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THE POTENTIAL OF INFORMATION AND COMMUNICATION TECHNOLOGIES IN THE TRANSITION TOWARDS GREEN ECONOMY

ABSTRACT

on a dissertation work for awarding the educational and scientific degree Doctor of Philosophy

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Scientific advisor:

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The dissertation was discussed and approved for defence pursuant to the Law on the Development of the Academic Staff and the Regulations for Its Implementation at D. A. Tsenov Academy of Economics – Svishtov by the Department of Business Informatics at the Faculty of Management and Marketing at D. A. Tsenov Academy of Economics – Svishtov. The author of the dissertation is a full-time doctoral student at the Department of Business Informatics at D. A. Tsenov Academy of Economics – Svishtov.

The dissertation consists of an introduction, three chapters, a conclusion, a list of references, and appendices. It has 223 pages, of which the introduction is 9 pages, the main text is 190 pages, the conclusion is 4 pages, and the list of references is 18 pages. The dissertation includes 33 tables and 9 figures. The list of references comprises a total of 194 literary sources in Latin script.

The defense of the doctoral dissertation will be held on 16.06.2025 at 13:30 in the Rectorate Conference Hall of D. A. Tsenov Academy of Economics – Svishtov.

All materials related to the defense are available on the internet page of D. A. Tsenov Academy of Economics – Svishtov.

I. GENERAL CHARACTERISTICS OF THE DISSERTATION

1. Relevance of the topic

The importance of information and communication technologies (ICT) in the transition to a Green Economy extends beyond the existing perspective and is fundamental to delineate a sustainable future. ICT offers the potential to promote inclusiveness that will bridge the digital divide and create an equal opportunity for all individuals, irrespective of their socioeconomic background or geographical location. Bulgaria and other countries can utilize Artificial Intelligence driven systems for smart grids to enable better integration of renewable energy, and GIS and satellite technologies can help to optimise sustainable management.

Construction activities frequently disrupt ecosystems, resulting in imbalances without adequately addressing environmental impacts. This dissertation aims to mitigate these effects by monitoring land use changes, tracking deforestation, and guiding afforestation efforts. Technologies such as Geographic Information Systems (GIS), satellite imagery, and remote sensing provide real-time data to inform urban planning, ensuring that development occurs sustainably and without compromising natural habitats.

This dissertation work can serve as a bridge, enabling real-time information exchange, public engagement, and ownership in environmental policy. Digital platforms can raise awareness of the importance of carbon footprint reduction, greening, and greening of industries. From a theoretical and practical perspective, ICT can encourage and can be part of the Circular Economy/Green Economy by promoting sustainable behaviour patterns.

2. Object and subject of the research

The object of the research presents the transition to a Green Economy at both the global and national levels with the integration of information and communication technologies.

The subject of the research is the possibility of information and communication technologies to accelerate the transition to a Green Economy through the implementation of a comprehensive Green Economy Transition Framework.

3. Research thesis statement

The main research thesis statement of the dissertation posits that the successful integration of information and communication technologies (ICT) with government policies and a public commitment to sustainable development is a key factor in Bulgaria's transition towards a Green Economy. While ICT presents promising solutions for resource management, energy efficiency, and data-driven decision-making, the path toward a Green Economy is fraught with challenges. Significant investments in infrastructure, skill development, and efforts to overcome resistance to change within traditional industries are essential for the implementation of green technologies.

With its rich historical and economic significance, Plovdiv serves as a compelling case study for exploring the potential of ICT in facilitating this transition. Its unique position makes it an ideal entrant for leading the way toward an ICT-enabled Green Economy in Bulgaria. This thesis investigates how ICT can contribute to this shift, providing practical understanding for policymakers, businesses, and researchers working to create a more sustainable and prosperous future for Bulgaria. The study presents expertise in ICT, environmental sustainability, and economic development, and it stipulates the conceptual frameworks and analytical tools needed to address the challenges involved at the intersection of these domains. The research seeks to inform and support the ongoing efforts in Bulgaria and Plovdiv to achieve long-term sustainability and economic growth.

4. Goals and tasks of the dissertation work

The aim of the dissertation is to provide an analysis of the potential of Information and Communication Technology (ICT) in the transition toward a Green Economy, with a specific focus on Bulgaria.

