Computering power goes green

“GO GREEN”

SUMMARY REPORT

on the readiness of the sectors for the digital transformation and the possible carbon footprint

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ABSTRACT

The economic growth accompanied by increased consumption and the irrational use of natural resources and energy negatively affect the environment and climate change, meaning that jeopardizes sustainable development. Greener economy and digitalization, as response to those challenges, creates opportunities for technologies and investments.

In order to reach its climate and economic goals, the digital sector must contribute its share and embrace sustainability in all its facets: circular economy, climate-neutrality and reduction of energy consumption.

This report presents the implemented digital transformation and perspectives of the sectors for green digitalization .

PROJECT: "Computering power goes green - GO GREEN"

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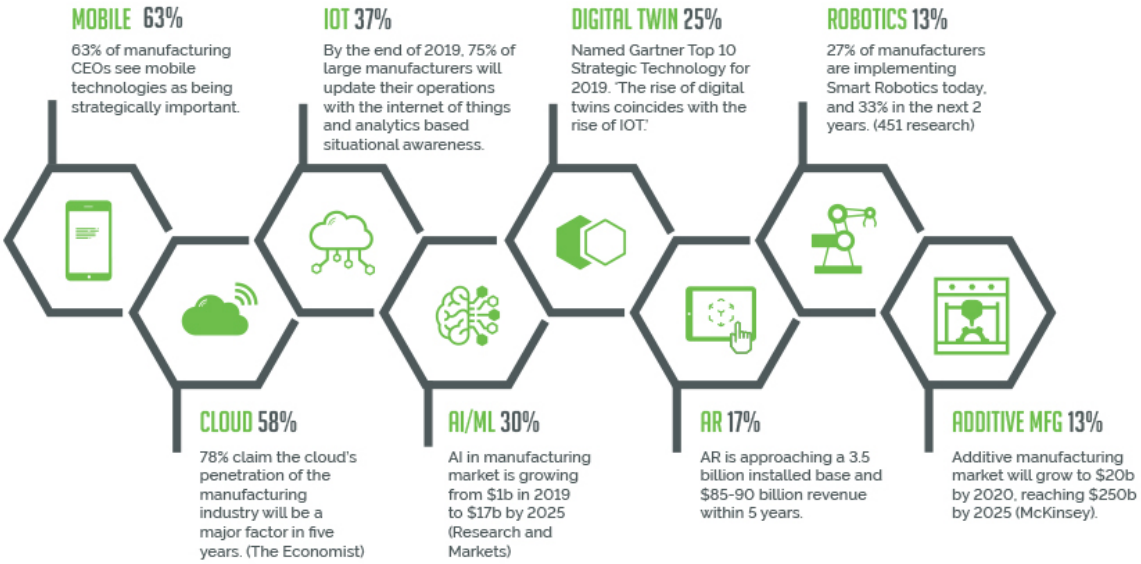

Prepared by PhD Risto Ivanov

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Foreword

Sustainable development is a framework for shaping policies and strategies for continuous economic and social development without harmful impacts on the environment and natural resources important for the future of humankind. The economic growth accompanied by increased consumption and the irrational use of natural resources and energy negatively affect the environment and climate change, meaning that jeopardizes sustainable development. Greener economy and digitalization, as response to those challenges, creates opportunities for technologies and investments.

To reach its climate and economic goals, the digital sector must contribute its share and embrace sustainability in all its facets: circular economy models for hardware, climate-neutral CPU models and server centres, software advancements to reduce energy consumption, and many more. Digital technologies such as artificial intelligence, 5G, IoT, cloud and edge computing, digital twin, robtics also have the capacity to accelerate and maximize the effects of environmental policies. However, in practice, investments are focused on measures that contribute to either the green or the digital transition. In other words, EU funding is usually directed on energy efficiency and climate or in digital transformation without focusing on the synergies between both.

The project "Computering power goes green- GO GREEN" aims at adoption of new approach that refers to the monitoring, assessment, and promotion of TWIN investments. It means that the digital transformation is not promoted in isolation but is seen under the lens of green development.

This document has been prepared based on the Agreement between Bureau for regional development and ZBK Creation Skopje, as service provider for "Mapping of the current trends and state with regard to digital transformation initiatives with significant environmental footprint"

The specific tasks of the assignment are:

Analysis of the main industrial and service sector of Macedonian economy in terms of their environmental footprint and opportunities for digital transformation;

- Selection of 3-5 sectors which will be subject to further studies.
- Research of the sectors regarding the degree of implemented digital transformation
- Conducting document and field research, covering authorities, business organizations and companies via questionnaires, interviews, site visits and meetings.
- Analysis of the environmental footprint of the sectors;
- Development of a Summary Report on the readiness of the sectors for the digital transformation and the possible carbon footprint

Those tasks result with deliverable Summary report, presenting the readiness of the sectors for green digitalisation and possible carbon footprint. It will be used for next project activities in terms of monitoring and manage the digital transformation in the country.

1 Introduction

The main objective of the project "Computering power goes green- GO GREEN" is to promote the adoption of an integrated approach and framework for the creation of combined green and digital transformation initiatives at the national and transnational level, that will lead to a 'greener' functioning of digital infrastructures using data centres. Achieving this objective is linked with creation of long-term cooperation structure and establishing of the Barometer as permanent monitoring mechanism. The parallel establishment of the Green Certificate results in concrete environment benefits (measurable energy efficiency gains) thorough the provision of incentives to public bodies, infrastructure manufacturers and private enterprises for a green-innovation economy. Creation of this "twin transition" needs institutional capacity building and culture in fostering for innovative environmental management approaches which will anticipate and manage adjustments and challenges towards transition to a greener economy.

The first step in introduction of new approach is to identify the sectors of North Macedonia economy in terms of their environmental footprint and opportunities for digital transformation, implementing the criteria about CO2 emissions (carbon footprint), Energy consumption, Circularity potential and Digitalization potential.

Implemented Methodology approach encompass of analysis and ranking of sectors and selection of 3 sectors for further researches (Annex 1), conducting research for selected sector and identification of perspectives for digital transformation (Annex2) and summary of findings about readiness of sectors for digital transformation.

The review of literature and statistics on industrial and service sector was conducted using official sources and studies from the Republic of North Macedonia, EU and other sources, documents and studies from research centres, think-tanks and associations.

The research has consisted of preparation of questionnaires for each sector and collection of responses form authorities, business associations, experts and business. The answers are analysed to draw main findings about potential for green digitization

The main sections of the report are:

- *First*, Digital transformation addresses Sustainable development Goals, is mapping of current trends in green and digital transformation as steps towards smart green development, encompassing of contribution to sustainable development goals, EU green and digital transition and role of data centres;
- *Second*, analysis of industrial and service sector in North Macedonian economy, presenting current trends in the sectors and its participation in energy and circular scenario defined in the National Strategic documents; and
- *Third,* ranking and selection of three sectors (Agriculture and forestry, Building sector and public sector) regarding to implemented digital transformation and perspectives for digital transformation that will affect environmental footprint.

Conclusions and recommendations will be used to implemented the next project activities and to introduced Barometer for green digitalisation the country towards achievement of project objectives.

2 Digital transformation addresses sustainable development (SDG)

Environmental footprint stem from of two main causes: energy consumption affecting climate change; and resources utilization affecting environment degradation. Therefore, two scenarios are deployed for transformation to greener economies:

- Energy scenario encompasses of savings in energy consumption by energy efficiency of economic activities and changes the energy structure through more intensive integration of renewable sources aiming at adverse impacts on climate change.
- Circular economy scenario introduces efficiency in resource consumption through 3R principle (reduce, recycle, reuse) aiming at decreasing environment pollution and degradation.

Those two scenarios as components of Sustainable development are framework for shaping policies and strategies for continuous economic and social development without harmful impacts on the environment and natural resources.

In 2015, the UN adopted the new 15 year Global Sustainable Development Program by 2030[1] which contains 17 sustainable development objectives. The set of indicators is organized according to the basic principles, following the economic, social, environmental and institutional dimension of sustainable development. Achieving the objectives is measured through an indicated indicator framework for each of them separately, both nationally and regionally and internationally[2].

North Macedonia has ratified international conventions in the field of environment protection and climate change[3] in order to harmonize policies and strategies also targeted, among other things, towards sustainable development. North Macedonia, as a party to the United Nations Climate Change Convention[4] is committed to contributing to achieve the global goal of stabilizing greenhouse gas concentrations in the atmosphere at a level that would prevent a rise in global warming by more than 2°C.

Digitalization provides access to an integrated network of unexploited big data with potential benefits for society and the environment. The development of smart systems connected to the internet of things can generate unique opportunities to strategically address challenges associated with the United Nations Sustainable Development Goals (SDGs) to ensure an equitable, environmentally sustainable, and healthy society. This perspective describes the opportunities that digitalization can provide towards building the sustainable society of the future. Smart technologies are envisioned as game-changing tools, whereby their integration will benefit the three essential elements of the food-water-energy nexus: (i) sustainable food production; (ii) access to clean and safe potable water; and (iii) green energy generation and usage. It then discusses the benefits of digitalization to catalyze the transition towards sustainable manufacturing practices and enhance citizens' health wellbeing by providing digital access to care, particularly for the underserved

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[1] Resolution adopted by the General Assembly on 25 September 2015 [without reference to a Main Committee (A / 70 / L.1)] 70/1. Transforming our world: the 2030 Agenda for Sustainable Development

[2] Z.Janevski, V.Krstik Tasheva, Circular Economy Resource Efficiency, Scientific paper in Economic development No.1-2/2019 , p.51

[3] Ibid p.53

[4] Article for ratification of the United Nations Framework Convention on Climate Change ("Official Gazette of the Republic of Macedonia" No. 6/97).

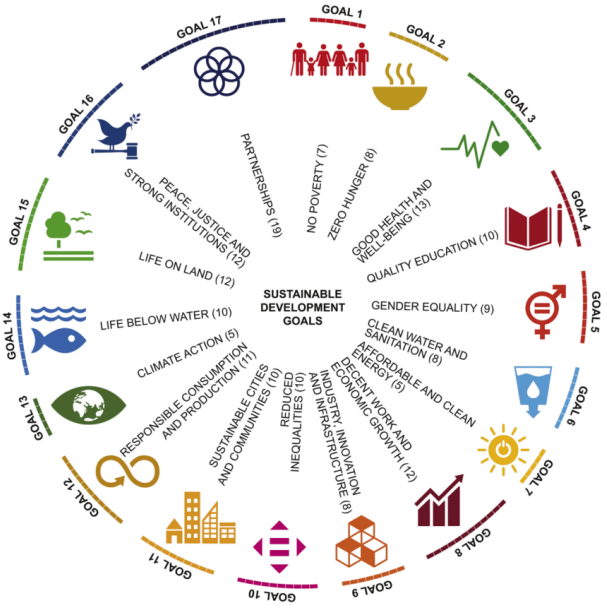
communities. Finally, the perspective englobes digitalization benefits by providing a holistic view on how it can contribute to address the serious challenges of endangered planet biodiversity and climate change[5].

2.1 Digital transition opportunities

The world is transitioning through the digitalization era in which most of our daily activities are highly dependent on innovative digital and computer technologies. These contemporary technologies have got their applications in socio-economic, environmental, sustainable, and climate research applications to enhance the productivity and efficiency of a given system.

Digitalization is the integration of digital technologies into everyday life. Such integration is possible by the digitization of information. Digitization is defined as the process of converting physically collected in- formation (e.g., sensors, written information, etc.) and knowledge into a computer-readable language. The tedious effort of digitizing information gathered over centuries (including paintings, images, and video formats) has given valuable fruits propelled by information technologies. The benefits resulting from digitalization contributed to the development of tools and sensors throughout integrated into the internet of things (IoT) environment. The IoT is a robust network of physical objects connected over internet through embedded sensors, software, and other technologies that enable interchange and collection of data. The convergence of simultaneously developed technologies for real-time analysis, machine learning, and artificial intelligence manages a massive amount of data, also known as big data. The high value of these massive data sets generated is not yet fully exploited but generates unique opportunities to catalyze the transition to more efficient and sustainable smart integrated cities.

The creative development of digital tools to generate, use, transmit, or source electronic data for organizational activities can be used to achieve SDGs. These tools that contribute to achieving these specific targets could be defined as digital sustainability. Digital Sustainability is understood as the effort of developing and deploying smart technologies to secure sustainable economic growth while considering and integrating the SDGs. Modern digital innovations like artificial intelligence and machine learning techniques have seen exponential growth in their value, estimated to add around 14% to the global economy by 2030.



