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INFLUENCE OF INFORMATION TECHNOLOGIES ON THE ENVIRONMENT AND SUPPORT FOR GREEN COMPUTING AS A SOLUTION TO ECOLOGICAL PROBLEMS

Purpose. Research of the impact of information technology on the environment, analysis of ways to solve ecological problems by Green Computing, consideration of the largest IT companies' participation in the implementation of "green technologies".

Research methods. Methods of analysis of literature sources on the issue, scientific articles and publications were used during researching the problem of the impact of information technologies on the environment.

Scientific novelty. A list of Green Computing areas that have a significant impact on reducing energy consumption and environmental pollution through the spread of information technologies has been defined.

Practical significance. The conducted research demonstrates that today, companies, which produce computer equipment, pay a lot of attention to reducing environmental pollution by recycling components with completed life cycle. Minimization of emissions into the environment, decreasing energy consumption and implementing virtualization and cloud technologies in workflows.

Results. It has been determined that significant carbon emissions into the atmosphere occur due to the manufacturing computing equipment and the production of the energy required for the functionality of data centers. The technological cycle of computer production causes the problem of toxic waste electrical and electronic equipment, which deteriorates the hydrosphere and lithosphere. Green Computing is responsible for the design, manufacture, use and disposal of computers, servers and their hardware to consume energy efficiently with minimal environmental impact. Modern IT corporations introduce new methods of computer equipment development, which improve ecological security and increase manufactory productivity. Green Computing includes virtualization and cloud computing. Throughout the analysis of the participation of IT corporations in the implementation of "green technologies", the achievements of Facebook, Google and Microsoft in setting up data centers in different parts of the world and even underwater were considered. Apple, Intel, AMD companies are to improve the environmental friendliness of products and production.

Key words: Green Computing, information technologies, energy consumption, environment, data center, virtualization, cloud technologies.

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The problem and its connection with scientific and practical tasks. Such issues as environmental pollution and high energy consumption are inherent in a large number of industrial manufacturers. At the same time, for the reason of the rapid development of the information technologies industry, these problems are becoming relevant in the context of computer equipment development, maintenance, exploitation and disposal. In order to reduce the harmful impact on the environment and decrease the quantity of resources consumed by computers, the concept of Green Computing has been actively implemented in recent years [1].

Analysis of research and publications. Green Computing, or "green information technologies", is an area of information technologies, which represents a comprehensive approach to ensure full compliance with ecological requirements throughout the cycle of development, production, maintenance, operation and disposal of computers and computer products [2, 3]. This area is actively studied by scientists from different countries [4-6], special attention is paid to the creation of eco-friendly electronics [7]. The issue of reducing the energy consumption of computing equipment is also considered quite important [8].

Task statement. Conducting the research on current environmental problems caused by the spread of information technology and considering ways to solve them.

Presentation of materials and results. The Green Computing is aimed at reducing the negative impact of companies producing electrical and electronic equipment on nature and man [9]. Therefore, "green technologies" contribute to the creation of a completely environmentally friendly computer, which has such features as the absence of toxic substances in components, low electromagnetic and thermal radiation, high-energy efficiency, ease of disposal and recyclability of individual components.

One of the most desirable factors in the design of a new computer is the economical consumption of power by the product and the use of renewable energy sources. Figure 1 represents the process of energy distribution both during the creation of computer equipment and its operation.

