating waste and basically operating as thermal power plants, are the most common. They are relatively cheaper, but fail to fully solve the issue of pollution (due to the complexity and cost of the additionally required purification systems), and also they produce a number of new waste materials, requiring disposal. Most of them cannot be used for the treatment of hazardous organic waste, dangerous chemicals, PVC, etc.

Table 1

Emissions comparison g/KWh

Таблица 1

Сравнение выбросов различных вредных веществ г/кВт · ч

	incineration	*coal**
CO_2	1335.33	1020.13
SO_2	0.36	5.9
NO_X	2.45	2.72

*The emissions during production and transportation should also be added here

Source: Wilson, Williams, Liss, & Wilson (2013) [11]

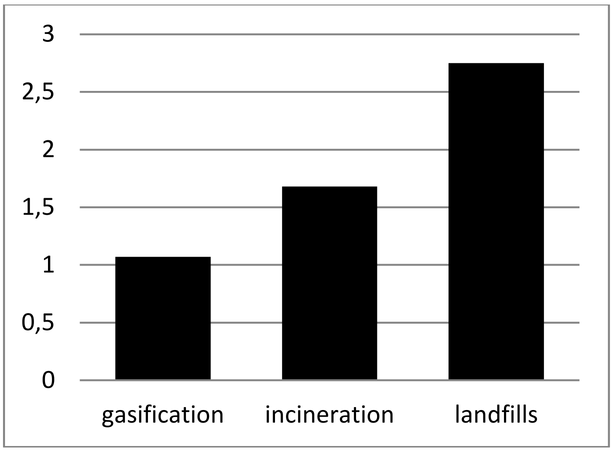
The application of plasma technologies for incineration is an endothermic process and in fact the processing costs exceed the energy obtained. This issue can be partially solved by the so-called quasi-plasma technology, e.g. by adding additional oxygen supply in the reactors, which, however, impairs somewhat the process safety, hence rarely preferred.

The various gasification technologies provide different advantages. These technologies include biogas, high-temperature gasification, pyrolysis and pyrolysis gasification, etc. Each has its own pros and cons. For example, the most promising is the pyrolysis gasification, but the successfully developed and used facilities are currently limited to the processing of merely several tons per hour per unit. They, however, are relative small, could be designed as mobile and most fully and environmentally-friendly process all sorts of organic waste, including hazardous one into energy and energy resources. They are perfect for local application, where the power requirements are within several MW/h (as the main or auxiliary source to other sources, incl. RES—solar, wind during their down-time—night-time, windless weather), and waste utilization is expensive, due to remoteness etc. Another advantage is that some of the pyrolysis gasification products can be stored for subsequent use. Same applies to the production of hydrogen from bio-waste like food or agricultural waste though steam gasification, or for example through de-composing waste plastic.

Not all technologies are equally efficient, in terms of their emission indicators. As evidenced by the table below, waste gasification ensures the lowest emissions. Though not included in this table hydrogen production is without doubt on par with the general gasification.

Table 2
Comparison of different technologies by unit of CO_2 per kW/h

Таблица 2
Сравнение различных технологий по выбросам CO_2 на кВт/ ч



Source: Wilson, Williams, Liss, & Wilson (2013) [11]

6. RES and SRES in the conditions of inter-fuel competition and the competition of the energy sources in general

The market availability of a wide variety of fuels and energy sources, results in a natural competition among them, where the costs for production, processing transportation to the end user and utilization, are decisive. At the same time, in general, the production and utilization cost is currently inversely proportional to the degree of their negative impact on the ecosystem. In the group of the cheaper, if not the cheapest, primary energy sources the coal is among the most serious pollutant of the environment, through harmful emissions and ash deposits (exceeding 20% of the volume of the original product). Meanwhile coal is not the most efficient fuel, from the perspective of energy output and efficiency of the systems, using it.

Often the evaluation of the cost of energy, generated by a certain source is (wrongly!) based on the so-called Levelized cost of energy (LCOE) (see for example [12]. Although this is a very important and valuable indicator on its own, it fails to show the complete picture. It refers mainly to production and the cost of electricity, produced from various sources and fails to take into consideration a number of other factors. One of these factors is the use of the energy sources for other purposes, such as coal in metallurgy, for heating, etc. The multiplying effect of the power output is also neglected—a thermal power plant, operating on coal or heating oil, with an output of 100 MW e.g. may be compared to a RES facility with the same output, only after a number of adjustments and assumptions are applied. Comparisons are often made, assuming costs for the construction of new facilities, failing to take into consideration the fact that globally there are a large number of facilities, built through the years, which are still being actively used, although they are based on obsolete technologies. Another important point in interfuel competition is that a number of fuels are optimal for certain operations or use, based on their costs, convenience or traditions. Transport is one of these sectors of operation. Although the focus is increasingly placed on gas motors, hydrogen and electric engines, their share is still insignificant, growing at rather slow rates. Furthermore, in the case of the electric cars, it should also be considered that not always the electricity, used for charging their batteries, is generated from a “green” primary source. Also, the currently existing electric vehicles can achieve a mileage of not more than 400–500 km with a single charge, and after that they need recharging, which is a significant limitation. With the development of the storage and fast charging technologies, this indicator will improve, which may make electric vehicles more universal means of transport over time.