Digitalization aspects related to SDG is presented in figure 1[6].

[5] The Authors. Published by Elsevier B.V(2021). This is an open access article under the CC BY license (http://creativecommons.org/licenses/by/4.0/), p 2

[6] M.E. Mondejar, R. Avtar, H.L.B. Diaz et al.(2021) Science of the Total Environment 794 (2021) 148539, p.5

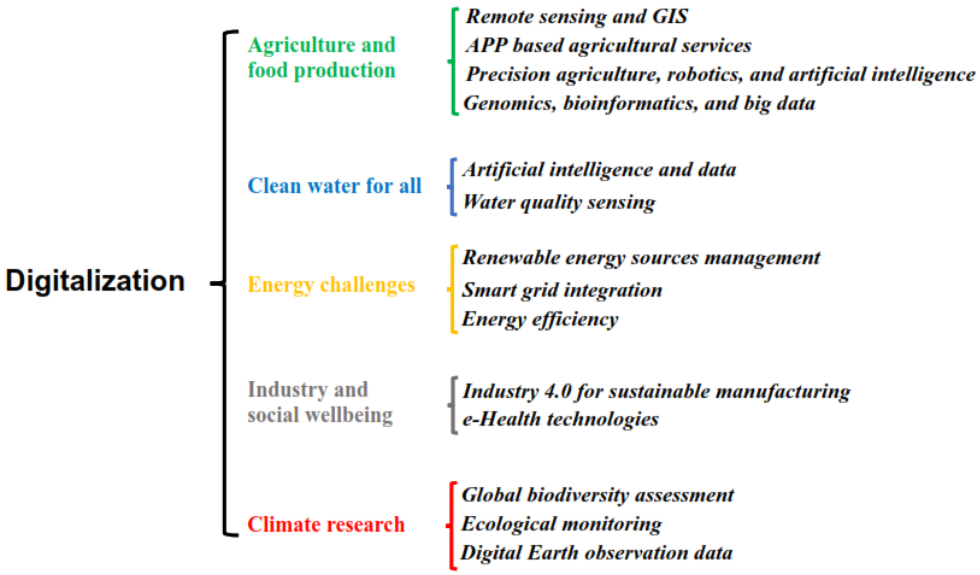


FIGURE 1 SUMMARY OF DIGITALIZATION ASPECTS RELATED TO SUSTAINABLE DEVELOPMENT GOALS

More detailed analyses about these processes of digital transformation are elaborated in Annex 1 of this report

2.2 A green and digital transformation of EU

Ministerial declaration of EU points out that smart use of clean digital technologies can serve as a key enabler for climate action, environmental sustainability, and reaching the UN Sustainable Development Goals by improving energy and resource efficiency and facilitating circular economy, reduced emissions, pollution, biodiversity loss and environmental degradation, and improved resilience to climate change impacts.[7]

It means that the ICT sector should ensure the environmentally sound design and deployment of digital networks and technologies and products as Europe can compete globally in the green tech market, particularly by promoting innovative technologies, low-power electronics and environmental sustainability of ICT solutions. Europe goal is to accelerate and take the global lead on the green digital transformation, building on the Council Conclusions of 17 December 2020 on "Digitalisation for the Benefit of the Environment", as well as on the Digital Strategy [COM/2020/67 final].

The signatories[8] of the Declaration on A Green and Digital Transformation of the EU will take action at national level in the following areas:

- Set up a digital twin of the earth to help monitor climate change;
- Make data available in common European data spaces;
- Support the deployment of green digital solutions that accelerate the decarbonisation of energy networks, enable precision farming, decrease pollution, combat the loss of biodiversity and optimise resource efficiency;
- Lead on energy efficient artificial intelligence solutions;
- Help cities become more green and digital;
- Use technologies to make buildings more energy efficient;

[7] https://digital-strategy.ec.europa.eu/en/news/eu-countries-commit-leading-green-digital-transformation

[8] Republic of North Macedonia doesn't sign Declaration yet.

- Support smart and sustainable mobility systems;
- Use digital product passports to track and trace products to improve circularity and sustainability;
- Promote eco-designed products and accessible digital public services;
- Contribute to the use of a climate neutral, sustainable and energy efficient European cloud and blockchain infrastructure;
- Propose permits for deployment of networks and data centres that comply with the highest environmental sustainability standards;
- Making green public procurement the default option overall;
- Develop low power hardware technologies;
- Use of EU funding programmes and private equity to support European green tech start-ups and SMEs

The signatories will regularly assess their progress made and feed it into the Commission's ongoing monitoring activities. They will also contribute to a shared repository of best practices and experiences to implement the Declaration. In addition, the establishment of the European Green Digital Coalition will accelerate the ICT sector's transition towards a sustainable, climate neutral, circular and zero pollution economy while at the same time contributing to innovative, sustainable, inclusive and resilient society and economy.

2.2.1 Potential for digital transformation on specific environmental areas

The most relevant studies[9] emphasize four specific areas with big potential for digital transformation: pollution control; waste management; sustainable production and urban sustainability.

2.2.1.1 Digital transformations in pollution control.

Digital technologies transform the ways pollution is measured, controlled, and managed. Four categories are included in digital transformation in pollution control.

- **Air pollution**: An unprecedented number of opportunities are afforded by digital technologies to study, control, man- age, and predict air pollution in cities across the globe. Digital technologies are transforming the relevant processes and mechanisms in this regard.
- **CO2 emission**: As governments and business organizations worldwide move to adopt practices to reduce carbon dioxide emissions into the atmosphere, the digitalization of environmentally sustainable practices is gaining traction;
- **Water treatment**: The treatment of wastewater through the application of digital technologies opens remarkable channels for efficient energy use and saves resources to minimize the impact on the environment;
- **Climate change/Disaster management:** Digital technology-driven methods can play a vital role in reducing the carbon footprint on the environment, regulating climate change, and managing natural disasters. Organizations are increasingly capitalizing on these opportunities

Furthermore, big data can play a crucial role in understanding the opportunities and challenges associated with climate change by measuring carbon emissions and employing techniques to reduce the footprint on the environment.

[9] Abdul Karim Feroz, Hangjung Zo and Ananth Chiravuri (2021) *Sustainability* 2021, *13*, 1530. https://doi.org/10.3390/su13031530

2.2.1.2 Digital transformations in waste management.

Four categories are included in digital transformation in waste management.

- **Solid waste**: Th accumulation of municipal and industrial waste is imparting significant damage to the environment. Digital technologies are being used to develop new ways of coping with waste on remarkably large scales that were not imaginable a decade ago. Organizations can rely on sustainability-related opportunities to develop new business models in the age of Industry 4.0.
- **E-waste**: There are increasing calls for effectively using digital technologies to manage the waste generated by electronic devices
- **Food waste**: Industrial and household food waste can be successfully disposed of using digital technologies such as IoT and big data.
- **Agri-waste:** Digital technologies are being employed to deal with the waste generated in agricultural processes for high-quality production

Digital technologies are widely used in the environmental sustainability domain. AI has been used in global warming, waste management, wildlife care, geographic information systems, environmental risk assessment, energy concerns, land-use planning, and geoscience. Big data is also gaining popularity in waste management and recycling

2.2.1.3 Digital transformations in sustainable production

Two categories are included in digital transformation in sustainable production:

- **Sustainable manufacturing**: Digital technology-driven manufacturing without harm to the environment are being sought after the circular economy concept has emerged. Such processes can reduce not only the cost but also the negative impact on the ecosystem;
- **Sustainable supply chain**: Digital technologies enable companies to eliminate waste across entire value chains to the fullest extent, enhance sustainable consumption, and eliminate harmful waste residue to the environment.

Sustainable production can allow manufacturers to reduce resource use, degradation, and pollution while achieving development goals. Sustainable smart manufacturing has been advanced by digital technologies such as IoT, cyber-physical systems, cloud computing, AI, big data analytics, and digital twin.

2.2.1.4 Digital transformations in urban sustainability

Two categories are included in digital transformation in urban sustainability:

- **Smart cities**: The technological developments of the modern world drive the transition of urban centers into smart cities by enhancing citizens' well-being, improving sustainability, expanding the scope of efficient energy use, and providing a conducive environment for healthy practices:
- **Sustainable cities:** Aided by digital technologies smart cities further evolve into sustainable cities when they adopt zero waste generation mechanisms, use of clean energy, and sustainable consumption practices.

Sustainable urban development has been facing severe environmental pollution, resource shortage, and traffic jams. A smart city is considered an effective approach to deal with such challenges. Many cities are increasingly adopting specialized digital technologies such as big data and IoT to address issues related to the environment and society.

2.3 European data centres

The Environmental data centre website[10] is the coordinated entry point for European data relevant to the selected theme and products related to the indicators. It provides users with easy searching, viewing and download functions. It also gives links to involved partners and supporting documents.

2.4 European data centres under responsibility of European Environment Agency (EEA)

2.4.1.1 European air pollution data centre

The air pollution data centre provides access to data and information related to the amount of air pollutants emitted into the atmosphere from different anthropogenic (human-made) sources as well as measured ambient air pollution at monitoring stations across Europe. The air pollution data centre also provides access to related products for air pollution indicators and assessments. Priority is given to policy-relevant data and information for European and national institutions, professionals, researchers and the public.

2.4.1.2 European biodiversity data centre

The biodiverstity data centre provides the coordinated entry point for data on species, habitat types and sites of European interest. The data and information maintained here are used in biodiversity indicators and assessments. Priority is given to policy-relevant data and information for European and national institutions, professionals, researchers and the public.

2.4.1.3 European climate change data centre

The climate change data centre provides access to data and information on greenhouse gas emissions, climate change impacts, vulnerability and adaptation in Europe. Priority is given to policy-relevant data and information for European and national policy makers, influencers (such as NGOs, business, media and scientists) and the general public.

2.4.1.4 Environmental data centre for land use

The environmental data centre for land use provides data to understand the relationship between land use and environmental impacts. Information is provided at different scales combining European coverage with global and in situ survey data. The core of data centre activities is related to dissemination of operational services in connection with key land cover/land use datasets, relevant indicators and derived products based on spatial analysis and change detection.

2.4.1.5 European water data centre

The water data centre provides the European entry point for water related data as part of the Water Information System for Europe (WISE). It contains the input (reporting mechanisms) and output (visualisation of results) for compliance information under several water directives (WFD, Bathing water, UWWT directive, etc) as well as voluntary information as reported e.g. under the EEA regulation through the Eionet. The information compiled and maintained here is used in indicators, assessments and policy developments that are further accessible through the thematic links in WISE.

2.4.2 Data centres under responsibility of EUROSTAT

2.4.2.1 European data centre for waste

The central entry point for reporting of data under Community legislation on waste and providing information on waste and the associated environmental impacts.

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[10] https://www.eea.europa.eu/data-and-maps/european-data-centres

2.4.2.2 Environmental Data Centre on Natural Resources

Eurostat's Environmental Data Centre on Natural Resources (EDCNR) is an online repository for a broad range of data on Natural Resources in Europe. The EDCNR provides information on Resource Efficiency Indicators, as well as basic statistics and indicators on Natural Resources.

2.4.3 Data centres under responsibility of Joint Research Centre (JRC)

2.4.3.1 European soil data centre (ESDAC)

The European Soil Data Centre acts as the primary data contact point for the European Commission's DG ENV in order to fulfill its soil information needs.

2.4.3.2 European forest data centre (EFDAC)

The European Forest Data Center (EFDAC) is a focal point for policy relevant forest data and information by hosting and pointing to relevant forest products and by providing web-based tools for accessing and updating information located in EFDAC.

2.5 Measures to improve the energy efficiency and circular economy performance in cloud computing and data centres.

Digital technologies can offer green solutions to different sectors of the economy. Equally important is the 'greening' of the digital sector itself.

It has been estimated that digital technologies account for between 5 to 9% of global electricity consumption. This is likely to increase with digitisation and emerging technologies such as artificial intelligence, the Internet of Things and blockchain. This may lead to problematic increase of greenhouse gas emissions if no proper action is taken.

The European Commission conducted a study on Energy-efficient Cloud Computing Technologies and Policies for an Eco-friendly Cloud Market[11] addressing the issue of growing energy consumption due to the expansion of cloud services in Europe. Study encompassed of 38 recommendations on how IT products, infrastructures and cloud systems can increase overall energy efficiency.

The topic of energy-efficient cloud computing has become a priority for the EU. Data centres need to become more energy efficient, reuse waste energy such as heat, and use more renewable energy sources, with a view to becoming carbon-neutral by 2030.