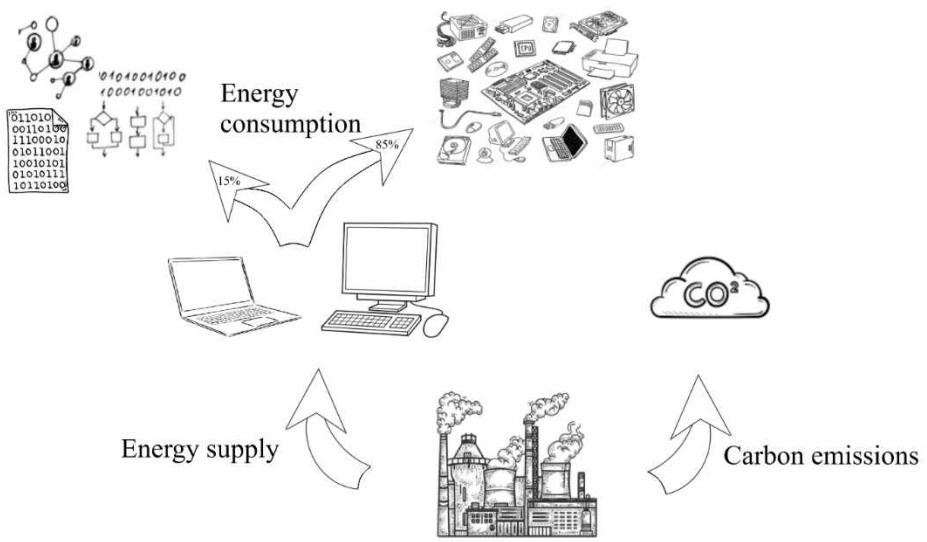

Fig. 1. The process of energy distribution

It has been estimated that only about 15% of the energy consumed by electrical and electronic equipment worldwide is spent on computing, the rest is spent on maintaining the computer's operating status when it is no longer in use but is still on. This power consumption provokes a lot of CO_2 emissions. Consequently, the use of computer equipment and computers in an energy-efficient way would significantly reduce carbon dioxide emissions per year, possibly, measured in tons. The energy-saving modes have been successfully implemented in almost all operating systems for daily use. It provides an opportunity to turn off automatically the hard drive or monitor after a period of user inactivity. At the same time, there is a large production of the unusual chips so-called "smart silicon" launched by AMD. These chips are famous for their low energy consumption. In 2006, the first "green" computer Crusader Carbon 3 PC went on sale, the main advantages of which were the lack of active cooling of the processor, which guaranteed quiet operation, environmentally friendly parts and, most importantly, power consumption of about 20 watts (for comparison: the average Pentium-4 processor consumes at least 100 watts). However, a significant drawback of this model was its low performance. An exemplary approach to these issues is the path of the corporation Intel. The company has launched a special ten-year strategy in 2020, which sets goals that should be achieved by 2030. One of the main goals is to accomplish clean positive water use, 100% renewable energy, zero landfill emissions and additionally absolute reduction in carbon emissions. Furthermore, the company put a lot of effort to commence developments for the application of purely stable methods of chemistry in technological operations [10].

The actual problem is considered as the lack of control over pernicious emissions into the atmosphere when generating the energy consumed by data centers. It is a common practice to use coal as fuel and diesel engines. However, the environmentally conscious company Apple has found another source of energy – biogas, which is obtained from the decomposition of biomass. Since 2014 the Apple data centers have consumed only renewable energy. One of Facebook's data centers, which was opened in 2013, is located 60 kilometers from the Arctic Circle and is fully supplied with the energy generated by the hydroelectric power plant at the confluence of the Luli River and the Gulf of Bothnia.

Moreover, there is a huge problem of toxic waste in the technological cycle of computer production, which deteriorates the state of the Earth's hydrosphere and lithosphere. The problem of waste electrical and electronic equipment (WEEE) is a constant increase in amount, considerable toxic potential, in the case of landfill operations as an option for disposal, loss of precious and rare materials in its composition. Adverse effects on human health that can be caused by components of various devices are summarized and represented in Table 1 [6].

The RoHS directive was introduced to restrict the use of detrimental materials in European Union enterprises. According to this document, heavy metals such as plumbum, cadmium, chromium and mercury, two types of organobromine flame retardants were excluded from the manufacturing processes. This led to the cessation of supplies to the EU of some products of several companies including Apple.

Table 1

Components of various devices and their effects on human health

Contaminants	Examples of WEEE sources	Toxicity
Aluminum	Computer monitors, cables and wires containing inorganic flame retardants, process control blocks, microchips, hard disk drives, device housing	Neurotoxicity, respiratory system irritant
Antimony	Tin-plumbum alloys, waste printed circuit boards, liquid crystal displays, plastics, cathode-ray tubes, cables and wires containing inorganic flame retardants	Respiratory system, eyes and gastrointestinal irritant
Arsenic	Dopant for semiconductors, plasma TVs, liquid crystal displays	Carcinogenicity, hematotoxicity, endocrine disrupter
Barium	Cathode-ray tubes, fluorescent lamps, liquid crystal displays, PTVs, gutters in vacuum tubes	Neurotoxicity, cardiotoxicity, gastrointestinal irritant
Cadmium	Batteries, toners, cartridges, plastics, waste printed circuit boards, solder, chip resistors, cathode-ray tubes, plasma TVs, cell phones, infrared detectors	Carcinogenicity, cardiotoxicity, nephrotoxicity, endocrine disrupter
Cobalt	Batteries, hard disk drives, laptop computers, liquid crystal displays, plasma TVs, cathode-ray tubes	Cardiotoxicity, allergen, possible carcinogenicity
Copper	Cables, electrical wiring, process control blocks, microprocessors, terminal strips, plugs, plasma TVs, cell phones	Respiratory system, eyes and gastrointestinal irritant
Hexavalent chromium VI	Corrosion-resistant coatings, waste printed circuit boards, floppy disks, pigments, data tapes, plasma TVs	Carcinogenicity, sensitizer, skin irritant
Plumbum	Cathode-ray tubes, liquid crystal displays, plasma TVs, fluorescent tubes, process control blocks, lead-acid batteries	Carcinogenicity, neurotoxicity, cardiotoxicity, nephrotoxicity, endocrine disrupter
Mercury	Fluorescent tubes, compact fluorescent lamps, batteries, switches, thermostats, sensors, monitors, liquid crystal displays, laptop computers	Neurotoxicity, skin, eyes and gastrointestinal irritant, endocrine disrupter
Silver	Plasma TVs, laptops, liquid crystal displays and light-emitting diodes	Neurotoxicity, reprotoxicity
Halogenated flame retardants	Process control blocks, plastics	Carcinogenicity, endocrine disrupter, neurotoxicity
Halogen-free flame retardants	Device housing, plastics, epoxy resins in process control blocks	Nephrotoxicity, endocrine disrupter, neurotoxicity
PVC	Wiring and computer housing	Toxicity of dioxins and furans generated throughout PVC burning

