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# Value Added and Capital Efficiency in Green and Brown Bulgarian Energy Companies

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**Abstract:** The paper explores the problem of the creation of value added created by companies in the energy sector in Bulgaria. Nuclear, coal, water, solar, wind, oil and gas energy companies are studied. The study covers 2019 and 2020. for some companies, an estimate has been made for 2018. From the point of view of the economic conjuncture, it covers the pre-covid crisis and the covid crisis manifestation. These years allow comparisons to be made about the performance of different enterprises – from the "green" and "brown" energy kinds in terms of value creation. The basic research method is the original VAIC[tm]. The primary data is the data from the financial statements of the enterprises. Through the VAIC[tm] methodology, the value added created by the capitals of each of the enterprises is measured. The VAIC coefficient is accepted as the indicator reflecting the "total efficiency" of the company or its "intellectual abilities". The effectiveness of the structural (physical) and intellectual capital in different types of energy enterprises has been established and a comparative analysis has been made. Based on the results obtained from VAIC[tm], the analysis of enterprise performance is extended using correlation analysis and cluster analysis. The relationship between the value added of intellectual capital and the carbon emissions of "brown" coal plants was calculated; the water footprint of hydropower plants was assessed. The cluster analysis shows results for the possibility of a smooth transition to sustainable green energy by combining brown and green energy. The measurement the water footprint raises the question of the proper and fair distribution of water resources between „green" hydropower enterprises, other industrial enterprises, agriculture and households. With the cessation of activities of non-environmental energy enterprises, the efficiency of Brown energy's intellectual capital will cease to be used. In this perspective, partial conclusions have been drawn (only for the surveyed enterprises) about the cost of losing the intellectual capital of brown energy.

**Keywords:** VAIC[tm], value added, intellectual capital, effectiveness, brown energy, green energy, effectiveness



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## 1 Introduction

In this study we aim to analyze 10 companies, producers and suppliers of energy that operate in Bulgaria through the coefficient VAIC tm and other applicable methods and techniques, to establish their effectiveness and resilience during the crisis.

VAIC tm is suitable for studying the contribution of intellectual capital to the value added of enterprises in that it can be carried out in a conservative accounting environment, based on the financial accounting of enterprises (Kasarova, 2013, p. 80). This makes it easy to use by the management of companies that have an interest in assessing the contribution of intellectual capital to the value added and efficiency of the capital they use.

The objectives of the study are achieved in the following algorithm:

Derive the indices of efficiency of human, structural and intellectual capital, and VAIC tm- as an indicator of the overall efficiency of capital in different types of energy companies.

Study the economic and environmental sustainability of enterprises, considering the efficiency of intellectual capital, using the VAICtm method in relation to some environmental footprints (carbon and water)

Make a comparative analysis of the results obtained and conclusions about the sustainability of enterprises.

Study of the components of Value Added Intellectual Coefficient (VAICtm) of different types of energy companies aims to show:

- Their ranking by capital efficiency ratio;
- What value of intellectual capital will be lost in the transformation from non-renewable to renewable energy sources;
- What overall efficiency and effectiveness of intellectual capital is lost in the elimination of coffee and nuclear energy.

To investigate the question: “Do renewable energy companies have a competitive advantage over non-renewable energy companies in the efficiency of using intellectual capital?”

## 2 Methodology Population and Limitations

The research methodology is the standard composition of VAICtm, explained in the text, primary data from the financial statements of companies, statistical research, and an environmental-economic study, which is the author's development. The multiple case study method has been used.

The original VAICtm method is used. This method can be assessed as a basis for the participation of intellectual capital in creating the value added in enterprises. Researchers recommend combining it, when possible, with other methods, such as Tobin's Q, Balanced scorecard or Economic Value Added (EVA) (Kasarova, 2013, p. 80).

In this study, VAICtm is combined with Spearman's correlation analysis method, cluster analysis (k Nearest Neighbours / single connection method), and carbon and blue water footprint calculation techniques.

The sample is small - it includes 10 companies in the energy sector, half in the category of "brown energy" and the other half in the category of "green energy", out of a total of 1721 companies in the energy sector (National Statistical Institute, 2022), and does not claim representativeness. The limited number of enterprises included in the survey is due to the lack of data from the accounting reports of a large part of Bulgarian energy enterprises, not entered in time in the Commercial Register for public use. Other companies are classified as objects of national security and their reports are not made public. Only 4 of the companies are listed on the Bulgarian Stock Exchange. Another difficulty that the study encountered is the lack of a uniform algorithm in these companies' financial statements, as well as their incompleteness regarding the requirements of IAS 1 Presentation of Financial Statements.

Due to the small sample of entities under study, the study does not claim to be exhaustive and there is no complete validity of the results shown. It aims to raise scientific questions about the contribution of intellectual capital to value creation in brown and green energy companies, the possibility of VAIC$^{tm}$ being combined with other methods in assessing the sustainability of enterprises, and the cost of the transformation and the possible balance of losses / benefits from it.

## 3 Literature Review

The application of VAIC$^{tm}$ in the energy sector has not been the subject of much research, unlike the voluminous literature that exists on the method itself.

To some extent, this study also tests the original VAIC$^{tm}$ method in a group of energy companies in Bulgaria, although this is not its main goal. The main method used in the VAIC$^{tm}$ study is popular and widely studied.

The method was developed by the Croatian scientist Ante Pulic (Pulic, 1998; 2000b). After this article, Pulic completes his understanding of the method (Pulic, 2004a; 2004b).