To meet this goal, the Commission will rely on a mix of existing instruments, reviews of existing legislation and new initiatives.

Existing instruments include:

- the Ecodesign Regulation on servers and data storage products
- the EU Code of Conduct on Data Centre Energy Efficiency
- the EU Green Public Procurement criteria for data centres, server rooms and cloud services

The Commission is also linking energy efficient data centres to policy and funding initiatives, notably through:

[11] https://digital-strategy.ec.europa.eu/en/library/energy-efficient-cloud-computing-technologies-and-policies-eco-friendly-cloud-market

- the Commission Proposal for a Directive on energy efficiency (recast) introducing new elements to improve the energy efficiency and sustainability monitoring of data centers;
- The Taxonomy Regulation and its Delegated Act adopted in July 2021, which sets the framework for investments to be qualified as sustainable and whose delegated act is currently under finalisation, has a section on data centres;
- Its funding programmes: Horizon Europe, Connecting Europe Facility 2, Digital Europe programme, InvestEU and the Recovery and Resilience Facility will support the deployment of an innovative, green and secure cloud.

The Commission is currently conducting a study to address the lack of commonly accepted definitions and methods to assess the energy-efficiency, climate-neutrality and overall sustainability of data centres: 'Greening cloud computing and electronic communications services and networks: towards climate neutrality by 2050'.

2.6 Conclusions

1. Relevant studies and countries' experience present significant role of digital transformation in reducing climate change and environment degradation. Digital technologies can redefine agriculture and food production system, support to ensure clean water, address energy challenges and catalyse changes in industry and social wellbeing. Furthermore, Digitalization tools can assist in climate research and ecological monitoring.

2. Green and digital transformation of EU is forward looking process to provide higher global competitiveness. In parallel the digital transformation is seen as opportunity to improve pollution control, waste management, sustainability of production and urban sustainability. It is linked with big data centres that provide better monitoring, management and control of the action related to reach UN SDG.

3. Despite digital technologies can offer green solution the important priority is the "greening" of the digital sector itself. ***Estimation that digital technologies account for between 5 to 9 % of global electricity consumption will be likely increase for the next period***. It will stem from digitisation and emerging technologies such as artificial intelligence, the Internet of Things and blockchain. Therefore, the R$D, legislation and investment will be focused on IT equipment, infrastructure and cloud systems that can increase overall energy efficiency of digital technologies.

3 Analysis of industrial and service sector in North Macedonian economy.

North Macedonia has taken action on both scenarios, energy and circular economy, as green and digital transformation can be accelerated. The government adopted strategic documents related to CO2 emission, energy consumption, circular economy and digital transformation. It can be organized according to energy and circular economy scenario.

3.1 Industrial and service sectors in energy scenario

The strategy has three scenarios, reference, moderate transition and green. For each scenario, the forecasts for average annual growth of the Gross Domestic Product are 3.3%, positioning the Republic of Northern Macedonia at the current levels of GDP per capita of the countries of Central and Eastern Europe (CEI).

The modeling in the Strategy is realized with the help of **software tools - MARKAL and Power2Sim**. The goal of the MARKAL model is to define the optimal development of the overall energy system in the North Macedonia based on the lowest price, while the Power2Sim model is used to simulate the market of electricity and determination of the results of the comprehensive MARKAL model..

3.1.1 Energy development strategy of North Macedonia 2040

3.1.1.1 Energy efficiency

The strategy maximizes energy savings that reach 51.8% of the primary and 27.5% of the final energy in the 2040 green scenario.

It will be achieved by maximizing the policies and measures for energy efficiency in the sectors of buildings, public, industry, transport, heating and cooling, transformation, transmission, distribution and response to energy demand. All these measures directly affect the reduction of emissions, reduce the dependence on energy imports and stimulate the domestic economy with local employment opportunities.

3.1.1.2 Usage of Renewable Energy Sources

Strategy recommendations are:

- greater integration of RES for electricity production, especially from **wind and solar, greater penetration of electricity vehicles, storage of energy in batteries.**
- Termination of operation of thermal power plants Bitola and Oslomej construction of new facilities for RES (photovoltaic power plants and natural gas plants), retraining of existing employees and new employment.
- Develop programs for socially responsible and equitable transition to eliminate the negative effects of job losses by retraining and replacement of employees and stimulating new jobs in low carbon technologies and services.

3.1.1.3 Decarbonization

Decarbonization: in the Green Scenario in 2040, GHG emissions are reduced by 61.5% compared to 2005 or 72.8% compared to the BAU (Business as usual) scenario, while significantly increasing the use of RES in a sustainable way, reaching their share of 45 % in gross final energy consumption. Despite the fact that Northern Macedonia has lower greenhouse gas emissions per capita by ~ 30% compared to the EU, greenhouse gas emissions by GDP are five times higher than the EU in 2014.

Two thirds of the total greenhouse gas emissions come from combustion in the energy sector, with the **transformation of energy, industry and transport having the largest share.**

Strategy aims at**:**

- Promoting the use of RES in a way that ensures sustainable development. The share of RES in total final energy consumption is increasing in all scenarios, reaching 35-45% in 2040. Photovoltaic (PV) and wind power plants will be the fastest growing technologies for electricity generation in all scenarios (up to 1,400 MW PV and 750 MW wind), while the construction of new small hydropower plants should be carefully assessed in terms of environmental impacts versus benefits. from the produced electricity
- Electrification of the heating and cooling sector by using more efficient heat pumps and central heating systems from thermal power plants-heating of natural gas and biomass (including waste biomass). Use of large heat pumps, waste heat and heat storage facilities in the production of heat in central heating systems. Promoting a combined hot water system using central heating, electricity and solar thermal systems.
- Increase the **share of biofuels to 10% in 2030 and increase the share of electric vehicles**. Financial incentives for the purchase of electric vehicles are provided, as well as the construction of the necessary infrastructure at national and local level.

3.1.1.4 Research, Innovation, Competitiveness and investment

The strategy minimizes the total cost of energy system based on optimization at the lowest cost, taking into account specific conditions in the country.

In the pillar research, innovation and competitiveness with the Strategy are recommended:

- Incorporate energy transition technologies into national research and development priorities and stimulate the cooperation of research centers (institutes, universities, development departments, etc.) with policy makers, industry, utilities, **municipalities** and associations.
- Stimulating new services and jobs, especially for small and medium enterprises (SMEs) in the field of RES and EE. North Macedonia has a positive business environment, which is a very good precondition for supporting these SMEs in strengthening new investments, reducing unemployment and stimulating overall growth. However, additional financial and technical assistance is needed for SMEs in the energy sector in order to facilitate companies' access to external services.
- Increasing the capacity for withdrawal of international donor funds. Primarily, this refers to the responsible ministries that need to provide effective units for planning, managing, monitoring and evaluating donor projects. This will enable the utilization of the many unspent funds from the international donors and financial institutions to which the country has the right to use, including the utilization of the funds related to the fulfillment of the obligations of the Paris Agreement.

In order to achieve an economically competitive transition, the system will need cumulative overnight investments in the range of 9.4 to 17.5 billion euros in the period until 2040, depending on the chosen scenario. Energy efficiency and RES investment are the main focus of all scenarios, which opens up the possibility of increased access to funds that recognize the importance of energy transition projects - primarily EU funds, as well as international financial institutions and donors. The national budget will also play a role as an important option for financing RES and EE projects, but also for the revitalization of TPP Bitola. The most cost-effective scenario is the Green Scenario.

Cumulative savings in the Moderate Transition Scenario are estimated at 5.4 billion euros, while in the Green Scenario the estimate is 7.4 billion euros.

From the point of view of the realization of the three scenarios, the critical year is 2025, and the decision on what will happen this year should be made in 2020 at the latest in 2021. This requires urgent action from relevant energy stakeholders to launch activities at all levels of management.

The Strategy recommends the establishment of a Steering Committee, which will be chaired by the Deputy Prime Minister of the Republic of Macedonia in charge of Economic Affairs , who will be responsible for its implementation.

As a first step, the Government should prepare a Program for implementation of the Strategy, within six months from the day of adoption of the Strategy.

Energy Efficiency Project in the Public Sector, Ministry of Finance and World Bank, LINK

Public call for use of funds for investments in municipal energy efficient facilities, with a total fund of 10.5 million euros, which was published on 26.05.2021

This is related to the national plan for energy efficiency (2020-2024) page 42. LINK for achieving Objective Renovation of existing public buildings in order to meet the objectives of the EE Directive and the Law on Energy Efficiency, where 21 million euros are provided for the renovation of municipal buildings.

3.1.2 4th National Energy efficiency plan (NEEAP 2020-2022)

NEEAP introduced two approaches:

- In Top-down approach 4 sectors are included: households Industry, Transport, commercial/ service sector,
- In Bottom up 7 sectors are included: buildings, households, public sector, commercial sector, Industry, Energy and Transport

Measures related to for NEEAP goals [12] are presented in the table below. Each measures is analysed about targeted sectors, Energy consumption savings, Green Gas emission (GGCO2 equivalent), Investment in Euro and tools for digitalisation.

- Financial Plan
  - ~1 billion Euro construction of residential and commercial buildings
  - ~200 million Euro, construction of public buildings of central and local self-government
  - ~130 million euro, EE appliances
  - ~ 480 milllion euro, electric vehicles
  - ~ 100 million euro solar and photovoltaic panels

[12] National Energy Efficiency Action Plan 2020-2022 p.25-65

TABLE 1 MEASURES IN 4TH NEEAP RELATED TO SECTORS, ENERGY CONSUMPTION SAVINGS, INVESTMENTS AND DIGTALISATION TOOLS

Measures	Sectors	energy consumption savings 2022 ktoe/GWh	Gg Co2 equivalent	Investments mil. euro/Sources	Digitalisation
Compulsory Energy efficiency (EE) scheme *Energy audit, Measuring and payment information*	All except transport	18,5	43	33,1 Consumers and private companies	Database for sectors, energy auditors, measuring consumption
Informative program for consumers 9 raising awareness for EE	Households and commercial	33	50	Private sector, donors, Central and local govern.	Information center for EE, internet platform, savings from appliances
Issuing certificate for EE of buildings	Households commercial, public	1	3,3	56,6 Private sector	BIM class A+, A &B, model MARKAL Buildings database of Energy Agency
EE of buildings (RES production and EE)	Households commercial, Industry	20,61	17,5	15,6 Private sector, donors, EE fund	Solar power, costs optimization, model MARKAL
Solar thermal collectors	Households, commercial	2,5	5,5	5,5 private sector, Central Government	costs optimization, model MARKAL
Denoting electric appliances and equipment	Households, commercial	7,8	23	20,8 Private, EE fund	costs optimization, model MARKAL
Replacement of windows	Households,	28,5	73,5	5,4 Private, banks, EE finds	costs optimization, model MARKAL
Renovation of existing building stock	Households, commercial	28,5	73,5	176,7 Private, donors, EE fund, Central Government	BIM software, costs optimization, model MARKAL

New residential buildings	Households,	28,5	73,5	176,7 (only for EE standards) Private, donors, EE fund, Central Government	BIM, costs optimization, model MARKAL, smart home, IoT
Construction of new commercial buildings	Commercial	28,5	73,5	176,7 (only for EE standards) Private, donors, EE fund, Central Government	BIM, costs optimization, model MARKAL
Construction of passive buildings	Households, private, public	1	3,3	56,6 (only for EE standards) Private investors, donors, EE fund, Central Government	BIM software, costs optimization, model MARKAL, database class A+ buildings
Throwing out the bulbs with hot fiber	Households	31,5	83	20,7 Private, Central and local Govern, donors	costs optimization, model MARKAL
Buildings of Central and local Government	Public	2,5	9,1	44,5 (only for EE standards), Central and local Government, donors	BIM software, costs optimization, model MARKAL, database class of buildings
Construction of new buildings of Central and local Government	Public	2,5	9,1	44,5 (only for EE standards), Central and local Government, donors	BIM software, costs optimization, model MARKAL, database class of buildings
Improvement of street lightening (LED bulbs)	Local self-government	4,2	20,3	1,8 Central and local government, ESCO PPP	costs optimization, model MARKAL,
Green public procurements	Public bodies	0,7	2,5	0,8 Central and local government,	costs optimization, model MARKAL, database class of green procurements

Energy management in manufacturing industry, ISO 50001	Industry	3,3	13	N/A	Energy management software
Introduction of efficient electric motors	Industry	1	4,3	6,8 Private investors	Energy software
Introduction of advanced technologies	Industry	23,3	78	56,7 Private investors	Automatization, robotics, CNC
Better utilization of railway	Transport	9,2	30	42,1 Central Government	Multimodal passenger ticketing, JPS
Renewal national vehicles stock	Transport	28,3	89	134 Central and local government, private	costs optimization, model MARKAL, database class of vehicles
Advanced mobility	Transport	0,9	2,6	2 local government, private	Software for subvention for bicycles
Electrification of transport (electric vehicle)	Transport	10,4	30	100 Central and local government, private	Database electrical stations, JPS monitoring
Power centrals with biomal, thermal pumps, biomass stoves	Households, commercial	62,5	185	26 Central and local Government, donors, private investors	costs optimization, model MARKAL, database of subventions
National RES production of electric power	Electric power producers	6,4	5	33,5 EBRD and PPP	

The table 1 are presented measures to be implemented in 7 sectors: buildings, households, public sector, commercial sector, Industry, Energy and Transport and their role in provision of energy servings CO2 emission and planned investment. The last column are comments about the needs for digitalization lied with the planned measures. The data from table 1 were used for selection of the sectors that will be further researched.