One of the ways to cope with waste is recycling, which facilitates waste reduction, environment protection and conservation of natural resources. Figure 2 represents a graph that shows the number of thousands of tons of electrical and electronic equipment in the market, the amount of waste EEE collected, treated, recovered, recycled and prepared for secondary use during 2011-2019 years in the European Union [11]. It is important to point out that recycling processes are considered appropriate only as long as their prime cost is lower than the cost of manufacturing the product using raw materials. The production of materials requires significantly more industrial capacity than their recycling, especially taking into account that processed feedstock is often more concentrated than primary raw materials. It is estimated that energy costs and carbon footprint provoked by metal processing are 50-99% lower compared to their production. For example, the recycling of ferrous metals shows excellent results: reduction of costs during the processing of aluminum by 92%, copper by 65%, nickel by 90%, zinc by 76%, plumbum and stannum by 99%. Nevertheless, the benefits of recycling should not make processing the best approach to handling solid waste. It is necessary to take preventive actions to deter waste generation and deal with reuse, recycling, recovery and, finally, disposal [12].

High computer noise is considered sometimes a minor disadvantage, but when it comes down to large servers and global data centers, there are serious concerns about the impact on the environment. The search giant Google has solved this problem by placing data centers on barges, keeping a sufficient distance from the coastline. This approach enables to save the corporation from property taxes and generate energy using the wave and wind power. Moreover, there is a great opportunity to cool down the data center nodes effectively without any additional equipment. The Microsoft team has gone even further by launching the Natick project to demonstrate the logistics, environmental friendli-

ness and cost-effectiveness of underwater data centers. Initially, the main goal was to provide the coastal population with high-speed cloud services and decrease energy costs. Researching data centers deployed in 2018 in the Orkney Islands of Scotland, it was concluded that such data centers are eight times more reliable than terrestrial ones. This is facilitated by the absence of corrosion caused by oxygen and moisture, as the container is filled with nitrogen. Coldwater flows provide an opportunity to adjust the heat exchange system completely eliminating the use of freshwater. The absence of people in this situation is advantageous because the components are not touched and do not receive unnecessary mechanical damage. The successful location of the data center allowed the system to be supplied with power using only wind and solar energy. There are plans of conducting test locating of data centers near offshore wind farms, which, according to estimations made by the Microsoft team, should provide the system with sufficient energy even in low wind. Additionally, the estimates showed that all servers would be replaced every five years, and the use of spare parts would be eliminated altogether [13].