This method is one of the many methods for measuring intellectual capital and its contribution to the performance of enterprises. It is classified as one of the Retrospective Income Approach Methods (Anderessen, 2003).

VAIC$^{tm}$ has a significant body of scientific literature and research that use it because it is attractive as it highlights the contribution of invisible intellectual capital to the efficiency of enterprises.

Thematic bibliography on VAIC$^{tm}$ is summarized by Arabella Volkov (Volkov, 2012). It is structured in several subcategories, which for the period since the publication of the model are 18 in the development of theory and model, categorized into 6 problem categories in which VAIC$^{tm}$ is used: Financial Performance, Market value, Capital gains, Corporate board structure, Longitudinal studies, Lifecycle studies (Volkov, 2012, p. 17).

Several authors such as Bornemann (1999) and Iazzolino and Laise (2011) explore the issue of calculating value added through the method.

Other scientists are beginning to study the algorithm and popularize the method and its application such as Fontana et al., 2018 and Paknezhad and Ahmadkhani (2012), as well as to test it in different fields such as Singla (2020), in enterprises of different sizes, including small and medium-sized ones such as Polcyn (2022).

Iazzolino et al. (2014) examines the metrics used in VAIC$^{tm}$ compared to EVA (Aitouche et al., 2015) also work in this direction by comparing data from IC-dVal, VAIC$^{tm}$ and NICI.

Nazari and Herremans (2007), created an extended model of VAIC that included client capital. Bontis et al. 2007 investigated in detail in support of its application the components of the method.

Silvestri and Veltri's (2014) paper on improving the model by overcoming the additive property "taking into consideration the synergies among different IC components." in the Italian financial sector, creating a model of the method by which the components of intellectual capital interact.

Andriessen (2004) explores and shows the limitations of the method, especially in the context of the direct calculation of human capital from the cost of wages and insurance.

VAIC$^{tm}$ is widely used for research in various sectors of the economy, but above all the financial sector such as Demuner Flores et al. (2017), Ibragimov et al. (2012), Ulum et al. (2014).

The method has been tested and successfully applied in the field of real estates in studies such as Singla (2020). In agriculture VAIC$^{tm}$ has been used by Xu et al. (2020), as well as in industrial enterprises such as in the studies of Ulum et al. (2017), Bayraktaroglu et al. (2019); and Singla (2020).

There are also applications of VAIC$^{tm}$ and its modifications in the energy sector. In the field of energy, the study of intellectual capital using the VAIC method also finds a place in the research of Xu and Liu, (2019).

Martin et al. (2018) study the return on investment in the mining industry and study the return on investment in intellectual capital in the mining industry, using methods such as Value Added Capital Employed (VACA), Value Added Human Capital (VAHU) and Structural Capital Value Added (STVA), which are close to VAIC.

In a broader comparative plan, Xu, Wu, and Zhang (2021) use the MVAIC-modified value-added intellectual coefficient model.

There are also critical analyses of the method, such as Ståhle et al. (2011).

Intellectual capital is an intangible asset. It may include, as defined by the European Commission, licenses, quotas and franchises, copyright, patents, trademarks, designs, brands, know-how, trade secret; capabilities like Leadership, workforce calibre, organizational (including networks), reputational, innovation, R&D, corporate renewal" (European Commission, 2003).

The issue of intellectual capital, such as intangible capital or assets, is complex and treated differently (Lev and Zambon, 2003). VAIC$^{tm}$ is also a method that has been criticized and considered imperfect, as in the study of Iazzolino G. and D. Laise (2013).

VAIC$^{tm}$ has its imperfections to assess the contribution of intellectual capital to value added as well as any other available method such as EVA, which is based on historical data (Gu and Lev, 2002), Tobin Q, which can only be applied to listed companies, Intellectual capital-index (Roos et al.,1997), and others.

## 4 VAIC$^{tm}$ and its components

VAIC$^{tm}$ is an indicator that reflects the "overall performance" of the company or its "intellectual capabilities".

The large numbers of studies in various fields show that the method is widely applicable.

In this study, we want to use VAIC$^{tm}$ in determining the value added, including intellectual capital, of various energy companies. We intend to establish the link between intellectual capital and other sources of value creation in energy enterprises, as well as in relation to their environmental performance.

The term "Value added" represents the value created by a firm for 1 year and then distributed to any group that has a stake in the firm, such as the shareholders, employees, government, lenders, and society (Donaldson and Preston, 1995).

According to A. Pulic and Kolakovic, VAIC$^{tm}$ is an indicator that reflects the company's "total efficiency" or its "intellectual ability". The higher indicator the better management has utilized existing potential (Pulic and Kolakovic, 2005).

VAIC$^{tm}$ is a method that shows the effectiveness of creating value added from different types of capital, as well as for monitoring and measuring the effectiveness of intellectual capital (Pulic and Kolakovic, 2005).

This analysis of the contribution of intellectual capital to the creation of value added of the enterprise assumes that the higher the VAIC$^{tm}$ ratio, the better the company uses its intellectual capital.

- The higher ratio shows that the company makes better use of its value added due to the work of intellectual capital.
- The higher the level of intellectual capital of an innovatively active company, the higher the performance of its activities outside the dependence on environmental performance and sustainability (Pulic, 2000a, 2000b).

The ability of employees to transform their knowledge and skills into value is crucial for the company. The higher value of coefficient shows that better the management has used the existing potential (Pulic and Kolakovic. 2003, p. 9).