3.2 Industrial and service sectors in circular economy scenario

Industrial and service sectors in circular economy are analysed in Plan for waste management of Republic of North Macedonia 2021-2031, Green agenda in Western Balkan and Smart specialization Strategy of North Macedonia.

3.2.1 Sectors in National waste management plan 2021-2031

The waste sector is analysed in regard to trends of increasing green house gas emissions and potential for circular economy.

The waste sector is one of the sectors with a trend of increasing greenhouse gas emissions reaching 610 Gg CO2-eq in 2016, which is doubled compared to 1990 or 6.3% more compared to 2014.Out of all sectors, the emission from the category "solid waste disposal" are the most significant participants with 77.5% in the total greenhouse gas emissions in 2016.The second category with a significant amount of greenhouse gas emissions is "treatment of wastewater and discharge ”by about 19% in 2016. Combustion and open combustion of waste contribute with about 4% in the last three reported years. CH4 and N2O emissions from the category Biological treatment of solid waste do not contribute largely of total emissions due to the small amount of reported composted waste. About 92% of GHG emissions in the last three years of the reporting period are CH4, while N2O and CO2 account for 7.2%, 1%, respectively.

The “Circular Economy Package"[13], in order to increase the recycling rate and achieve a higher level of resource efficiency, includes the following objectives:

- 50% recycling rate (including preparation for reuse) of municipal waste by 2020, increase of 55% by 2025, 60% by 2030 and 65% by 2035.
- Recycling rate of packaging materials from 65% by 2025, and 70% by 2030
- Limitation of communal waste disposal from 10% until 2035.
- Separate collection of materials for reuse - paper, metal, glass and plastic by 2025.
- This separate collection will be expanded to include bio-waste by 2024 and textiles as well as hazardous household waste by 2025.
- Processing rate of 70% (preparation for reuse, recycling and other processing of materials) for all inert and non-hazardous, waste construction waste by 2020.

Achieving the objectives is supported by Action plan for circular economy for cleaner and more competitive country[14]

Among the key activities to reach the objectives are establishing waste management sector and Agency for living environment as the data about implementation of Plan can be monitored and managed.

The investment in digital monitoring system is estimated in the amount between 1,5 and 4 million euro with maintenance costs of 185.000 euro per year. Five employees are planned to manage to system, to collect and analyse data from municipalities[15].

Currently Macedonian Information Centre for living environment is responsible for data collection related to air, land, water and generated waste from municipalities.

[13] Plan for waste management in Republic of North Macedonia 2021-2031, p.22 Link to the document

[14] Ibid. p.25

[15] Ibid. p.43

3.2.1.1 Communal waste

The communal waste is continually increased from 351 in 2010 to 452 kgr per capita in 2020. The generated communal waste, in North Macedonia, is from **households, commercial and commercial activities, business buildings, public institutions, small businesses, waste from yards and gardens**, the content of waste containers, street waste and garbage from the markets.

The largest part of municipal waste in the country was created by households in the areas covered by the municipal waste management system (83% of the total collected). As a result of the long-running economy based on linear economy, North Macedonia now has about 1,000 municipal "dumps", especially in rural areas, which are not recorded and 54 active landfills.

3.2.1.2 Commercial and industry sector waste

The statistics data show that production, followed by agriculture, forestry and fisheries, as well as mining and quarrying, are the most important sources of commercial and industrial waste in the Republic of Northern Macedonia.

Total commercial and industrial waste, generated by sectors in Macedonia in 2018 year (last processed data published in March 2020), was1,142,663.00 tons. The largest quantity (531,762.00 tons) was created in the processing industry sector. The total amount of hazardous waste generated was 20,484.00 tons, in the mining and quarrying sector[16].

There are more than 150 registered entities for collection, storage and treatment of non-hazardous waste (paper, plastic, scrap metal). There is no information about responsible body for monitoring and collection of data for this kind of waste/

3.2.1.3 Waste in Construction sector

The annual generation of construction waste and rubble depends on the fluctuations of the construction market and the estimated quantities are around 460,000 to 500,000 t / year.

The Waste Framework Directive sets a target of achieving a processing rate of 70% (including preparation for reuse, recycling and other processing of materials) for all non-hazardous construction waste and rubble by 2020. Achievement of this target is postponed until 2030.

The building sector is one of the key areas where the highest energy cost savings could be reaped. Different financial instruments (guarantee facilities, energy performance contracts, on-tax and on-bill financing) could be used to achieve higher renovation rates of both private and public buildings through attracting private finance. Digital upgrades can also improve energy efficiency of buildings by 15-25% and at the same time provide possibilities for telework, telehealth and tele-education. Extending the "EU renovation wave" to the Western Balkans could stimulate investment and create jobs.

At the same time, greater circularity and more efficient use of materials present new opportunities for further reducing greenhouse gas emissions in buildings. Hence, comprehensive approaches targeting materials efficiency along the entire lifecycle of buildings should be encouraged and supported, for example during renovation efforts.

3.2.2 Sectors in Green Agenda in Western Balkan

Addressing climate change is a priority for the politics of the region. EU implements Green Agenda for Western Balkan where EU approximation process include alignment of national legislation in terms of climate change, clean energy transitions and circular economy: sustainable production and consumption. The WB countries adopted national strategic documents that set up national targets related to energy efficiency and waste management. National authorities managed those targets by increasing resources

[16] Plan for waste management in Republic of North Macedonia 2021-2031, p.67 Link to the document

productivity and its retaining in economy. Regarding waste and plastics is noticed low recycling rate (3 % in Western Balkan in comparison of EU 44%)[17]

Half of total greenhouse gas emissions come from resource extraction and processing. It is not possible to achieve the climate-neutrality target without transitioning to a fully circular economy. In order to achieve circularity, measures should be taken to address the entire life cycle of products, from design and manufacturing to consumption, repair, reuse, recycling, and bringing resources back into the economy.

The recommendation is that the region has to look for options to reduce the consumption footprint and increase the circular material use rate, which in turn will boost economic growth.

The sectors with significant footprint are agriculture, manufacturing, building sector, transport and waste collection and disposal.

3.2.3 Sectors in Smart Specialization Strategy of North Macedonia

Draft Smart specialisation Strategy of North Macedonia has selected 6 areas for smart specialization:

1) Food and beverage production with two sub-sectors: smart agriculture and food processing with high added value;
2) Information and communication technologies (ICT) sector, with sub-sectors custom software development and IT infrastructure;
3) Buildings sector with smart buildings and sustainable materials;
4) Manufacturing with electrical equipment and mechanical parts;
5) Sustainable tourism and catering;
6) Energy sector with energy production for future and cross-sectorial connections

Selected sectors has high potential for digitalisation that will decrease its environmental footprints.

3.2.4 Sectors in National ICT Strategy

ICT Strategy of North Macedonia 2020-2025 is mainly focused on digitalisation of public services (e—government) and establishment of Central Digital Agency of North Macedonia.

The digital transformation of commercial, industrial and service sectors is not included in the Strategy.

3.2.5 Data Centres in North Macedonia

Data centres in North Macedonia are analysed as public service, private companies database and e-sales centres.

3.2.5.1 Data centres for public service

Data centers for public services are located in Ministry of interior affaires, Ministry of Finance, Ministry of Information society and administration, Agency for real estate Cadaster, National Energy Agency, Macedonian information centre for living environment, State statistical Office, National Bank of Republic of North Macedonia, Public revenue office, Central registration office, Custom office. The most of them are data center that doesn't meet requirements for data center and the deployment is in premise. Only Agency for real estate Cadaster and Register of population in Ministry of Information society and administration are data centers with cloud computing and can provide valid digital documents.

There is no accessible information about the size of the centers, IT infrastructure and digital technologies used. For further research the data centres linked with environmental footprint will be selected National

[17] Guidelines for the implementation of the Green Agenda in Western Balkan, https://ec.europa.eu/neighbourhood-enlargement/guidelines-implementation-green-agenda-western-balkans_en

Energy Agency, (energy data) Macedonian information centre for living environment (waste disposal and recycling data) and Custom office (EE equipment and imported materials).

3.2.5.2 Private companies' data base

Net.Bit Datacenter

Datacenter is designed and delivers services according to the highest international standards, including ISO27001 for information security and ISO20000 for service management.

(1) https://www.datacentermap.com/macedonia/skopje/netbit-datacenter.html

Datacenter DTS

Datacenter DTS Corp is an independent datacenter service provider. The company offers: dedicated and virtual servers for best price, domain registration, cloud hosting, disaster recovery.

(2) https://www.datacentermap.com/macedonia/skopje/datacenter-dts.html

neoDC

Location/Facility: 1st floor in Neocom's Head Quarters, Premises of 250m2Access by freight/service elevator or stairs. **Preparation room**: Dedicated power and communication trays, Two physical paths for network, communication and power feed, Server and telecommunication cabinets. **Two independent power feed rooms** and Two independent interconnection rooms - MeetMe Room 24x7x365 access.**Power**:2x112KW dedicated power feed on different paths.**Own power substation**: 2 diesel generators with total capacity of over 455KVA;2 independent redundant modular UPS (2x100KW; 2 independent modular rectifiers for -48V (2x12KW) with dedicated batteries. Over 2 tons of UPS batteries

Security: Multilevel granular access control from welcome desk to cabinet;24x7x365 physical security;24x7x365 CCTV surveillance;Auditing all access control events;Cabinet open door alarms

Cooling: Controlled temperature of 22oC (+/- 2 oC) with two redundant HVAC;Controlled humidity of 40%-60% with integrated humidifiers and dehumidifiers;Special procedures in place for particles contamination control;Environment monitoring sensors, including water leak and airflow

(3) https://www.datacentermap.com/macedonia/skopje/neodc.html

NOC Telesmart Telekom

Skopje Exchange Teleroom (SET) is the first independent telecommunication point in Macedonia where all operators may use the full spectrum of wholesale products and services with highest guarantied reliability and quality, including: Managed network solutions supporting voice and data applications, Internet protocol including Voice over IP, High speed data, Ethernet access, Call centers, Metro ring solutions offering extensive reach and scale, Innovative network-based security solutions detecting and preventing network security threats, etc.

*Colocation services: S*ystem room in Skopje is the place for collocation and interconnection services like PoP and vPoP for operators. They provide carriers and providers with an efficient marketplace for integrated broadband and communication services. Collocation services gives fast and reliable links to other available carriers in the whole area, in the meanwhile maintaining financial and technical

independence from the network providers. The big international carriers in the market guarantee you a long-term customer links as well as the security, quality and the agreed standards of our services.

Telesmart's node is the first Macedonian who is directly connected, by a big capacity link, with the biggest and the most significant European node in Wien.

Skopje Exchange Teleroom aims towards being one of the main players on the Macedonian telecommunication market, and one of the most familiar names in the ICT business in our country.

Interconnection services Telesmart as a telecommunication operator offers interconnection services which can be used by all operators. We are offering a wide range of international telecommunication services:

1. Digital Leased Lines - DLL
2. IP (internet protocol)
3. IP VPN (Internet protocol virtual private network)
4. Collocation of equipment in independent telecommunication room - SET

Telesmart make efforts to better its quality level, reliability and speed at the telecommunication services, and to supply a wide range of services with the biggest possible standards, in order to have satisfied clients.

Security services

Telesmart's system room in Skopje is the perfect place for collocation and interconnection services like PoP and vPoP. It provides carriers and providers with an efficient marketplace for integrated broadband and communication services.

SET has standard DC power supply system (-48V DC) used by transmission equipment such as SDH multiplexers and the mediatory systems, with additional 220V AC if needed.