Another practical example is the use of biofuels in the aviation sector. The parameters of the existing biofuels do not allow the complete and thorough replacement of the aviation fuel. Nevertheless, Boing, KLM, etc. are actively working on programs for partial substitution, as well as for the improvement of the indicators of the suitable biofuels.

In general, it should be noted that there is a global trend of decreasing investment costs in RES, as for example, the LCEO indicator of some of them–especially wind energy—are close or even lower in some scenarios than that of coal or other fossil fuels, even in some non-subsidized cases.

To a significant degree, this is due to enormous investments, already made in the last decades and that are still being invested in the research and development in the area of the traditional RES. At the same time, some RES, such as mini-solar plants are still several times more expensive to build and operate, than wind-operated facilities. Such investments would not be feasible, without the introduction of a number of incentives and regulatory measures, related to the development of “green” energy, which will be further discussed below. Under the effect of such incentives and measures, the structure of the global energy sector is gradually changing, as the share of the environmentally friendly energy sources and technologies increases.

The current situation with the SRES may be compared to the more expensive RES, as the investment costs of co-generation systems start from EUR 3,000–4,000 per 1 MW/h of power output. As with the other RES, with the exception of the hydro-power sources, the existing SRES technologies (with certain exceptions for some incinerator and open downdraft systems, which however face other problems) currently offer an output that is closer to just several MW/h, rather than dozens or hundreds of MW.

Based on the above it can be concluded that the alternative energy sources (excluding nuclear, subject to certain assumptions) require significant initial investments, which on the free market, could never be attracted and repaid within a reasonable period of time, from the perspective of a successful business model. The eventual projects, relying on alternative technologies, which may compete in terms of investment costs, cannot yet provide the necessary volume scope for a significant change in the structure of the energy sector. This is the basis for the claim that the development of the alternative energy sector would be impossible without certain governmental adjustments to the purely market mechanisms, based solely on the demand-supply balance.

7. SRES as an economic category

As with the other energy sources, SRES and their use are subject to the basic economic laws and in certain cases may be reviewed as different economic categories.

SRES may be considered chiefly as a *product*. The specificity here, however, is that they often provide no evident advantage or are not *a generally accepted good*, and sometimes these are even the opposite – especially in terms of hazardous, non-recyclable or not easily usable waste. Nevertheless, by the application of suitable technologies, these can be transformed into useful products, becoming a *complete good*, i.e. satisfying the needs of energy and other useful products, and simultaneously meeting the interests of the respective person, related to the preservation of the ecosystem.

From this perspective, the use of SRES is both a *technological process*, and *service*, which together form the *economic process*. Furthermore, the development and implementation of the technologies, using SRES for obtaining useful products, is closely related to the economic category *innovations*.

Thus, the SRES and their use may be considered as either a specific economic category, or a combination of the above categories.

7.1. RES and SRES, and the modern economic theories

The current need of providing some sort of incentives for the implementation of RES, by definition precludes the application of economic theories based on purely market driven relations. Therefore the researchers focus mainly on the theories, allowing outside intervention. These include the neo-classical school, and particularly its liberal section, which—for the purposes of a better distribution of the existing resources, in a number of cases more inclined to accept outside limitations, imposed on the liberal market, compared to the conservative section.

The Neo-Keynesian school offers even more opportunities for the implementation of market-adjusting factors for the purpose of economic development. For example, it allows the consideration of some specific incentives for the implementation of RES, such as feed-in tariffs, state guarantees; grants and governmental investments in research and development activities, related to RES; tax and tariff reliefs, etc.

A number of researchers justifiably focus also on the opportunities, reviewed in the modern take on the innovation approach to the theory of economic development, originating from J Schumpeter; Pigou's theory of external effects, etc. [13].

In the case of the SRES, however, there are not always firm and specific external factors or effects (such as limitations, feed-in tariffs, etc.) that play a key role and in certain instances, SRES' economics can fall within the classical theories, based on market self-regulation of demand and supply models (including the use of business models with a positive balance).

For example, the cost of destruction of one kilogram of biologically hazardous waste is as a rule around 1 (one) Euro. A plant, processing up to 100 kg per hour of such waste and operating 7,500 hours per annum would achieve an annual income of approximately EUR 750,000. Using average CAPEX and OPEX for similar technologies in this sector in Bulgaria, the investments may be returned within not more than 2–3 years (while this period in the case of RES exceeds 6–7 years with feed-in electricity preferential tariffs), without taking into consideration the possible add-on income from the syngas, electricity and heat co-generation (CAPEX/OPEX would also increase in these case at the expense of the costs for peripheral and generating devices).

The philosophy of using SRES unlike that for RES, is anchored around the specific need of elimination of existing results of human activity (harmful and hazardous waste), followed by the issues, related to the production of green energy as added value. This ensures a wider choice of approaches in the area of economic theories, applicable to the SRES.