A company can have the best qualification structure, i.e., Intellectual potential, but if it creates little value in terms of its resources, its capabilities have not been used effectively (Pulic and Kolakovic, 2003, p. 8).

The intellectual capital of companies can be studied by different methods. Here its quantity and dynamics are compared with the performance of companies in the field of sustainability of their performance.

VAIC$^{tm}$ is a method that demonstrates the "efficiency of value creation" to monitor and measure the effectiveness of intellectual capital (Pulic and Kolakovic, 2003, p. 2).

Practically VAIC calculates and shows economic incomes. The analysis of the contribution of intellectual capital to the creation of value added by the enterprise assumes that the higher the ratio, the better the company uses its intellectual capital.

There are three types of intellectual capital: human capital, structural capital, and capital employed. The value of capital employed is equal to the book value of the net assets of the firm (Anderssen, 2003, p. 116). The key resources of the company that create value added VAIC are Invested (capital employed) which is the sum of equity and long-term debt and Intellectual capital (IC), (Pulic, 2004a, p. 352).

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VAIC shows us how much intellectual capital and how much other capital used creates value for the company. This ratio also shows us the extent to which intellectual capital affects the company's efficiency and its "intellectual abilities" (Pulic and Kolakovic, 2003, p. 9).

## 4.1 Capital structure in the VAIC $^{tm}$ model

**Value added** is calculated as the sum of EBIT + Expenses for depreciations + Human capital

**Structural capital** - Value added minus Human capital

The method is calculated on the balance sheet and income statement of the enterprise. The method treats labor expense as an asset, not as a cost (Anderessen, 2003, p.115). It includes the following components:

Value added – (it is in fact is the economic income) - VA:

- VA = EBIT + DA + HC (where DA - Depreciation and Amortization)

HC - Human Capital

- HCE–coefficient the efficiency of human capital

Capital employed efficiency coefficient- CEE

Intellectual capital efficiency coefficient - ICE, when

ICE = HCE + SCE, where:

- SCE - potential structural capital

HCE = VA / HC, where or HCE = (EBIT + DA + HC) / HC

Pulic's model assumes that value added is created by intellectual capital through its application to physical capital, called "structural capital".

Intellectual capital consists of human capital and structural capital. It is calculated on the balance sheet of the enterprise and represents the sum of the capital employed CEE efficiency ratios and the ICE intellectual capital efficiency ratios. The efficiency ratio of intellectual capital, in turn, is the sum of the ratios of human capital potential plus capital potential.

$$VAIC = ICE + CEE \qquad (1)$$

or

$$VAIC = HCE + CSE + CE \qquad (2)$$

- The efficiency of the invested capital (SEE) shows how much value added is created by a unit of invested capital in the enterprise.
- Human capital efficiency (HCE) shows how much value added each monetary unit invested in staff development creates.
- Structural Capital Efficiency (SCE) shows each value added currency by how many structural capital currencies have been created.
- The potential of intellectual capital is the sum of the potential of human capital and the potential of structural capital.
- The efficiency of the enterprise is the sum of the Potential of Invested (capital employed) CE (CEE) and the potential of intellectual capital (Bykova and Molodchik, 2011).

Or, as Pulic himself defines it in the accounting aspect:

*"Value Creation Efficiency Account (VCEA).*

*Value Added / Human Capital (HC) = Human Capital Efficiency (HCE).*

*Value Added / Capital Employed (CE) = Capital Employed Efficiency.*

*(CEE) Structural Capital (SC) / Value added = Structural Capital.*

*Efficiency (SCE) HCE + CEE + SCE = TOTAL EFFICIENCY VAIC ™"* (Pulic, 2004a, p. 356).

The labor cost in the model is not treated as an element of the profit and loss account but is recognized as an asset on the balance sheet of the enterprise (Pulic, 2004a, pp. 349-359). In fact, VAIC$^{tm}$ calculates and shows economic incomes.

Pulic considers that human and structural capital are inversely related - the more value added human capital creates, the less structural capital it creates (In the calculation of value added are not included the costs of salaries, insurance, and other remuneration). The greater the efficiency of structural capital - its contribution to the creation of value added of the enterprise, the lower the efficiency - the contribution of human capital in the creation of value added of the enterprise (Pulic and Kolakovic, 2003, p. 9).

## 5 Empirical component

### 5.1 Study of VAIC$^{tm}$, Effectiveness of Intellectual Capital (ICE) and Effectiveness of Structural Capital (SCE) of 10 Bulgarian energy companies

In this study we use primary data from the accounts of the following energy companies:

1. One nuclear power plant - "Kozloduy" NPP, which is state-owned, with two nuclear reactors type WWER-1000 - Pressurized water reactor with a total capacity of 2000 MW (Nuclear Plant "Kozloduy", https://www.kznpp.org/bg/za-nas/za-aec- "Kozloduy".
2. Two thermal power plants producing electricity from coal:
- TPP Contour Global Maritsa Iztok 3 AD with a total capacity of 908 MW which is a private power plant in Bulgaria with American owners and
- TPP "Maritsa Iztok 2" with a total capacity of 1586 MW, which is a state coal-fired power plant. These plants use the same type of coal – lignite.