Maximum safety from electrical failures and loss of local power supply is maintained by use of uninterruptible power supply (UPS) with backup batteries. High performance generators are used as additional safety solution.

Collocation facilities are kept constantly monitored for temperature and humidity changes and maintained by its central air-conditioning system.

In cases of fire emergency, SET relies on our it's fire detection system combined with FM-200 fire extinguishing, non-toxic, Eco-gas.

As a rule, telecommunication equipment is always integrated in existing racks.

(4) https://www.datacentermap.com/macedonia/skopje/noc-telesmart-telekom.html

Interspace MK1

Interspace is a provider of communications and data center services. Colocation at Interspace means a secure partner that your business can rely 24/7. Our carrier-neutral colocation center is resilient, secure and ready to serve high uptime demands.

Date center features: Dedicated A+B power line feeds to each rack; Redundant cooling system; UPS protection and power generator protection; Power transformer connected to the power substation in a ring topology; Open access and open interconnectivity; Anti static floor that meets Motorola R56 standard; Fully enclosed and grounded metallic cable trunking system, dedicated trunks for data and power lines; Multi-zone fire detection system, and total-flooding fire suppression system using clean agents; Door and electric cables certified for 90 min fire resistance; Experienced professionals managing and monitoring all data center systems 24/7; 24/7 manned security presence at the site by certified security company; Linked to geographically diverse fiber optic routes; Located inside the Capitol City;

(5) https://www.datacentermap.com/macedonia/skopje/interspace-mk1.html

3.2.5.3 E-sales and call centres

In North Macedonia there are many e-sales centres[18] and call centres[19] that use IT infrastructure and big data about costumers. The digital technologies including cooling systems they used are spending high quantity of electricity. The investment in eco-design of equipment, IT infrastructure and software can reduce the energy consumption with significant environmental footprint.

3.3 Conclusion

1. Industrial and service sectors in North Macedonia are enforced by legislation to decrease environmental footprint and to introduce digital transformation of its activities. The digital transformation takes place on two level: public level, (central and local self-government)data collection and processing towards better monitoring, control and managing decisions and actions for decrease the impact on climate change and reduce environmental footprint of economic activities; and private sector level, introduction of digital technologies for more efficient use of energy and resources through circular economy.

2. Adopted legislation and strategic documents related to energy and circular economy scenario emphasize energy, agriculture, manufacturing, construction, transport, waste collection and disposal and tourism as sectors with higher potential for digitalisation that can have high impact on environmental footprint.

3. Implementation of laws and strategies for energy efficiency, waste management, circular economy, smart specialization and digitalization impose the needs for establishment of big data centres which according to EU commission regulation [20] should monitor the key performance indicators for achievement of expected results. However, the information about those data centres is not accessible and the characteristics of servers and data storage products are not available as the investment needs can be estimated.

4. Higher visibility is noticed for the big data centres established by private companies for the commercial use of data storage space and cloud systems.

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[18] https://www.google.com/search?q=e-sales+centers+mk&rlz=1C1GCEA_enMK948MK948&oq=e-sales+cnters+&aqs=chrome.1.69i57j33i10i160l2j33i22i29i30j33i15i22i29i30j33i22i29i30l5.8981j0j15&sourceid=chrome&ie=UTF-8

[19] https://www.google.com/search?q=call+center+macedonia&rlz=1C1GCEA_enMK948MK948&oq=call+center&aqs=chrome.2.69i57j0i512l2j0i457i512j0i402j0i512l5.11616j0j7&sourceid=chrome&ie=UTF-8

[20] Ecodesign Regulation on servers and data storage products; EU Code of Conduct on Data Centre Energy Efficiency; EU Green Public Procurement criteria

4 Ranking and selection of sectors for further research and analysis

Starting point in ranking of sectors for further research and analysis was growth of sectors GDP and share in total GDP in RNM. Using statistical data, the comparison of sectors by GDP, gross capital formation and number of business entities was carried out. It was analysis in regard to environmental footprint and legislation requirements in RNM as to digital potential can be estimated.

TABLE 2 SHARE OF GDP BY SECTORS 2017-2020

Sector	Share of GDP (%)			
	2017	2018	2019	2020
Gross Domestic Product	100	100	100	100
A Agriculture, forestry and fishing	7.9	8.5	8	9.1
B, C, D and E Mining and quarrying; Manufacturing; Electricity, gas, steam and air conditioning supply; Water supply; sewerage, waste management and remediation activities	17.8	18.6	18	16.9
C Manufacturing	12.6	13.3	13.3	12.5
F Construction	6.5	5.4	5.5	5.7
G, H and I Wholesale and retail trade; repair of motor vehicles and motorcycles; Transportation and storage; Accommodation and food service activities	19.9	19.9	20.3	19.7
J Information and communication	3.4	3.4	3.7	3.9
K Financial and insurance activities	3.1	2.9	2.8	2.9
L Real estate activities	9.6	10	9.9	10.2
M and N Professional, scientific and technical activities; Administrative and support service activities	3.6	3.6	3.8	3.9
O, P and Q Public administration and defence; compulsory social security; Education; Human health and social work activities	12.1	11.6	11.9	13.3
R, S and T Arts, entertainment and recreation; Other service activities; Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use	2.8	2.8	2.9	3.1

Source: MAKSTAT

The table 2 shows that the agriculture, information and communication, real estate activities and public administration are the sectors that increased its share in GDP, meaning that they have higher rate of GDP growth. GDP share was criteria for selection of sector for further research as the growth trends affect higher energy consumption and environmental footprint that have to handle in order to provide energy efficiency, circular economy and climate neutrality.

TABLE 3 GVA, GROSSS FIXED CAPITAL FORMATION (GFCF)AND BUSINESS ENTITIES BY SECTORS

Sectors	Gross value added by sector					Gross fixed capital formation					Busienss entities		
	2018	2019	2020	Index 2020/2018	Share %in 2020	2018	2019	2020	Index 2020/2018	Share in % in 2020	2021	Index 2021/2019	Share % in 2021
Total	**573.922**	**601.462**	**574.732**	**100,14**	**100%**	**132387**	**145756**	**144779**	**109,36**	**100%**	**72922**	**99,81**	**100,00%**
A Agriculture, forestry and fishing	55.979	56.331	56.523	100,97	9,83%	3.798	4.067	3.249	85,55	2,24%	2.363	98	3,24%
B_E Mining, manufacturing, electricity, gas and water supply, sewarage , waste management, remmediation activities	**123.187**	**125.196**	**113.441**	**92,09**	**19,74%**	**31.233**	**33.178**	**31.858**	**102,00**	**22,00%**	**8.618**	**100**	**11,82%**
F Construction	**35.757**	**38.994**	**35.878**	**100,34**	**6,24%**	**45.539**	**53.701**	**47.199**	**103,65**	**32,60%**	**5.386**	**102**	**7,39%**
G_I Wholesale and retail trade,repair of motor vehicles and motorcycles, transportationand storage; accomodation and food service activities	131.737	140.322	126.076	95,70	21,94%	21.060	25.716	24.965	118,54	17,24%	32.118	99	44,04%
J Information and communication	**22.612**	**24.365**	**25.592**	**113,18**	**4,45%**	**7.482**	**7.958**	**8.011**	**107,07**	**5,53%**	**2.199**	**106**	**3,02%**
K Financial and insurance activities	19.276	19.293	19.579	101,57	3,41%	1.864	1.735	3.626	194,53	2,50%	482	102	0,66%
L Real estate activities	66.152	68.258	69.143	104,52	12,03%	2.290	874	2.939	128,34	2,03%	602	99	0,83%
M_N Professional, scientific and technical activities; administrative and support aservice activities	23.822	26.298	24.341	102,18	4,24%	3.541	3.180	2.958	83,54	2,04%	9.702	102	13,30%
O_Q Public administration and defence;compulsory social security; education;human health and social work activities	**76.943**	**82.218**	**87.513**	**113,74**	**15,23%**	**11.627**	**11.979**	**14.971**	**129**	**0**	**4.841**	**100**	**6,64%**
RSTU Arts, entertainment and recreation, repair of household good and other services	18.458	20.187	16.646	90,18	2,90%	3.952	3.368	5.005	127	0	6.611	98	9,07%

Source: MAKSTAT

Tbale 3 present the sectors' trends in GVA, GFCF and number of entities. The sectors with significant trends are agriculture (GVA growth&share), construction (GVA growth & share, GFCF growth&share and number of entities), Information and communication (GVA and GFCF growth&share, increased number of entities) and public administration (GVA and GFCF growth&share, increased number of entities). Those three criteria were used in selection of sectors for further resrch and identification of potential for digita transformation.

Analysis of statistical data shows that **potential for digitalisation** is most manifest in construction, ICT sector, agriculture and rural development, tourism, renewable energy sources, processing industry and waste management. The support of these sectors opens opportunities in the green and digital trasnformtion of the sectors, as follows:

- The potential in **construction** is in building facilities and renovation of existing facilities with lower CO_2 emissions, use of sustainable materials and energy efficiency (construction according to the standards for energy performance of buildings). These processes increase the demand for digital transformation and usage of digital (Building Information Modelling software and 3D design) data about labelled EE materials.
- The **agriculture** needs to apply the standards for good agricultural practice, support for organic production and waste management. Development is related to the use of fertilizers and pesticides, soil, water and air protection, waste management and recycling, and agricultural waste recycling, covering higher education profiles (environmental engineers, technologists, agricultural engineers) as well as lower education profiles (general workers for fertilizer and pesticide use, and waste collection, sorting and recycling).
- The trends in the sector of **sources of renewable energy** are focused on decarbonisation and energy efficiency , focusing on the design and installation of thermal, solar, and photovoltaic panels. The strategic documents at national, regional, and local level contain projects related to the installation of thermal and solar panels in public institutions.
- The **manufacturing industry** is focused on decarbonization, energy efficiency, circular economy, guided by environmental standards, new technological processes, and the use of recycled materials, concerning to the use of environmentally friendly materials, technologies with lower energy consumption, and waste management throughout the product life cycle.

- The **recycling industry** is an underdeveloped sector, where most of the activities are focused on waste collection and selection, and the recycling sector is missing due to lack of recycling facilities (except for paper recycling) and therefore the selected waste is exported to other countries.
- The **ICT sector** has a highest growth in GRD, Gross fixed capital and number of business entities. The potential is identified in IT equipment, Infrastructure for IT environment, Communication networks, ICT energy metering, control and analytics, Cloud management, Cloud application software.[21]
- constant shortage of workers with advanced IT skills, and the need for them will increase in the coming period. This sector offers the more opportunities for young people up to 29 years old.

TABLE 4 POTENTIAL FOR DIGITALISATION OF THE SECTORS

Sectors	CO 2 emission	Energy consumption	Circularity	Digitalization potential
Agriculture, hunting and forestry	**Medium agricultural meteorologists;**	**High consumption of fossil fuels Energy efficiency**	**Waste for production of energy Organic production soil and water conservation,**	**Internet promotion and e-trade of agricultural products - smart digital devices for regulating water and fertilizers**
Manufacturing	High from buildings and production process Usage of RES	High consumption of electricity and fossil fuels technologies with lower energy consumption	Use of environmentally friendly and recycled materials employing, Waste selection and disposal	Internet promotion and sales, mobile applications IT systems and equipment maintenance, web designer Automation and robotics of the production process,
Energy supply, Renewable energy sources	**High**	**Medium**		**Using BIM software Installation of Photovoltaics, maintenance of technology**
Construction	**High > 30 % Facade, Windows and Doors Plasterboard HVAC**	**High ~ 40%**	**Rubble, debris Construction material**	**Use of BIM software in design and construction. Data for EE materials Labeling of Buidlings**
Wholesale and retail	Low	Medium	N/A	Using digital inventory management tools
Repair of vehicles, motorcycles, personal and household items	Medium	High	Repair of hybrid and electric vehicles Waste selection and disposal	Vehicle dispatcher Use of GPS.

[21] EU Commision (2021) Energy-efficient Cloud Computing Technologies and Policies for an eco-friendly Cloud market, Final Study Report, p.248-268

Hotels and restaurants	Medium	Medium Using RES	Waste selection and disposal	Smart specialization, booking and sales and digital data
Transportation and storage	High	High	Bio fuels Drivers of environmentally friendly or hybrid motor vehicles	Vehicle dispatcher Use of GPS.
Information and communication	**Medium**	**High**	**Waste selection and siposal**	**Big data centers ICT infrastructure, equipment, networks , Cloud system with lower power consumption**
Financial mediation			Evaluation of credit applications	E-banking
Public administration and defence	**High from buildings**	**High**	**Data collection, control and managed**	**Data centers for monitoring of indicators**

Table 4 presents the analysis of the sectors with GDP growth rate in regard to CO2 emission energy consumption, circularity and digitalization potential. The ranking with high, medium and low potential is estimated regarding to role of the sectors to participate in achieving the objectives in energy scenario and circular economy scenario set up by national Strategic documents.