In connection with the implementation of the goal, the following research tasks are defined:

- *in a theoretical aspect:*

1) Proposing a new definition of a Green Economy, which extends the traditional concept of sustainability by integrating principles of collaboration, inclusivity, resilience, and ICT integration.

2) Analysing the structural disadvantages of the Linear Economy in the context of case studies on the role of ICT in the Green Economy transition.

3) Introducing a Green Economy Transition Framework (GETF) positions ICT as an essential transformative enabler of resource optimization, energy efficiency, and the transition to a low-carbon, Circular Economy.

- *in practical aspect:*

4) Introducing a methodology for reducing the carbon footprint in ICT and proposing strategies relevant to Bulgarian practice for designing and operating digital technologies energy-efficiently.

5) Mathematical Framework for Optimizing ICT Integration in Bulgaria's Green Economy Technological Sector: Introducing a Modified Mathematical Representation for ICT integration and data analytics improvement in environmental management and for Improved Decision-Making.

6) Adapting the concept of the "Billion Tree Tsunami Project" to the Bulgarian practice as a potential opportunity to accelerate the green transition of the city of Plovdiv in the direction of increasing the urban forest cover, improving air quality, increasing community resilience, and promoting local biodiversity.

5. Research methodology

Several research methods are used in the dissertation, which include mixed research methods, qualitative case study methods, information gathering, triangulation, economic analysis, comparative analysis, methods of modelling, quantitative surveys, and data analysis.

The use of mixed research methods - combining both **qualitative** and **quantitative** approaches – is chosen to ensure a comprehensive exploration of the research problem. Mixed methods allow this thesis to collect both numerical data and descriptive insights.

Systematic information gathering involves collecting data from various primary and secondary sources, including academic literature, official reports, expert opinions, and relevant databases. This process helps the thesis with a solid foundation of evidence and ensures that the research is grounded in existing knowledge.

Triangulation in this thesis refers to the use of multiple data sources, methods, or theoretical perspectives to cross-check and validate findings. In this study, triangulation is employed by combining different types of data (e.g., qualitative interviews, quantitative surveys, and economic analysis) to enhance the credibility and reliability of the results.

Economic analysis was utilized to evaluate the financial and economic implications of the research topic, providing insights into cost-effectiveness, efficiency, and the broader economic impact.

Comparative analysis is employed to examine and contrast different cases, groups, or systems, identifying patterns and differences. This method allows for the identification of factors that contribute to variations in outcomes and provides a broader context for understanding the research problem.

Modelling methods in this thesis were employed to simulate and predict behaviours or outcomes based on certain variables or assumptions. This includes the use of mathematical or computational models to analyse complex systems and predict potential future scenarios.

Data analysis involves the systematic examination of collected data to identify patterns, trends, and relationships.

6. Limiting parameters of the research

The study commenced in March 2022, with data gathering continuing until March 2023. The collection of additional data is ongoing, including economic analysis and other pertinent information. It is important to note that this research does not aim to address all potential external variables, such as climate change or future technological advancements. The focus of this research is the Green Economic model with ICT, using Plovdiv as a case study.

While the researcher's passion for the subject has been a key motivator in pursuing this PhD, several challenges, particularly in gathering relevant data, have induced obstacles. One considerable limitation has been difficulties in accessing essential information, interacting with local stakeholders, and avoiding the complexities of Bulgaria's institutional landscape.

Approbation

Despite the challenges encountered, this process has been an invaluable learning experience, contributing not only to the development of academic research but also to cultural immersion and personal growth. Engagement with a diverse array of individuals - ranging from academics and government officials to local business owners and community leaders - provided valuable insights into Bulgaria's transition toward a Green Economy. These interactions have deepened the understanding of the country and reinforced the commitment to supporting its sustainable development.

II. STRUCTURE OF THE DISSERTATION

1. General description

The dissertation consists of 223 pages, of which 195 are the main text, with 9 figures and 33 tables. Structurally, it includes an introduction, an exposition in three chapters, a conclusion, and a list of 194 literary and internet sources used.

A declaration of originality and credibility is attached.