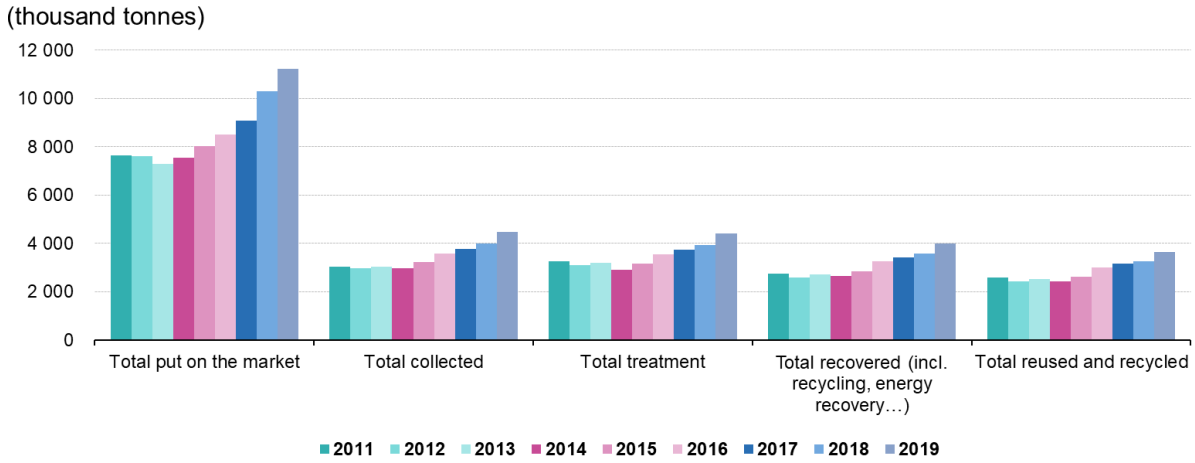

Fig. 2. Electrical and electronic equipment put on the market and waste EEE collected, treated, recovered, recycled and prepared for reuse, EU

The most significant contribution to "green computing" was made simultaneously with the creation and occurrence of cloud computing technology. The results of the implementation of cloud computing are a reduction in server use by 77%, energy by 84%, carbon emissions by 88%. Energy savings are occurred due to the location of cloud data centers near users, which prevents losses of transmitting power over long distances. Costs are also minimized owing to optimized hardware setup compared to traditional data centers. Cloud technologies introduce replacing carbon physical products with virtual equivalents, which considerably decreases waste generated during the disposal of the products. There is a significant saving of energy as a consequence of transferring software to the cloud. A study funded by Google and conducted by the Lawrence Berkeley National Laboratory in collaboration with Northwestern University discovered the fact that moving business programs such as email, CRM, (nationwide) to the cloud reduce the software's overall energy consumption by 87 %, this power is enough for supplying Los Angeles for 12 months [14].

Conclusions. Analysis of the impact of information technologies on the environment has shown that there are significant emissions of carbon dioxide into the atmosphere due to the manufacturing enterprises in this industry and as a result of the production of energy needed for the operation of data centers. Also, it was considered that there is a global problem of large toxic waste in the technological cycle of computing equipment production, which deteriorate the hydrosphere and lithosphere. Additionally, attention was paid to noise pollution, which is constantly caused by data centers. Green Computing is to be responsible for the design, manufacture, use and disposal of computers, servers and their hardware, such as monitors, printers, storage devices, networks and communication systems, to consume energy efficiently with minimal environmental impact. Thanks to the "green technology" movement, modern IT corporations are introducing new methods of computer hardware development, which improve environmental safety and allow to increase productivity. Green technologies include virtualization and cloud computing. Virtualization eliminates the need for electrical and electronic equipment by replacing physical servers with virtual machines. Cloud computing uses the concept of

virtualization by placing servers on the Internet which allows companies to eliminate the need for energy-intensive servers. Cloud computing is also used in networks, data warehouses, operating systems and software applications, potentially decreasing equipment consumption and associated energy consumption. Furthermore, the transition to cloud computing saves companies time, money and resources on maintenance and support of appropriate equipment. The analysis of the participation of IT corporations in the implementation of Green Computing considers the achievements of such corporations as Facebook, Google and Microsoft in setting up data centers in different parts of the world and even underwater. Also, a survey of plans and goals launched by Apple, Intel and AMD companies are to improve the environmental friendliness of products and manufacturing processes.

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ПІДВИЩЕННЯ РОЛІ ЦІННОСТІ ЛЮДИНИ НА ІННОВАЦІЙНИЙ РОЗВИТОК ПІДПРИЄМСТВА

Мета. Метою даної статті є визначення підвищення ролі цінності людини і вплив фінансово-економічних аспектів формування людського капіталу на такі важливі аспекти для сучасного стану функціонування суб'єктів господарювання, як: інноваційний розвиток підприємства, корпоративне управління і економічна ефективність.

Методи дослідження. Результати і наукові положення отримані з використанням певних методів (різних за напрямом і масштабом охоплення предмету дослідження): узагальнення результатів попередніх досліджень, комплексного аналізу та синтезу, логіко-структурного й логіко-динамічного аналізу, науково-аналітичний, порівняння й аналогії тощо.

Наукова новизна. Аналіз зарубіжних і вітчизняних літературних джерел показує, що до теперішнього часу чітких, узгоджених міркувань і положень стосовно змісту, тлумачення, методології та методики оцінювання категорій «цінність людини» і «людський капітал» у їх єдності і підпорядкованості не існує.