Studying of the applicability of the main modern economic theories to the RES and SRES shows that their scope is limited or insufficient to understand and regulate the respective processes. The close interweaving and interrelations of economics, energy and ecology within the Sustainable Development concept, require new, more extensive approaches.

One of them is related to the occurrence in the late 1980s of the *Environmental economics*.

In practice, this is an interdisciplinary area of science, dealing with research of the interrelations of the economic and ecosystems and aimed at finding solutions for the transformation of the destructive contradictions between ecology and economics in a harmonically developing model.

Environmental economics is based on the modern concepts of the neoclassical and resource economic theories, combining them with environmental impact assessment (EIA) and ecology in general.

Unlike the classical economic theories, consumption is reviewed here not merely as the subject of financial and budget limitations, but in combination with natural limitations (e.g. maximum capacity of the ecosystem) and the limitations, resulting from the laws of physics.

People, as consumers, are considered as one of the main categories, and not as the central and dominant one. A great significance is attached to the research, related to the environmental manifestations of entropy and methods of their reduction.

The temporary research frameworks are also much more extensive than those of the classical economic theories.

8. Types and methods of providing incentives for the implementation of SRES

In general, it can be stated that the main types of incentives coincide with those, applicable to the RES.

Three major groups of incentives can be differentiated—administrative, price-related and capacity-related.

Each specific incentive is based on different types of direct support or limiting approaches. Some of the main of them are:

• Budget support by the government or an international organization

• Relieving the tax burden, low customs tariffs, applicable to the equipment etc.

• Establishing feed-in tariffs (at the expense of the consumer, through a higher price of the mix; imposing specific taxes to the general population; transferring the burden to the system and grid operators, including providing them with incentives for economies of traditional fuels, etc.)

• Limitations of emissions, cap-and-trade, other trade of emissions, green certificates, etc.

• Introduction of quotas for a mandatory share of "green" energy

• Voluntary measures

• Increased demand of "green" energy through extensive promotion/propaganda.

Apart from these, the use of SRES may rely on additional incentives, based on the requirements and provisions for waste utilization (failing which results in financial and other sanctions), the so-established utilization market and the emergence of the institute of the so-called gate-tax, paid by the polluter to the utilizer.

8.1. Economic model of the use of SRES

On a global level (together with the other alternative sources) the model includes the balance of needs of energy, the need of preservation of nature and socially acceptable costs, required for that purpose.

As indicated above, the SRES however have unique nature and double application: with direct environmental protection (solving the issue of waste) function and at the same time as a source of "green" energy. In this respect they may be defined as "double-green".

On a national and sometimes regional level (e.g. within the EU), the model is based on the system of providing incentives for the implementation of RES and SRES, based on the resulting measures of the respective policies and specific financial and economic factors. The key role here is plaid by the incentives, listed above, which establish a favourable environment for the development of the SRES sector. As already noted, SRES can often benefit at the same time from income from the utilization on one hand, and from feeding "green" energy to the grid and/or selling the other useful products, obtained from using the SRES, on the other [14].

On more specific levels: regional, municipal, city, district, etc., the model is again based on the specified incentives and principles in general, with respective specificities and mix in each individual case.

At the production unit level, it is more similar to a classical business model, as the balance of CAPEX/OPEX and income, i.e. it includes costs, revenues, taxes, preferences and reliefs etc.

9. Conclusion

On the background of diminishing traditional energy sources, increasing negative impact on the environment, also due to some energy sectors, as well as the increasing threat of extreme increase in the waste on a global scale, SRES have a serious potential to play the role of one of the key methods to achieve a sustainable balance, without any harm to the economic development. In practice, if we assume that the total population of the Earth is 7 billion people, at least 5 million tons of waste is generated on a daily basis. Of them, circa 2 million tons are non-recyclable, but these could be transformed into energy (not counting industrial waste which is multiple times more). Modern technologies offer up to 50% conversion of the source materials into usable free energy—i.e. there is a potential for the generation of approximately 1 million MW/h per day, or at least 300–350 TW/h per annum. As a comparison—in Bulgaria, in 2016 and 2017, the electricity consumption amounted to approximately 38,000 billion KW/h per annum. That means that the waste-to-energy conversion world-wide could satisfy the electricity needs of 5–10 countries Bulgaria size-wise. However, enormous investments will be necessary, at an average cost of EUR 1,500–4,000 per 1 KW of installed capacity.

The improvement of the SRES technologies will require significant expenses for scientific research and development. A part of these expenses can be covered by the general provision of incentives for alternative energy sources, another part should be provided by external sources, including funding from the central budgets, grants, as part of public-private partnerships etc.

A specific and serious contribution would be that of an extensive and thorough scientific research of the problems, related to the development of SRES technologies, their implementation in practice, the development of new financial and economic incentives and models, etc. The results of the scientific research will significantly contribute also to the promotion of SRES as a ***"double-green" solution***.

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