4.1 Conclusion

Having in mind implemented statistic data criteria (GDP share, GVA share&grwth, GFCF share and growth and number of entities in the sector) and involvement of the sectors in national policies and strategic documents, five sectors with higher potential for green digitalisation transition are: Electricity, gas, steam and air conditioning supply; Water supply; sewerage, waste management and remediation activities; Agriculture, forestry and fishing, Construction, Public administration and ICT sector

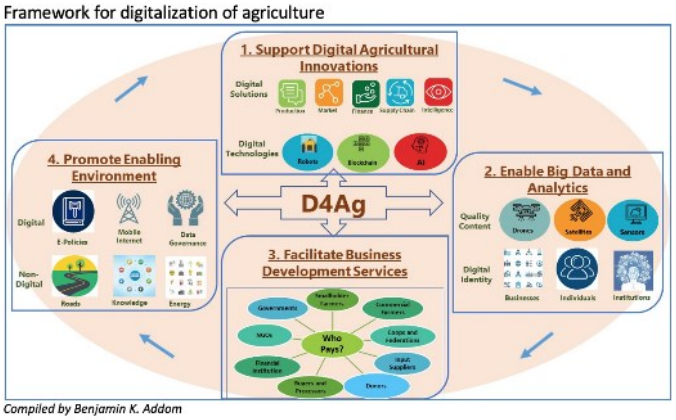
4.2 Selection of three sectors

According to analysis of sectors in table above, five sectors were identified: **Electricity, gas, steam and air conditioning supply; Water supply; sewerage, waste management and remediation activities**; **Agriculture, forestry and fishing**, **Construction**, **Public administration** and **ICT sector**

Out of five prioritized sector (bold letters in table 5, three were selected for further research as it follows:

1) **Agriculture, forestry and fishing**
   The further research will be focused on:
   - Digitalisation of data collection about waste disposal and reuse, encompassing data about soil, water and air pollution. Involved institution is Macedonian information centre for living environment.

Framework for digitalization of agriculture



Compiled by Benjamin K. Addom

- Private Companies with higher environmental footprint and collection of ideas for digitalisation of economic activities that will support reduction of pollution.

2) Construction

Construction sector, particularly building sectors, has highest impact on CO2 emissions, energy consumption and waste generation. Categorisation of buildings in regard to EE performance and labelling of construction materials need creation of data base to monitoring and control the process of renovation and new buildings.

BIM software supports the EE in design, building and maintenance of buildings and it is already compulsory in many EU countries.

Involved institutions for additional analysis are Energy Agency and construction companies .

3) Public administration

This sector is responsible for implementation of laws and strategic programs and plans for energy efficiency, waste management and smart specialisation. It has to be supported with digitalisation of data collection and monitoring of implementation of adopted plans.

Involved institutions are Ministry of economy, Ministry of environment, Ministry of agriculture, Customs administration, Energy Agency, Macedonian information center.

5 Implemented digital transformation and perspectives in the sectors

Implemented digital transformation in the sectors was analysed according to current degree in usage digitl technologies, trends in the sector and envisioned measures in the national strategic documents.

5.1 Agriculture and forestry

On policy level the measures related climate neutrality and environmental sustainability in agriculture are defined in strategic documents for the sectors. The review of those documents shows as follows:

- ***National Strategy for Agriculture and rural development 2022-2028*** includes interventions for management of natural resources and alleviation of climate change impacts, big data should be monitored and control the water, agricultural land and forestry. The most of proposed measures lean on digital technologies for adoption of agriculture on the climate changes. Support to digitalization of the sector is foreseen in provision of whole access to internet access in rural area, better access to public data, and usage of modern digital technologies, robotic and IoT for more efficient production.

  As a main **future public investment** are listed: web-based technology for Agricultural market inspectorate information system, with data for soil and agroecological mapping; and integrated platform for agricultural land characteristics with free access for public administration, farmers and business. Estimate budget is ~10 million euro and sources of financing would; be Budget and EU IPA finds.

- ***Programs for development of 8 planning regions 2021-2026:*** **Skopski**, E-government and data base for business and rural development; **Southea**st, modernization of agricultural production and promotion of circular economy; **East,** Integrated waste management system and promotion of circular economy, promotion of energy efficiency and RES, and introduction of new technologies in agricultural production and smart specialization; **Vardarski,** promotion of agricultural products, waste selection and recycling, investment in energy efficiency and RES; **Polog,** support for competitive and sustainable agriculture; **Northeast**, integrated and digitalized system for special planning, and smart specialization in agriculture; **Southwest,** support for modern and productive agricultural sector and creation of data base farmers and agro-business, **Pelagoniski,** increasing competitiveness and innovation in agriculture, smart and sustainable management of air, water and soil pollution, promotion of circular and green economy.

  Total public investments for six years are estimated in the amount of ~ 50 million euro, without allocation of funds per measures. Having in mind available budget of the regions the most expected sources of financing are donors and EU programs.

- ***At municipality level*** support for agriculture is included in Strategy for local economic development of all Municipalities. However, the green digitalization is still not considered as priority in municipality activities. The measures for green economy and digitalization are planed separately.

Huge potential and opportunities for digital transformation is identified in creation of data base and coordination on local regional and regional level, encompassing data for environmental sustainability

and climate neutrality form one side, and introduction of digital technology for managing the big amount of data for agriculture.

The identified strategic priorities and measures for green digitalization were starting point in consultations and interviews with target groups representatives about implemented digital transformation and perspectives. The consultations were carried out with previously prepared questionnaire for the sector. The representatives from project target groups were contacted through online survey, telephone and meetings

5.1.1 Findings

(1) Degree of implemented digital transformation
   - highest, for computers and emails,
   - medium for social media and
   - low for data base and mobile apps)

(2) Cloud Data storage model (Cloud computing) is used by 33.3% of the respondents, 56,7% respondents use own computers (in premise).

(3) Implemented digital technologies
   - Highest for ICT equipment,
   - Lower for advanced digital technologies as big data analysis, Smart sensors and IOT, and artificial intelligence

(4) Only 11 % of respondents have monitoring of the electricity consumption of the ICT infrastructure

(5) There is no legal restriction on the use of ICT equipment in terms of electricity consumption

(6) The most mentioned effects of the implemented degree of digitization are: reduced costs, efficient communication, reduced energy consumption, analysis of a large amount of data, and improved perfromances);

(7) Business operations with greatest potential for digital transformation are:
   - production, sales, Promotion and marketing, data collection and analysis, purchases, implementation of environment standards and organic production.
   - The focus is on ICT infrastructure and low awareness about digitalisation of the process.

(8) Digital technologies with greatest potential of the agriculture sectors:
   - highest, for digitalization of production and marketing;
   - medium, clean production, energy efficiency,
   - low, RES and waste management.

(9) Activities undertaken to encourage the growth of private companies through digitalization concern to digitization of all data and documents, smart mobile phones, with applications, e-banking, e-sales, digital technologies in indoor food production

(10) Perspectives for digital transformation of the sector are seen in mobile apps and bioinformatic technologies

(11) Planed investment in digital transformation in agriculture is small amount that can be encourage by grants > 5.000 euro.

In addition to online survey, consultation with business associations were organized, Ministry of agriculture forestry and water economy, Chamber of Commerce, Macedonian association of agricultural co-operatives and export company of agricultural products.

In consultations are identified barriers and perspectives for green digitalisation

5.1.2 Barriers for green digitalization in the sector

Barriers on the public sector levels related to agriculture:

- Lack of legislation for eco-design requirements for servers and online data storage products (PSU efficiency[22] and power factor requirements; material efficiency requirements)[23], The EU the EU Code of Conduct on Data Centre Energy Efficiency, the EU Green Public Procurement criteria for data centres, server rooms and cloud services
- Absent coordination in common actions for the creation of public infrastructures (green data centres) that guarantee an energy source renewability
- Lack of monitoring of green transition

Barriers on the private sector level:

- Low level of digital literacy of farmers and employee in the agriculture sector
- Low motivation for usage of digital technology and build a culture for green digitalisation
- Lack of skills to use of infrastructure that creates efficiency gains, meaning available ICT infrastructure but needs for technical staff:
- Needs for adoption of green digital guidelines, frameworks, plans adopted by the public authorities
- Not available capacity building activities (training and creation of green - digital skills)

5.1.3 Perspectives for green digitalisation in agriculture

Perspectives can be grouped according to target groups segments:

Public sector

- Implementation of interventions for management of natural resources and alleviation of climate change impacts, big data should be monitored and control the water, agricultural land and forestry. The most of proposed measures lean on digital technologies for adoption of agriculture on the climate changes.
- ***Investment web-based technology*** for Agricultural market inspectorate information system, with data for soil and agroecological mapping; and integrated platform for agricultural land characteristics with free access for public administration, farmers and business. Estimate budget is ~10 million euro and sources of financing would; be Budget and EU IPA finds.
- E-government and data base for business and rural development; *Integrated* waste management system and promotion of circular economy, promotion of energy efficiency and RES, and introduction of new technologies in agricultural production and smart specialization;
- promotion of agricultural products, waste selection and recycling, investment in energy efficiency and RES; support for competitive and sustainable agriculture; integrated and digitalized system for special planning, and smart specialization in agriculture;

[22] Power supply efficiency is the amount of the actual power delivered to the components divided by the electrical power drawn from the mains supply socket

[23] Commission regulation (EU) 2019/424, eco-design requirements for servers and data storage products

- ***Total public investments for six years*** are estimated in the amount of ~ 50 million euro, without allocation of funds per measures. Having in mind available budget of the regions the most expected sources of financing are donors and EU programs.
- ***Re-organization*** – Adoption of legislation for smart agriculture, establishing data center or participate in EU data center for air, soil, water pollution.

Private sector

- Support to digitalization of the sector in provision of whole access to internet access in rural area, better access to public data, and usage of modern digital technologies, robotic and IoT for more efficient production.
- Modernization of agricultural production and promotion of circular economy;
- Modern and productive agricultural sector and creation of data base farmers and agro-business, increasing competitiveness and innovation in agriculture, smart and sustainable management of air, water and soil pollution, promotion of circular and green economy.
- Investment refers to Introduction of industry 4.0, automatization and robotics, CNC equipment (Computer numbering control) and:
    - **Food waste**: Industrial and household food waste can be successfully disposed of using digital technologies such as IoT and big data.
    - **Agri-waste:** Digital technologies are being employed to deal with the waste generated in agricultural processes for high-quality production

Citizens

- Promotional and educational activities about green digitalization

5.1.4 Conclusion

(1) Agriculture is top priority in national, regional and municipal policies. Their main strategic documents aim at introducing advance digital technologies that impose needs for human competences and finance. Allocated resource are estimated on ~ 60 million euro for six years period. Potential and opportunities for green digitalization is identified in creation of data base and coordination on local regional and regional level, encompassing data for environmental sustainability and climate neutrality form one side, and introduction of digital technology for managing the big amount of data for agriculture.

(2) Implemented digital transformation in private sector is mostly focused on ICT equipment and ICT infrastructures. However, there is lack of advanced digital technologies as big data analysis, Smart sensors and IOT, and artificial intelligence. The usage of data base center and cloud system is at the beginning phase.

(3) Green digitalization practice is not identified in the sector and it is not on the agenda for further investment. Lack of legislation that will support introduction of green digitalization.

5.2 Construction/building sector

On policy level the measures related climate neutrality and environmental sustainability in constrctuin sector are defined in strategic documents. The review of those documents shows as follows:

- The construction sector has the greatest impact on CO2 emissions, energy consumption and waste creation. Categorization of buildings in terms of energy performance and labelling of building materials need to create a database to monitor and control the renovation process and new buildings.
- BIM software supports energy efficiency in the design, construction and maintenance of buildings and is already mandatory in many EU countries.
- ***The Energy development strategy of North Macedonia 2040*** : and ***4th National Energy efficiency plan (NEEAP 2020-2022:*** Planned Investment ~1 billion Euro construction of residential and commercial buildings; ~200 million Euro, construction of public buildings of central and local self-government; ~ 100 million euro solar and photovoltaic panels
- ***National waste management plan 2021-2031***: Processing rate of 70% (preparation for reuse, recycling and other processing of materials) for all inert and non-hazardous, waste construction waste by 2020.
    - In Construction sector waste, digital upgrades improve energy efficiency of buildings by 15-25% and at the same time provide possibilities for telework, telehealth and tele-education. Extending the "EU renovation wave" to the Western Balkans could stimulate investment and create jobs

The identified strategic priorities and measures for green digitalization were starting point in consultations and interviews with target groups representatives about implemented digital transformation and perspectives.