The coal used in both plants is low-quality, brown lignite coal, locally produced from the Mariska coal basin. Coal is low in calories, with an average calorific value of 1550 Kcal / kg, low carbonization, high ash content ranging from 16% to 45% and moisture content from 50% to 60%, and significant sulfur content of working fuel 2, 4%. This makes them highly anti-environmental, and the energy they produce is highly emitting equivalent units of CO2. Due to these characteristics, their transportation over long distances are also unprofitable (Mines Maritsa Iztok EAD, Coal, https://www.marica-iztok.com/page/vaglishta-10-1.html)

3. A state-owned gas transmission company
4. A state-owned oil and gas discovery and production company
5. Four enterprises for production of electricity from renewable sources:
- Two from wind (private power plants)
- One for production of electricity from the sun, (private power plant), and
- One hydroelectric power plant, which is a complex of nine micro-water electricity plants.

Some of them, such as hydropower, solar and wind power, are classified as "sustainable" enterprises.

The nuclear power plant is classified as "temporarily sustainable transitional activity" until 2045 and the gas suppliers, which are classified as sources of temporarily sustainable energy, like nuclear power plants until 2030.

Greenhouse gas emissions over the life cycle of gas and nuclear energy are below the threshold of 100 g CO2e / kWh (CO2 emission equivalent per kWh). It is the conversion of kWh into kilograms of carbon by a factor of 0.23314 kg of CO2 saved for each kWh produced from a carbon-free source (RenSmart, 2022).

The gas and nuclear capacities that can be built up to the specified periods must meet certain technological conditions and requirements, which are regulated by EU regulation (Official Journal of the European Union, 2021).

The enterprises were surveyed for 2019 and 2020, the time of the Covid crisis, and two of them, which are for production of electricity from wind, were surveyed for the pre-crisis years 2018 and 2019, in order to distinguish between the years of crisis and their normal potential for efficiency of the used capitals. In the analyses, we are trying to answer the following questions: (1.) Do the electric power companies of different energy types -

solar, wind, nuclear power plants, thermal power plants, hydro power plants, gas and oil create or decompose value before and after the crisis, and (2.) What is the rating of the different companies in creating value added and to make a comparison between the different types of energy companies.

The data are taken from the annual financial statements of the surveyed companies. For "Kozloduy" NPP and Maritsa Iztok 2 the annual financial statements are taken from those published on the website of the Bulgarian Stock Exchange Sofia (Bulgarian Stock Exchange, available at: https://www.bse-sofia.bg/bg/), and for the other enterprises from the Registry Agency (Commercial Register of the Republic of Bulgaria).

The data result from the calculations are given in the following Table 1.

**Table 1** VAIC$^{tm}$ coefficients, value added, efficiency of intellectual and structural capital in the surveyed enterprises

| **Entity** | **VAIC$^{tm}$** | | **Effectiveness of Intellectual Capital (ICE)** | | **Effectiveness of Structural Capital (SCE)** | |
|---|---|---|---|---|---|---|
| **Year** | **2019** | **2020** | **2019** | **2020** | **2019** | **2020** |
| 1. Nuclear Plant "Kozloduy" | 3,240 | 3,660 | 3,893 | 3,645 | 0,688 | 0,665 |
| 2. Marisa Iztok 2 Coal electricity Plant | 10,880 | 7,418 | 3,893 | 5,809 | 0,702 | 0,800 |
| 3. Marisa 3" Contur Global" Coal electricity Plant | 2,155 | *1,868 min* | 2,150 | 1,864 | 0,422 | 0,0005 |
| 4. "Bulgartransgas "–gas delivery | 5,068 | 3,704 | 4,953 | 3,625 | 0,761 | *0,0001min* |
| 5. Oil and Gas – discovery and production | 3,060 | 2,370 | 2,911 | 2,242 | 0,572 | 0,444 |
| 6. Wind electricity plant "ELIA" 2018 and 2019 | *1,799 min* | 3,183 | 1,219 | 1,971 | *0,103 min* | 0,374 |
| 7. Wind electricity plant "WINDFERM" 2018 and 2019 | 4,066 | 14,21 | 3,86 | 13,944 | 0,685 | 0,923 |
| 8. Solar electricity plant SOLARPRO Group | 8,749 | 10,295 | 0,877 | 0,724 | **8,15 max** | **3,628 max** |
| 9. Devnya Solaris-solar electricity plant | 9,315 | 4,516 | **8,421 max** | **10,195 max** | 0,868 | 0,893 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 10. Water Electricity Plant "Svoge" | **13,973 max** | **18,500 max** | *0,059 min* | *0,126 min* | 0,923 | 0,943 |
| *Average without wind plants* | *9,025* | *6,927* | *3,223* | *4,198* | *1,387* | *0,867* |

### 5.2 Analysis of the Effectiveness of Intellectual Capital (ICE)

As mentioned, the ratios show how many monetary units (in this case the data are in Bulgarian currency levs (BGN)) the company earns when investing a unit of cash (1 BGN) in a given type of capital.

The change in the efficiency of ICE in the positive direction is the highest at the waterpower plant Water Electricity Plant "Svoge" (+ 4,495), a maximum increase of IC 2020 compared to 2019, and the Iztok in the positive direction at the Nuclear Power Plant (-0,248). In addition to "Svoge" and Maritsa 2 and Devnya Solaris-solar electricity plant, the ICE has increased, while other energy companies have seen a decrease in the efficiency of their investment in Intellectual Capital.

In the pre-crisis period 2019 compared to 2018, Wind electricity plant "WINDFERM" (+ 10,084) shows a very high increase in efficiency in invested intellectual capital, while the other solar power plant ELIA has a very modest positive increase in efficiency of its investment in intellectual capital (+0.752).