2. Contents of the dissertation

II. BRIEF EXPOSITION OF THE DISSERTATION

The **first chapter** is the foundation of the thesis, elucidating the conceptual foundation of the Green Economy in conjunction with ICT within the context of sustainable development. This aligns with the thesis topic, "The Potential of Information and Communication Technologies in the Transition towards a Green Economy," and includes case studies for illustration and representation. This chapter presents an alternative (author's) definition of the Green Economy, presenting a fresh perspective that emphasizes **integration**, **collaboration**, **inclusivity**, and **resilience**. **A key aspect of this definition is the integration of information and communication technology (ICT) as a fundamental driver of sustainability, within both economic and environmental systems.**

The First Paragraph of this chapter introduces the conceptualization of the Green Economy and its relationship to the Circular Economy by discussing the principles of sustainability. The comprehension and analysis of the Green Economy, as articulated by various organizations and institutions such as UNEP, OECD, EEA, UNDP, and the World Bank, is essential for acquisitive the principles and foundations necessary for transition to a Green Economy through information and communication technology (ICT).

The concept of a "Green Economy," illustrated in Figure 1, exemplifies the idea of "sustainable development."

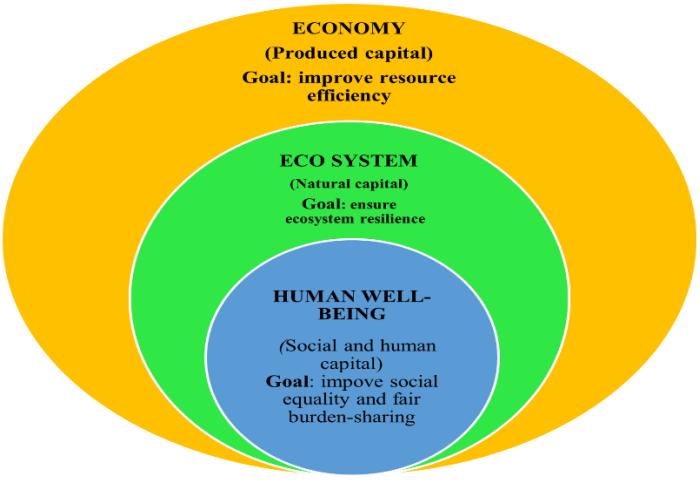

Figure 1. The Green Economy Idea.

Source: Author's illustration.

The 7th Environment Action Programme (7th EAP), titled "Living well, within the limits of our planet "(EC, 2013), advocates for a sustainable economic strategy. This program, aimed at directing environmental policy until 2020, was approved by the European Union Council and the European Parliament in November 2013. The primary objective is to improve Europe's ecological resilience and transform the EU into an inclusive and sustainable Green Economy. **The 7th EAP establishes *nine primary objectives*, with the initial three being thematic** and **the remaining six offering a framework for effective implementation** (EUR-Lex Access, 2013).

The 7th European Action Programme (EAP) places a substantial emphasis on the importance of a Green Economy that ensures sustainable growth and development while also protecting human health and well-being. This method also endeavours to generate satisfactory employment opportunities, reduce inequalities, and allocate resources to the conservation of biodiversity, which encompasses the ecosystem services it provides (popularly referred to as "natural capital"). These endeavours are driven not only by the intrinsic value of biodiversity but also by its critical role in promoting economic prosperity and enhancing human well-being (European Commission, 2013).

The 7th European Union Environmental Action Programme (EAP) emphasizes the necessity of integrating environmental considerations into several policy areas, including energy, transport, commerce, economics, industry, and employment (EC, 2013). This highlights the significance of policy integration, as previously noted. The 7th EAP has delineated particular targets to be accomplished by 2020 (EUR-Lex Access, 2013).

The expression of long-term aspirations in recent EU policies signifies a notable progression in conceptualization and poses problems for policy development in the forthcoming decades. The current emphasis of EU initiatives is predominantly on attaining short- and medium-term goals, especially those established for 2020. Although most objectives will remain pertinent to the anticipated goals for 2050, there is a promise to eschew strict adherence to the 2020 targets and instead embrace a comprehensive approach to policy measures spanning the years 2015, 2020, 2030, and 2050.

By Article 11 of the Consolidated Version of the Treaty on the Functioning of the European Union[1] the notion of environmental integration is a fundamental component of EU policy (EUR-Lex, 2016).