The consultations were carried out with previously prepared questionnaire for the sector. The representatives from project target groups were contacted through online survey, telephone and meetings.

5.2.1 Findings

(4) Degree of implemented digital transformation
    - Highest, for computers, web sites and emails,
    - Medium for social media and data base storage,
    - Low for energy efficiency software and e-learning platform)

(5) Cloud Data storage model is used by 62.5 of the respondents, 12.5 % respondents use own computers and 25% own software

(6) Implemented digital technologies
    - Highest for ICT equipment, and IT network,
    - Medium for big data analysis BIM and Smart sensors and IOT,
    - No answers for and BMS-Building management system and artificial intelligence.

(7) Only 12.5 % of respondents have monitoring of the electricity consumption of the ICT infrastructure, 62.5% don't have it, and 25% don not know.

(8) majority 75% answered that there is no legal restriction on the use of ICT equipment in terms of electricity consumption, and 25% do not know.

(9) The most mentioned effects of the implemented degree of digitization are: More efficient operation., greater efficiency and facilitated communication, More efficient construction, cost control, Increased efficiency and ability to work from home, Less paper consumption

(10) Business operations with greatest potential for digital transformation are:

- Building (automatization and robotic), data collection and analysis, procurement of material, Classification of Buildings and BIM software. .

(11) Digital technologies with greatest potential for the sector:

- highest, for digitalization of building, energy efficiency and BIM
- medium, recycled and sustainable materials, waste management and circular
- low, production of material

(12) Activities undertaken to encourage the growth of private companies through digitalization encomapsed of data bases creation, software for energy efficiency, creating and introducing training programs

(13) Perspectives for digital transformation of the sector are:

- Highest, RES and Energy efficiency of buildings,
- medium, data base for buildings energy performances,
- Low, data base of materials and buildings maintenance.

(14) Investment in digital transformation is planned for cloud system, digital bookkeeping, international verification fo training programs

(15) Digital transformation in building sector could be encouraged by investment grants > 75.000 euro.

In addition to online survey, consultation with business associations were organized, Ministry of economy, National Energy Agency, Chamber of Commerce, experts and construction company .

In consultations are identified barriers and perspectives for green digitalisation.

5.2.2 Barriers for green digitalization in building sector

Barriers on the public sector levels

- High regulated sector regarding building standards and by rules for energy efficiency performances of buildings
- Lack of legislation for eco-design requirements for servers and online data storage products (PSU efficiency and power factor requirements; material efficiency requirements)[24], The EU the EU Code of Conduct on Data Centre Energy Efficiency, the EU Green Public Procurement criteria for data centres, server rooms and cloud services
- Absent coordination in common actions for the creation of public infrastructures (green data centres) that guarantee an energy source renewability
- Lack of monitoring of green transition

Barriers on the private sector level:

- Low level of digital literacy of blue collar workers farmers and employee in the agriculture sector
- Low motivation for usage of digital technology and build a culture for green digitalisation
- Lack of skills to use of infrastructure that creates efficiency gains
- Needs for adoption of green digital guidelines, frameworks, plans adopted by the public authorities

[24] Commission regulation (EU) 2019/424, eco-design requirements for servers and data storage products

- Not available capacity building activities (training and creation of green - digital skills) for workers in whole value chain.

5.2.3 Perspectives for green digitalisation in building sector

Perspectives can be grouped according to target groups segments:

Public sector

- ***Data base*** for categorization of buildings in terms of energy performance Located in Ministry of Economy;
- ***Data base of*** constructed of residential and commercial buildings; and public buildings of central and local self-government; installation of solar and photovoltaic panels
- ***Integrated Data base (municipality and central level) for*** construction sector waste (preparation for reuse, recycling and other processing of materials for all construction waste.
- ***Establishing data centre*** that will integrate all data base related to construction sector

Total public investments for six years are estimated in the amount of ~ 20 million euro (creation of data bases and establishing of data center)

Re-organization – Implementation of legislation and data monitoring (key indicators) through established data center .

Private sector

- Plan for digital transformation
- Labelling of building materials and creation of database
- Data base created by BIM software for new and renovated buildings
- Digitalization of building process and automatization of construction operations.
- Circular economy for reuse of construction materials

Citizens

- Promotional and educational activities about green digitalization

5.2.4 Conclusion

1) Buildings ector is highly regulated sector. It is involved in strategic plan for energy efficiency, waste management and circular economy. Main strategic documents aim at introducing advance digital technologies that impose needs for human competences and finance. Allocated resource are estimated on ~ 1.500 million euro for six years period. Potential and opportunities for green digitalization is identified in creation of data base and coordination on local regional and regional level, encompassing data for environmental sustainability and climate neutrality form one side, and introduction of digital technology for managing the big amount of data for agriculture.

2) Business operations with greatest potential for digital transformation are: Building (automatization and robotic), data collection and analysis, procurement of material, Classification of Buildings and BIM software. .

3) Implemented digital transformation in private sector is mostly focused on ICT equipment and ICT infrastructures. However, there is lack of advanced digital technologies as big data analysis, Smart sensors and IOT, and artificial intelligence. The usage of data base center and cloud system is at the beginning phase.

4) Green digitalization practice is not identified in the sector and it is not on the agenda for further investment. Lack of legislation that will support introduction of green digitalization.

5.3 Public sector

This sector is responsible for implementation of laws and strategic programs and plans for energy efficiency, waste management and smart specialisation. It has to be supported with digitalisation of data collection and monitoring of implementation of adopted plans.

Involved institutions are Ministry of economy, Ministry of environment, Ministry of agriculture, Customs administration, Energy Agency, Macedonian information center for environment.

On policy level the measures related climate neutrality and environmental sustainability are defined in strategic documents. The review of those documents shows as follows:

On central level:

- Adopted legislation and strategic documents related to energy and circular economy scenario emphasize energy, agriculture, manufacturing, construction, transport, waste collection and disposal . such as Energy development strategy of North Macedonia 2040, National Energy efficiency plan (NEEAP 2020-2022), National waste management plan 2021-2031, EU Green Agenda for Western Balkan, Smart Specialization Strategy of North Macedonia, National ICT Strategy , Climate change adoption program etc.
- Those strategic documents required monitoring of the key performance indicators for achievement of expected results. However, the information about those data centres is not accessible and the characteristics of servers and data storage products are not available as the investment needs can be estimated.

On reginal level

- Programs of Regional development contained indicators for each strategic goals that should be monitoring by Centers for planning Regions during implementation of their activities planning centers

On municipal level

- Strategic documents, local economic development, Energy efficiency, Protection of environment, need data base that will support implementation process of those documents and monitoring of indicators related to success in achieving goals.

The identified strategic priorities and measures for green digitalization were starting point in consultations and interviews with target groups representatives about implemented digital transformation and perspectives.

The consultations were carried out with previously prepared questionnaire for the sector. (annex 3). The representatives from project target groups were contacted through online survey, telephone and meetings.

5.3.1 Findings

(1) Degree of implemented digital transformation
- Highest, computers, web sites, social media and emails,
- Medium , data base and finance/budget, ,
- Low data base storage, document management system,

(2) Cloud Data storage model is not used, 100 % respondents use own computers for data base storage

(3) Implemented digital technologies
- Highest, ICT equipment, and IT network, Medium, E-Government , no answers for big data analysis and artificial intelligence

(4) 50% % of respondents have monitoring of the electricity consumption of the ICT infrastructure,

(5) majority 75% answered that there is no legal restriction on the use of ICT equipment in terms of electricity consumption, and 25% do not know.

(6) The most mentioned effects of the implemented degree of digitization are: greater efficiency and effectiveness in the work of the bodies and services. Transparency in decision-making, monitoring and implementation of projects. Improved communication between the institution and the citizens, increased opportunities for access to services and online requests and their realization, increased volume of information and improved communication.

(7) Business operations with greatest potential for digital transformation are: Policy monitoring, data collection and analysis, green procurement, Classification of public Buildings and BIM software for public buildings, data for pollution of air, land and water.

(8) Digital technologies with greatest potential for the sector:
- highest, , energy efficiency data and monitoring of waste management and circular
- low, sustainable cities.

(9) Activities undertaken to encourage the growth of private companies through digitalization encomapsed of procurement of IT equipment and networking,Digitization of services in Urban Planning, Digitization of fee and tax collection –
- Collection through internet platforms and through E-Kiosk. Digitization is being introduced in the preparation process - in the part of waste collection, introduction of smart containers, but also monitoring of the entire work, up to cleaning and maintenance of the same. Introduced several tools for cooperation and communication with citizens, daily and social media are used.
- Digitization of processes from registration for training to obtaining a certificate.
- In limited conditions and a scarce budget - planning future purchases of assets that are energy efficient and with low electricity consumption. energy, electronic archive, digitization of every urban community as a basic organizational form for direct contact with citizens, ISO standardization of processes and handling of electronic waste, etc.

(10) Perspectives for digital transformation of the sector are:
- *Highes*t, establishing data centers, register for energy efficient buildings,
- *Medium*, data base for buildings energy performances, taxes data base and IT networking,
- *Low,* public buildings maintenance.

(11) Planning investments and/or reorganization for the digital transformation: JPS monitoring of waste transport, improvement of IT infrastructure

- improvement of IT infrastructure in the Municipality to the level of redundancy and self-sustainability, significant future savings with dedicated and long-term planning and implementation of best practices from local government, implementation of new content and technology to improve existing G2C services, overcoming the technology gap in knowledge and skills of generations in future training of personnel for work in the municipality, investment in IT personnel of the municipality in the public sector (municipality, schools, kindergartens, etc.) ...

(12) Digital transformation in building sector could be encouraged by investment grants > 100.000 euro.

In addition to online survey, consultation with business associations were organized, Ministry of economy, MAFWE, Macedonian Environmental Information Centre, National Energy Agency, MASIT, Chamber of Commerce, Neocom Data center (visit), experts and construction company . In consultations are identified barriers and perspectives for green digitalisation

5.4 Barriers for green digitalization in public sector

- Lack of legislation for eco-design requirements for servers and online data storage products (PSU efficiency and power factor requirements; material efficiency requirements)[25], The EU the EU Code of Conduct on Data Centre Energy Efficiency, the EU Green Public Procurement criteria for data centres, server rooms and cloud services
- Absent coordination in common actions for the creation of public infrastructures (green data centres) that guarantee an energy source renewability
- Lack of monitoring of green digitalisation transition

5.4.1 Perspectives for green digitalisation in public sector

Perspectives can be grouped according to target groups segments:

- ***Integrated Data base*** creation for air, land, water pollution and waste management;
- ***Data base of*** classified/categorized energy efficient buildings
- ***Web-based technology*** for Agricultural market inspectorate information system, with data for soil and agroecological mapping; and **integrated platform for agricultural land characteristics** with free access for public administration, farmers and business
- ***Establishing data centre*** that will integrate all data base related to climate neutrality and environment sustainability
- ***Increased the number of valid digital document*** issued to companies and citizens, It means to implement digitalization of processes that provide issuing valid digital document for the nneds of companies and citizens.

Total public investments for six years are estimated in the amount of ~ 30 million euro (creation of data bases and establishing of data center).***Re-organization*** – Implementation of legislation through established data center, monitoring of electricity consumption, green procurement for servers and data storage products; reuse of heat produced by IT infrastructure.

5.4.2 Conclusion

(1) The biggest potential for green digitalization that can be used by introduction of legislation framework and allocation of human resources and finance in order to overcome listed barriers in point 5.3.2.

[25] Commission regulation (EU) 2019/424, eco-design requirements for servers and data storage products

6 The environmental footprint of the sectors

The power consumption of ICT infrastructure includes the consumption of IT resources that are used directly (e.g. servers) or indirectly (e.g. access networks) for the provision of products. In addition, the energy consumption of secondary infrastructure such as cooling or power supply should be taken into account.