### 5.3 Structural Capital Performance (SCE) analysis

The biggest drop - 4,552 is on Solar Pro, while there is a slight increase of + 0, 025 of Solaris Devnya, as well as an increase of + 0.0196 of "Svoge" waterpower plants, + 0.098 of "Marisa Iztok 2". For the other energy companies, a decrease is observed. In the pre-crisis period, there was a slight increase of about BGN 0.20 per BGN 1 of investment in structural capital at the wind power plants.

### 5.4 Analysis of Total efficiency / Intellectual ability – VAIC

The data show that all businesses, whether they use renewable or non-renewable energy, create, and do not break down value. The energy sector is also efficient in a crisis.

Solar energy developed well during the pre-crisis period. The value added of solar power plants as sources of renewable energy has increased dynamically in the pre-crisis period.

The cascade of 9 waterpower plants in "Svoge" demonstrated high efficiency of the invested capital in the crisis.

The data show that hydropower plants have the lowest efficiency of their intellectual capital, at the expense of the overall high efficiency of capital that they demonstrate. In general, during the crisis period, the contribution of intellectual capital decreased.

In the pre-crisis period, high efficiency of the invested capital according to the VAIC indicator is shown by Wind electricity plant "WINDFERM" 2018 and 2019, unfortunately the performance of the other studied company for production of wind electricity is not so good.

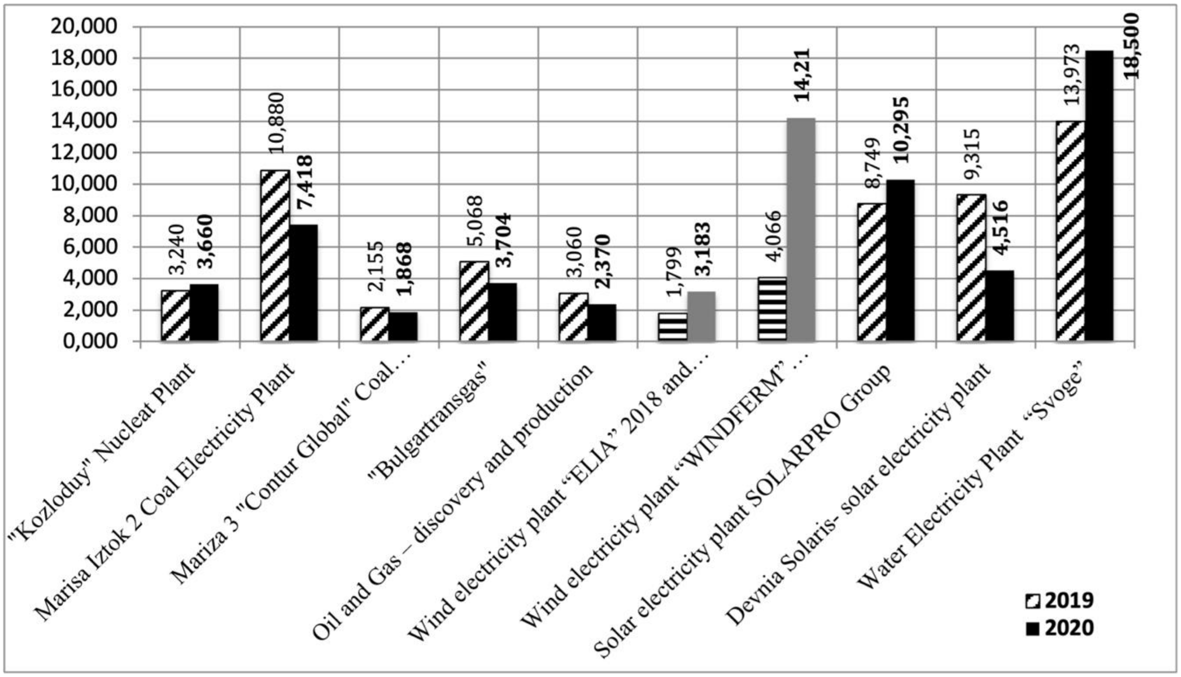


**Figure 1.** VAIC tm (2019, 2020; "ELIA" and "WINDFERM" 2018, 2019)

From the data for the VAICtm factor, after calculations on the primary data, we can conclude that the Covid crisis has negatively affected energy companies, both from renewable and non-renewable sources, except for the nuclear power plant and the group of 9 micro-water-electricity plants- "Svoge". For the Solar electricity plant SOLARPRO Group the VAICtm coefficient also increases, but it should be borne in mind that the group is not only engaged in the production of electricity from solar sources, but also in engineering and design work in the field of solar energy production, as the activities are not separated in its reports. The other studied clean producer of solar energy Devnya Solaris- the solar electricity plant does not increase the efficiency of its capital in the crisis.

**Table 2.** Changing the positioning of companies 2020 vs. 2019

| VAICtm 2019 | VAICtm 2020 |
|---|---|
| Water Electricity Plant "Svoge" | Water Electricity Plant "Svoge" |
| Marisa Iztok 2 Coal electricity Plant | Solar electricity plant SOLARPRO Group |
| Devnya Solaris- solar electricity plant | Marisa Iztok 2 Coal electricity Plant |
| Solar electricity plant SOLARPRO Group | Devnya Solaris- solar electricity plant |
| "Bulgartransgas"–gas delivery | "Bulgartransgas" –gas delivery |
| Nuclear Plant "Kozloduy" | Nuclear Plant ""Kozloduy" |
| Oil and Gas – discovery and production | Oil and Gas – discovery and production |
| Marisa 3" Contur Global" Coal electricity Plant | Marisa 3" Contur Global" Coal electricity Plant |

The reasons for this picture can be sought in different directions: technology, local market, reduction of energy consumption due to closure or reduced volume of electricity demand in the free and regulated market (In this analysis, we ignore these variables and study the data "ceteris paribus").