This paragraph succinctly outlines the **Author's Definition, Core Principles, and Key Objectives of a Green Economy**, briefly listed as follows:

a) Definition

"A Green Economy is an economic model that prioritizes sustainable development by encouraging the efficient use of renewable resources, the conservation of natural capital, and the integration of ***information and communication technologies (ICT)*** *to support ecologically responsible practices. It aims to achieve long-term economic growth while minimizing* ***environmental degradation****,* ***supporting substantive equality****, and ensuring that all ecosystem components are preserved and* ***interconnected****. The Green Economy seeks to* ***decouple economic growth from environmental harm****, reduce poverty, and create a more equitable and sustainable future".*

b) Core Principles

- ✓ *Efficient Utilization of Renewable Resources*
- ✓ *Conservation and Restoration of Natural Capital*
- ✓ *Strategic Integration of Information and Communication Technologies (ICT)*
- ✓ *Ecological Health and Resilience*

c) Key Objectives

- ✓ *Decoupling Economic Growth from Environmental Impact*
- ✓ *Economic Justice and Equity*
- ✓ *Alleviating Poverty using Sustainable Development*
- ✓ *Application of Game Theory for Strategic Interaction*

[1] Consolidated versions of the Treaty on European Union and the Treaty on the Functioning of the European Union - Consolidated version of the Treaty on the Functioning of the European Union - Protocols - Annexes - Declarations annexed to the Final Act of the Intergovernmental Conference which adopted the Treaty of Lisbon, signed on 13 December 2007 - Tables of equivalences.

The Second Paragraph emphasises the dynamic nature of information and communication technologies (ICT) as they evolve. An analysis of ICT innovation and its development, as well as future trends in ICT, leads to the conclusion that ICT can adapt to the challenges of a changing Green Economy. It explores the relationship between ICT and the SDGs as part of the challenges and adaptation explained by ICT and the SDGs and the ICT Vision for 2030.

The SDGs consist of 17 goals (see Figure 2) aimed at promoting prosperity while protecting the planet. Key areas include poverty alleviation, education, gender equality, clean energy, and climate action.

Figure 2. The 17 Sustainable Development Goals (SDGs).

Source: Environmental and Resources Authority, 2024.

- **ICT Contributions to Specific SDGs**
  - *SDG 4: Quality Education*
  - *SDG 5: Gender Equality*
  - *SDG 7: Affordable and Clean Energy*
  - *SDG 9: Industry, Innovation, and Infrastructure*
  - *SDG 11: Sustainable Cities and Communities*

- *SDG 13: Climate Action*

The Third Paragraph further elucidates how to navigate the key challenges in future integration with data support from Case Studies. While the incorporation of information and communication technologies (ICT) into the Green Economy offers numerous opportunities for enhancing sustainability, these opportunities are thoroughly examined alongside the challenges. These challenges include technical and economic barriers to policy, infrastructure, and social considerations, which are explained with the following outline of key obstacles to merging ICT with Green Economy goals.

- *Energy Consumption of ICT Infrastructure*
- *E-waste and Resource Scarcity*
- *Digital Divide and Inequality*
- *Cybersecurity Risks*
- *High Upfront Costs*
- *Lack of Standardization and Interoperability*
- *Data Privacy and Ethical Concerns*
- *Policy and Regulatory Challenges*
- *Technological Complexity and Integration*

In the long-term vision for 2050, ICT will continue to evolve, providing essential tools for decarbonization, Circular Economy/Green economic practices, and the digital transformation of key economic sectors. This paragraph explores the future of the Green Economy in the context of ICT, addressing the anticipated contributions of emerging technologies in sectors such as energy, transportation, agriculture, waste management, and environmental protection:

- *ICT and Energy Efficiency: Decarbonizing Energy Systems by 2050*
- *ICT and Sustainable Transportation: Electrification and Automation*
- *ICT in Agriculture and Food Security: Precision Agriculture*
- *ICT and Waste Management: Enabling the Circular Economy*
- *ICT in Climate Monitoring and Environmental Protection*

The Fourth Paragraph exemplify the relationship and importance of ICT and the Green Economy in the new world order. The term New World Order (NWO) refers to the shift in global economic governance and the emergence of new economic paradigms in response to changing geopolitical, technological, and social factors. This concept covers different dimensions, including the emergence of developing economies, the impact of digital technologies, and the drive toward sustainability.

The chapter sets the stage for subsequent exploration of the intersection between technology, policy, and sustainability, highlighting that a Green Economy and ICT can be an achievable model for a sustainable future.