According to the definition of the EU Parliament, energy-efficiency represents "the ratio of output of performance, service, goods or energy, to input of energy". This definition can also be applied to ICT infrastructure, bearing in mind that an increase in energy-efficiency in the ICT sector does not automatically lead to a reduction in absolute energy consumption, but is often compensated or even overcompensated by a growth or rebound effect. If this definition of energy-efficiency is applied to cloud computing, the output depends on the service model. For IaaS[26] (Infrstructure as a Service) and PaaS[27] (Platform as a service) , output can be represented in terms of usable virtual resources, such as the number of virtual machines or vCPUs, or the amount of virtual storage (file, block, or object storage). However, some further criteria (RAM, network connection, etc.) have to be considered in order to assess the output objectively.

The output of SaaS[28] (Software as a service) products is much more versatile and, accordingly, more heterogeneous, since the output is strongly dependent on the individual application. A cross-application comparison of "output per energy consumed" is not possible here. Output can at most be application-specific for different products/providers. However, especially in the area of cloud computing, there are more and more products that combine elements from different cloud environments and possibly also on premise systems, making it very difficult to assign a cloud application to a specific physical ICT or its power consumption.

In addition, the administration and management software of cloud providers is also highly relevant for energy-efficiency. This includes, for example, the algorithms that are responsible for the distribution and scaling of virtual machines, automatic backups of cloud storage, or the control of physical hardware.

Having in mind the difficulty to monitor energy consumption of ICT infrastructure without built-up separate system for monitoring, the analysis of environmental footprint is carried out on the approximated implemented ICT infrastructure and planned digital transformation in the future. Therefore, it is very difficult to quantify exactly how much energy is needed for ICT infrastructure.

There for the environmental footprint is approximated in the following manner:

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26 **Infrastructure as a service** (IaaS) is a type of cloud computing service that offers essential compute, storage, and networking resources on demand, on a pay-as-you-go basis.

27 Platform as a service (PaaS) is **a complete development and deployment environment in the cloud**, with resources that enable you to deliver everything from simple cloud-based apps to sophisticated, cloud-enabled enterprise applications.

28 Software as a service (SaaS) allows users to connect to and use cloud-based apps over the Internet. Common examples are email, calendaring, and office tools (such as Microsoft Office 365)

- CO2 emission, Electricity: **Input value (in KWh/Yr) X 0.85 (Emission Factor) = Output value in (Kg of CO2)** ; Petrol: **Input Value(In Litres/Yr) X 2.296(Emission Factor) = Output value in (Kg of CO2); decrease of CO2**
- Energy consumption: **PUE (power utilization efficiency)** meaning electricity needed fot the operation of ICT equipment 0.23314 kg CO2e per kWh from carbon free source
- Circularity: life cycle of ICT equipment . For example in EU life cycle for servers is 4,5 years while in Republic of North Macedonia from 7,5 to 10 years/
- Digital potential: Type of digital technologies to be used, state of digitalization of process and usage of cloud system (virtualization, scalability, sensibility and automatization).

A comprehensive assessment of the global environmental impacts related to the total energy and resources demand of the whole digital infrastructure has not been undertaken thus far . However, regarding energy demand, it is estimated that the ICT sector accounts for approximately 7% of the global electricity consumption, and it is forecasted that the share will rise to 13% by 2030. It is important to note that this analysis is focused solely on selected centers regarding servers rooms and data centres.

The electricity demand of data centres specifically is close to 0.8% of the global final electricity demand, and amounts to approximately 200 TWh globally in 2019 . By 2030, their energy consumption is estimated to grow 5-fold up to 974 TWh worldwide (3.9%) with a best-case scenario of 366 TWh (1.5%).

The similar ratio is in Macedonian economy. However, the lack of data about the electricity demand of installed ICT infrastructure can be overcome with research of end-users in the sectors.

The main components of data centers that have impact on electricity consumption, carbon footprint and circularity are presented in the figure 2

	Data centre equipment	Lifespan (Years)
Power generation	Uninterruptible power supply (UPS)	20
	Transformers	20
	Switchgear	20
	Backup generators	20
	Power distribution units (PDUs)	20
	Batteries	3-5
	Power cables	20
IT	Servers	3-8
	Storage equipment	3-5
	Network equipment (switches, routers, etc.)	3-5
	Chassis	20
	Network cables	10
Cooling system	Chillers	20
	Computer room air conditioning units (CRACs)	20
	The direct expansion air handler	20
	Pumps	20
	Cooling towers	20
	Heat exchange systems	20
	Reservoir storages for collecting rainwater	20
Security system	Fire-suppression system	20
	Video-cameras	20
Building structure	Lighting, infrastructure, etc.	20

Source: Weloop, 2020, consulted online: http://weloop.org/wp-content/uploads/2020_04_16_CEDaCI_situation_analysis_circular_economy_report_VF.pdf

FIGURE 2 MAIN COMPONENTS OF A DATA CENTER FACILITIES

The analysis of environmental footprint of the selected sectors is shown on table 5.

TABLE 5 ANALYSIS OF ENVIRONMENTAL FOOTPRINT OF THE SECTORS

Sectors	CO 2 emission	Energy consumption	Circularity	Digitalization potential
Agriculture, hunting and forestry	Low >2% share, usage of traditional fuels, methane for livestock, transport of goods	High consumption of fossil fuels Energy efficiency	Waste for production of energy Organic production soil and water conservation,	Internet promotion and e-trade of agricultural products - smart digital devices for regulating water and fertilizers
Recommen-dations	Re-organization of livestock, and replacement of traditional fuels	RES , biofuel, Energy efficiency measures	food waste and agri-waste can be successfully disposed of using digital technologies such as IoT and big data. Reuse for energy	Modernization of agricultural production and promotion of circular economy
Construction	High > 30 % Facade, Windows and Doors Plasterboard HVAC	High ~ 40% electricity and thermal energy, building equipment	Waste: Rubble, debris Construction material	Use of BIM software in design and construction. Data for EE materials Labeling of Buidlings
Recommen-dations	Building standards upgraded	Classification of Buildings and labeling of EE materials	Collection and reuse of debris and usage of digital technologies	Big data center for buildings
Public sector	Medium > 5% share from buildings	High	Data collection, control and managed	Data centers for monitoring of indicators
Recommen-dations	Building standards upgraded, replacement of cars	Classification of Buildings and labeling of EE materials	Integrated approach in waste management	Integrated data base creation for air, land, water pollution and waste management
For all sectors	ICT Infrastructure	Computers, servers, Networking	e-waste creation	Cloud system
Recommen-dations	Harmonized national with EU legislation for eco design requitements for ICT equipment		Life cycle management for ICT infrastructure in sectors	Legislation for usage of Cloud computing with collocation services that meet EU requirements
Environmental footprint	20 % increase of energy consumption of ICT infrastructure will cause >5 % CO2 emissions, < 1% usage of cooling from free carbon sources		Slow circularity because of longer life cycle of ICT infrastructure (7.5-10 years compare to 4,5 in EU	Increase in power utilization will increase carbon footprint

Table shows environmental footprint of the sectors and recommendations that cen be led to green digitalization of the sector, meaning to implement reuse of energy and circular economy as the energy consumption will be decreased. The actions for implementation of recommendations are given in the next headings.

6.1 Recommendations

(1) Climate change and environmental sustainability is on Agenda of authorities and it is managed separately from digitalization process. There is no knowledge and information about the twin investments, green digitalization. Because of low ***awareness about green digitalization*** regarding impact of ICT infrastructure to CO2 emissions, energy consumption, circularity and trends in digitalization it is recondited to prepared and implemented awareness campaign on three levels: first one, authorities and municipalities, second, business and professional associations; and third, industrial sectors.

(2) *Legislation and framework for cooperation of different stakeholders.* Needs for implementation of EnISO 20000 (international ITSM (IT service management) standard; EnISO 27000 information security management standards is a series of mutually supporting information security standards that can be combined to provide a globally recognised framework for best-practice information security management; and enforcement of Law for issuing digital documents. In the near future the EN 50600 should be implemented: the first European-wide, transnational standard that provides comprehensive specifications for the planning, construction and operation of a data center with a holistic approach.

(3) *Eco design requirements*; To harmonized national legislation with Commission regulation (EU) 2019/424, eco-design requirements for servers and data storage products, The European Code of Conduct for energy efficiency in data centers and the EU Green Public Procurement criteria for data centres, server rooms and cloud services.

(4) *Green digitalization monitoring system*. The Government should developed monitoring system and barometer for green digitalization as the process can be accelerate and managed accordining to the country needs.

(5) *Incentives for big data centers and change from in premise (enterprise data center) to cloud (co-location data center).* In order to support big data centers, the incentives have to established for big data centers., higher operation temperature for ICT equipment (from 22^0 to 26^0 as the energy consumption can be decrease, subvention for utilization of RES for cooling as the PUE can be decrease between 1,1 and 1,6 compared to existing PUE of data centers, from 1,25 to 1,32. Like wise the share of RES energy in the electricity bills to be changed from 5% to 30% as national data centers can be competitive in the EU and global markets.

(6) *Readiness of agriculture sector is the lowest* as the digitalization is at the beginning stage more focused on investment in ICT infrastructure than on processes digitalization. In parallel the lack of technical staff is barrier for the sector. Therefore, the environmental footprint of this sector because of digitalization is the unsignificant.

(7) *Readiness of construction sector is medium* as the digitalization is implemented through introduce digital technologies and digitalization of processes. The introduction of cloud computing, IoT and data centers will increase environmental footprint by 15% (electricity consumption transfer in kgr CO2).

(8) *The readiness of public sector is the highest* since the investment in ICT infrastructure but deployed by in premise model. The potential for digitalization of processes due to strategic priorities for climate neutrality and environmental sustainability will increase carbon footprint >20%. It is recommended to change the model of data centers and to use co-location services with cloud computing as the electricity consumption is lower, meaning less carbon footprint.

(9) *Readiness of the three sectors for green digitalization* is still not priority of the stakeholders and end ussers of the ICT equipment. It is worth to mentioned that measures for energy consumption, carbon footprint and circularity should be introduced by both models (in premise and cloud computing). The minimum measures for managing the green digitalization will concern to:

a. Renewable Energy Factor defined by usage of RES free from carbon footprint

b. In house reused Factor as ratio of recovered energy over the total energy consumption of ICT infrastructure nad/or data centers:

c. Energy efficient infrastructure measured by PUE (Power usage effectiveness) . This should be strating point as the electricity consumption per server room is >500 vat/h and should be decrease to 200vat/h.

d. Resource management such as energy, water e-waste that will be monitored and measured by CO2 -equivalent resulted from facility energy consumption multiplied by carbon emission factor.

7 Barometar for green digitalization

Existing Indicators

Enterprises

- Enterprises having access to the INTERNET (in %)
- Enterprises having access to the Internet via xDSL (ADSL and others) (in %)
- Enterprises having WEBSITE and/or HOME PAGE
- Enterprises using the Internet for interacting with public authorities (e-government) (in %)
- E-commerce in enterprises of non-financial sector, with 10 or more employees (in %)
- Broadband connection to the Internet (fixed or mobile) in the enterprises of non-financial sector (%)
- Enterprises using social media (%)

Households

- ICT usage in the households by type of settlement, by years (in %)
- ICT usage in the households by type of household, by years (in %)
- Computer users in the last 3 months, by years - by sex, age, education, status, type of settlement
- Computer users (aged 15-74) in the last 3 months, by years - according to place of access
- Internet users in the last 3 months, by years - by sex, age, education, status, type of settlement
- Individuals regularly using the Internet (every day or at least once a week), by years - by sex, age, education, status, type of settlement (% of individuals aged 15 to 74, by breakdowns)
- Internet users (aged 15-74) in the last 3 months, by years - according to place of access
- Using the Internet for private purposes by individuals (aged 15-74)
- Use of e-government services for private purpose by the individuals (15-74), in the last 12 months, by years
- Individuals (15-74) having ordered/bought goods or services over the Internet, in the last 12 months, by years - by sex, age, type of settlement (% of individuals aged 15 to 74, by breakdowns)
- Type of ordered/bought goods or services over the Internet by individuals (aged 15-74), in the last 12 months

Green digitalization indicators

Established legislation and standards

- Infrastructure
- Networking
- Software
- Cloud servers and data storage products

Installed ICT infrastructure

- Energy demand of the national economy
- Electricity demand of data centers

Green indicators/studija

- CO2
- PUE

Size of data centres, according to criteria in figure below:

	Small deployment	Large deployment	Hyperscale deployment
Floor size	100 m² - 1000 m²	1000 m² - 10.000 m²	more than 10.000 m²
Number of racks	6 to 200	200 to 2000	2000+
Power capacity	50kW – 1 MW	1MW – 10MW	10MW+

Minimum efficiency and eco design requirements

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