## 5.5 Correlation analysis of the value added of coal-fired power plants and carbon emissions

Correlation analysis shows that the link between value added, and carbon emissions is strong. The value in these companies was created primarily by intellectual capital, while structural capital, as shown in Table 1, contributed insignificantly to the overall efficiency of the enterprises and therefore shows a weak correlation with carbon dioxide emissions.

With the closure of these plants, according to the EU Green Deal, the losses will be on the efficiency of intellectual capital.

**Table 3.** Spearman's correlation coefficient: Carbon emissions of Maritsa 2 and Maritsa 3 (2019 and 2020, tones of $CO_2$)

| CO2 emissions, t | 2019 | 2020 |
|---|---|---|
| Marisa 2 | 7 874 098 | 4 292 307 |
| Marisa 3 | 5 703 965 | 5 312 942 |

**Table 4.** Spearman's correlation coefficient: Correlation between $CO_2$ emissions and VAIC$^{tm}$ for Coal plants Marisa Iztok 2 and Marisa 3 "Contur Global"

| Indicator | p | Means |
|---|---|---|
| VAIC/$CO_2$ | 0,400 | strong |
| Structural Capital/$CO_2$ | 0,200 | week |
| Capital Employed/$CO_2$ | 0,400 | strong |
| Human Capital/$CO_2$ | 0,400 | strong |
| Intellectual Capital/$CO_2$ | 0,400 | strong |

## 5.6 Blue water footprint of Water electricity Plants

Water footprint of business is the sum of the Water Footprints of the final products that the business produces (Galliet al., 2011; Mekonnen and Hoekstra, 2011).

The total installed capacity of all 9 plants of the project is 25.6 MW, with the expected annual production of green energy from them of about 145 million kWh. at 9 small power plants.

The formula for calculating the blue watermark that we will stick to here is

$$WF = WE / EG \qquad (3)$$

where:

WE-quantity of generated water per year - measured in cubic meters (m3)

EG - the amount of energy - measured in giga joules (GJ).

The water footprint of electricity produced from hydropower is calculated as the quotient of the amount of water generated and the electricity generated and is measured in cubic meters per gigajoule (WF, m3 / GJ). The water footprint of a product is equal to25 the amount of fresh or consumed fresh water divided by the amount of water produced product.

The minimum water evaporation is 6 m3 / s, while the outflow of the Iskar River is 54.5 $m^3/s$ (National Institute of Meteorology and Hydrology, https://hydro.bg/bg/t1.php?ime=&gr=data/&gn=tablRekiB2017).

Hydrological data show that there is a great variety of blue water available in the Iskar River every month. The available data show that in some places it is possible with minimal values of the water volume of the Iskar River, production to be unsustainable, considering even the minimum volume of water evaporation and lead to water shortages. "*The blue water scarcity in a river basin is defined as the ratio of the total blue water footprint to the blue water availability in a river basin during a specific time period.*" (Hoekstra et al., 2012).

**Table 5.** Operational information about the river outflow of the Iskar River 06.04.2022 08:00 local time

| River | Hydrometric station (HMS) | Q min m3/s | Q average m3/s | Q max $m^3/s$ |
|---|---|---|---|---|
| Iskar | village Novi Iskar | 7,510 | 21,412 | 1 330,000 |
| Small Iskar | village "Svoge" | 0,649 | 9,186 | 650,000 |
| Iskar | Station Roman | 8,000 | 49,874 | 1 102,000 |

*Source: National Institute of meteorology and hydrology, http://hydro.bg/bg/t1.php?ime=&gr=data/&gn=tablRekiB2017*

Due to the lack of detailed data, we accept the minimum water evaporation - 6 cubic meters / sec, for which we have data for minimum evaporation and present this amount for the year. The total volume of evaporated water (WE, m3 / yr-1) from the hydropower for 1 year.

Water footprint calculation:

145 million kWh = 522 000 000.00 gigajoules (GJ)

Blue Footprint $_{min}$ = 3,535448276 Gm3 /yr. = 1/3,535448276=0.283 Gm3 / $yr^{-1}$

This is the water footprint of the electricity produced by the nine plants.

This is the amount of blue water that is used at least for the electricity produced.

The water meter shows the amount of blue water that is used to produce electricity from the plant in total (Water footprint network). The blue water footprint is the water that is obtained from surface or groundwater resources. Since the power plants are located on the Iskar River and use its water, the footprint of the work of these power plants is in the category of "blue water footprint". This is the direct water system, without calculation up the chain. This water system is calculated with minimal evaporation and can vary between micro-vents and depending on the season.

To answer the question of whether this water footprint does not harm the sustainability of electricity generation, we need to determine whether it is environmentally sustainable, socially sustainable, economically sustainable (Hoekstra et al. 2011, p. 77) but also whether it is economically efficient and socially equitable.

The ratio between the footprint and the availability of blue water by months and in general shows whether the production is sustainable or not.

## 5.7 Blue water availability

Whether this imprint is significant is determined if it exceeds the "available blue water" (Hoekstra et al., 2011).

Hydrological data show that there is a great variety of blue water available in the Iskar River every month. The available data show that in some places it is possible with minimal values of the water volume of the Iskar River, production to be unsustainable, even when the minimum volume of water evaporation has been considered this can lead to water shortages. "*The blue water scarcity in a river basin is defined as the ratio of the total blue water footprint to the blue water availability in a river basin during a specific time period*" (Hoekstra et al., 2012).

The average annual volume of water flowing in the river varies between 716 million $m^3$ (near Novi Iskar point in the upper part of the Middle Iskar Gorge) to 1,325 million $m^3$ (at the end)[1].

Careful production management is needed, depending on the season and water volumes, so that the principles of sustainable production are respected.

## 5.8 Cluster analysis of enterprises

Cluster analysis groups enterprises based on their ICE and VAIC ratios.

**Table 6** Results from cluster analysis

| Clusters | P value | Entities |
|---|---|---|
| Cluster 1 | 0,0483 | Nuclear Plant "Kozloduy" and "Bulgartransgas" gas delivery |
| Cluster 2 | 0,628 | 1. Marisa 3" Contur Global" Coal electricity Plant, and 2. Oil and Gas – discovery and production, and 3. Wind electricity plant "ELIA" 2018 and 2019 |
| | 0,857 | (3. Wind electricity plant "ELIA" 2018 and 2019) |

[1] According to Hoekstra et al., (2012), "*... low blue water shortage (<100%): the blue water footprint is less than 20% of natural runoff and does not exceed the presence of blue water; the river flow is unchanged or slightly changed; the presumed ecological flow requirements are not violated.*

*Moderate shortage of blue water (100-150%): the footprint of blue water is between 20 and 30% of natural runoff; the outflow is moderately altered; the requirements for the ecological flow are not met.*

*Significant shortage of blue water (150-200%): the footprint of blue water is between 30 and 40% of severe water shortage (> 200%). The monthly footprint of blue waters exceeds 40% of natural runoff; the outflow is seriously altered; the requirements for the ecological flow are not met*. "

| | | |
|---|---|---|
| Cluster 3 | 5,84 | 1. Marisa Iztok 2 Coal electricity Plant, and 2. Solar electricity plant SOLARPRO Group |
| Cluster 4 | 10,39 | 1. Wind electricity plant “WINDFERM” 2018 and 2. 2019 Devnya Solaris- solar electricity plant, 3. Water plant “Svoge” |

The cluster analysis shows the optimal combination of enterprises with the perspective of their sustainability and the most optimal use of value added and efficiency of intellectual capital.

These are crisis-resistant energy companies that create sustainable value but are environmentally unsustainable.

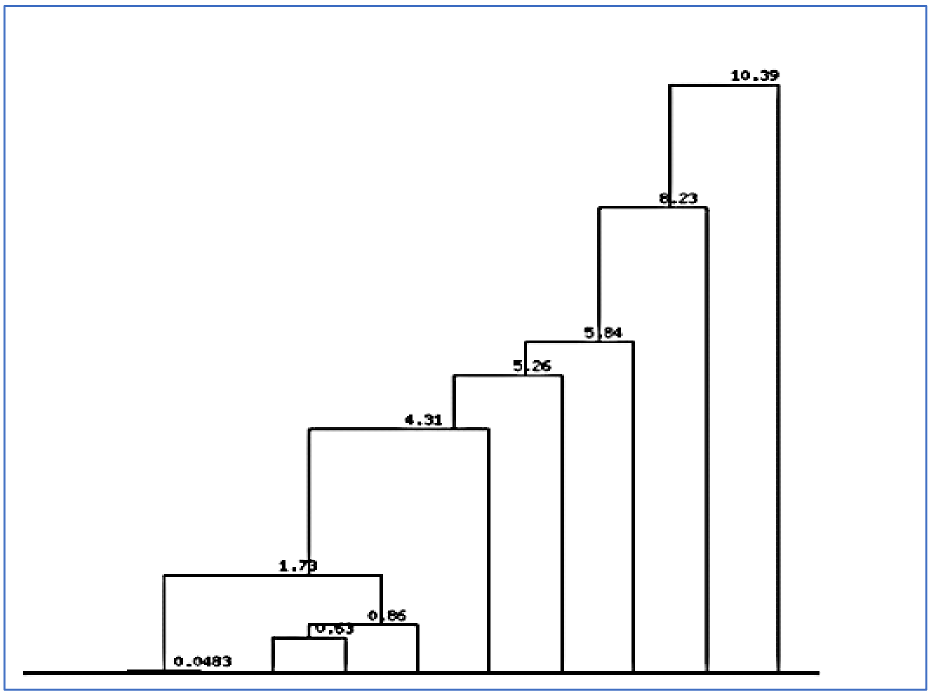


**Figure 2.** Cluster analysis of enterprises based on "Nearest neighbor" based on ICE and VAIC, P values

The results show that 4 main clusters are grouped according to the criterion "Closest distance or closest neighbor" according to their indicators of VAIC$^{tm}$ and ICE.

The gas company (for gas transportation and supply) and the nuclear electricity plant are in the same cluster at the closest distance. This result speaks of the closest demonstrated efficiency of the two enterprises. Both companies are in the group of "relatively and temporarily environmentally friendly".

The Second Cluster includes Maritsa 3, a coal-fired power plant, an oil and gas company, and ELIA, a small wind farm, due to a very modest increase in the efficiency of its investment in intellectual capital and the start-up period, although the data for it are from the pre-crisis period.

The third cluster strangely at first glance groups the Maritsa 2 coal-fired power plant, the SOLARPRO solar group. This is formally due to our studies and the significant increase in the efficiency of the ICE of Maritsa Iztok 2 in 2020. This cluster also shows that the intellectual capital that works effectively, even with "brown energy" can give comparable results. with those of an energy company from the clean energy group.

The cluster analysis shows us the optimal combination of productions based on their performance in the efficiency of the use of intellectual capital. We can conclude that with good governance and investment in intellectual capital, "brown energy" can perform well and sustainably, if, of course, it is able to overcome its carbon footprint. The correlation analysis made above showed that the link between value added and carbon emissions is strong. This is an insurmountable obstacle to the sustainability of such companies, even with excellent management of their intellectual capital and good governance.

The highest indicators are grouped by Windfarm, Devnya Solaris and the group water electricity plants “Svoge”. These are the companies that show the highest efficiency of their intellectual capital who are producers of energy from renewable sources. They are in the fourth cluster.

**Table 7.** Loses of effectiveness when the Fossil and Nuclear Plants be closed

| Entity | VAIC tm | Effectiveness of Intellectual Capital (ICE) | Effectiveness of Structural Capital (SCE) |
|---|---|---|---|
| Fossil and Nuclear energy plants* | 19,02 | 14,19 | 1,90 |

* Nuclear plant “Kozloduy”, Marisa Iztok 2 Coal electricity Plant, Marisa 3” Contur Global” Coal electricity Plant, “Bulgartransgas” –gas delivery, Oil and Gas – discovery and production

## 6 Results and Discussion

The energy sector is of utmost importance for both the current economy and the New Economy. The success of the new "green revolution" and the new economy based on renewable energy sources largely depend on it. A significant part of our energy sector today is based on the extraction, production, distribution, and supply of non-renewable (unsustainable) energy, such as coal, oil, and gas.

This part of it is associated with the centennial creation of intellectual capital, the creator of which is human and social capital. This capital includes the knowledge, skills, qualifications, but also the spirit of the workers, the engineers, the spirit of the regional societies that created this capital. Regional development based on it will change its characteristics.

A problem for further research is the thorough analysis of the losses that societies will make in the name of the new economy. These losses do not include only quantitatively measured material losses. They include human losses as well - the loss of engineers, professionals, the miners’ spirit and the decline of the mining towns, regions and communities associated with this energy share. Establishing this complete loss of value and efficiency is the price that the current generation is required to pay in the name of future generations, in the name of sustainability. Societies have a right to know the price paid for sustainability. Such losses were suffered by societies in the first and second industrial revolutions, when wind and water sources were replaced with steam, then in the replacement of a batch engine with an internal combustion engine and electricity from non-renewable sources.

In every industrial revolution, the efficiency of intellectual capital is sacrificed, which is lost at the expense of the introduction of new methods of production. From one state of resilience, socio-economic systems move to another state of resilience, which goes through an inevitable crisis and uncertainty. The market economy itself finds the way to the new balance. Our current economy is highly regulated with elements of dirigisme, and the new sustainability and efficiency of capital is defined as based on renewable energy sources. The deadlines for the transition to new sustainability are short, and for countries with small populations and productive capacity - a difficult and largely difficult task. Such a country is Bulgaria. The efficiency losses of intellectual capital and spirituality for such countries can prove to be dramatic.

## 7 Conclusions

The study demonstrates an approach to the problems of new sustainability based on renewable energy sources, not one-dimensionally and not only in terms of environmental benefits, but also multidimensionally - in terms of losses and the price to be paid in the efficiency of the use of intellectual capital. In the transition to renewable energy, the intellectual capital and efficiency of energy companies will disappear.

The approach includes the complex VAIC$^{tm}$ method for measuring the efficiency of the use of tangible and intangible capital in several energy companies of different types. It is complemented by a correlation analysis of Spearman's coefficient between the value added created in enterprises and their carbon emissions, water footprint and water availability for hydropower plants and a cluster analysis of enterprises.

The study shows that all energy companies, both renewable and non-renewable, create value added even in an unusual circumstance such as the Covid crisis.

The carbon footprint of coal-fired power plants correlates correctly with value added, intellectual, human, and employed capital, but not with structural capital. In the transition to a new economy, their losses will be mostly in intellectual capital.

Renewable energy companies are still unstable in Bulgaria.

The state power plant Maritsa Iztok 2 shows significantly better results than the private Maritsa 3 "Contur Global", comparable to the Solar electricity plant SOLARPRO Group and even better in the crisis year 2020 than the Solar electricity plant SOLARPRO Group. To explain these results, a more in-depth study is required, including the influence of factors such as organization, management, personnel development system and others, which is outside the scope of this study.

There are significant differences in the performance of the studied indicators of different energy companies working with non-renewable sources. They are still not competitive in the efficient use of intellectual capital and the creation of value added of old energy companies.

The best results of value added and increase in efficiency of intellectual capital are demonstrated by the micro-vents "Svoge". The problem with them is the water footprint and water availability. Calculations have shown that it is possible that in certain periods with reduced flow of the Iskar River, electricity production is not sustainable. However, this stable source of clean energy faces the problem of allocating water resources between the needs of energy production and the water needs of households, agriculture, and industrial enterprises. This circumstance puts the planning of the capacity of hydropower plants with the domestic, agricultural, and industrial needs of the regions and the creation of a fair, dynamic balance between energy production and other economic activities.

The cluster analysis according to the "Closest distance" method proved the uniformity in the creation of value added in enterprises working with renewable and non-renewable sources. The only difference was the reporting of a cluster between Maritsa Iztok 2 Coal Plant and SOLARPRO. However, this anomaly gives us reason to believe that in the transition to renewable energy there is an optimal opportunity to combine renewable production with well-managed companies of the old type, efficient in the use of intellectual capital, creating value added energy.

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