Chapter Two extends the theoretical fundamentals set out in Chapter One by providing practical insights into the role of ICT in facilitating the Green Economy's transition. By addressing the structural constraints of the Linear Economy and combining ICT-driven solutions, this chapter provides a framework for achieving a more sustainable, Circular/ Green Economy and puts the focus over the importance of adopting frameworks like the Green Economy Transition Framework **(GETF)** towards a more sustainable future. The integration of ICT into the Green Economy is not only an important step in reducing environmental degradation but also an essential component of upbringing long-term economic resilience with social equity and justice.

The First Paragraph of the second chapter *explains the structural drawbacks of the Linear Economy through global Case Studies on its adverse impact on well-being.* The discussion begins by identifying and analysing the **structural drawbacks of the Linear Economy**, particularly its constant resource extraction and waste generation, which directly contradict the principles of sustainability. This section is crucial to demonstrate why we are moving towards a Green Economy and to answer indirectly the question, why we should not implement ICT within the Linear Economy rather than pursuing a Green Economy. The case studies' explanations support their negative impacts.

The Linear Economy is graphically illustrated in Figure 3.

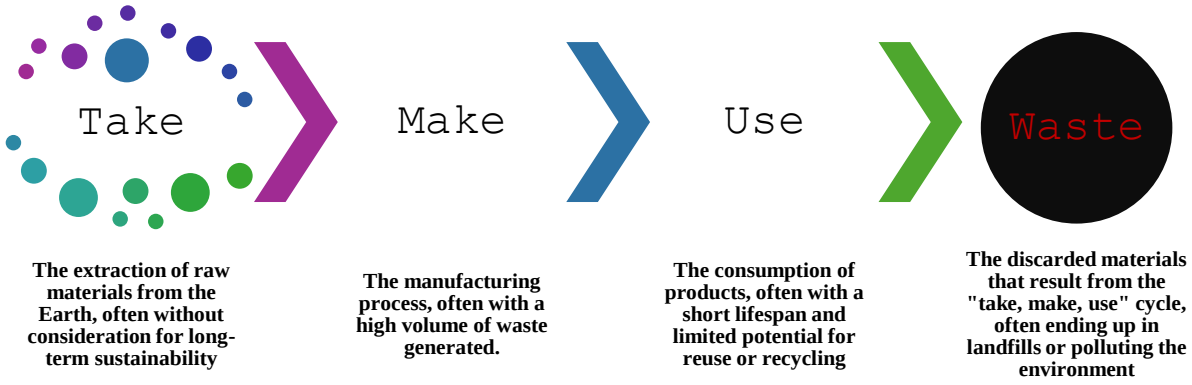

Figure 3. Linear Economy Model.

Source: Author's illustration.

Structural deficiencies *exemplified by an author* in linear economic models refer to the limitations and shortcomings inherent in these models that can lead to inaccurate predictions, misinterpretations, and ineffective policy recommendations in several key aspects, as briefly outlined below:

a) <u>Assumption of Linearity</u>

- *Simplistic Relationships*
- *Over-Simplification*

b) <u>Static Nature</u>

- *Time Invariance*
- *Lack of Feedback Loops*

c) <u>Homogeneity of Agents</u>

- *Representative Agent Assumption*
- *Neglect of Behavioural Economics*

d) <u>Exclusion of Externalities</u>

- *Market Failures*
- *Incomplete Markets*

e) <u>Inadequate Treatment of Uncertainty</u>

- *Risk and Uncertainty*
- *Stochastic Elements*

f) Limited Scope of Variables

- *Omission of* Key *Factors*

The Second Paragraph explains and demonstrates that ICT is not only a potential driver for the Green Economy but plays a crucial role in enabling the transition to a Green Economy. This is illustrated through various case studies.

The information and communication technology (ICT) landscape plays an essential role in enabling a sustainable Green Economy, as evidenced by various transformative case studies. The information and communication technology (ICT) sector is at the forefront of this transformation, using technologies such as artificial intelligence (AI), the Internet of Things (IoT), big data, blockchains, and cloud computing to enable green innovation. As industries undergo digital transformation, they are positioned to align economic growth with sustainable development, enhance resource efficiency, and mitigate greenhouse gas (GHG) emissions. Digital transformation with green transition is illustrated in Figure 4.

Figure 4. Digital Transformation with Green Transition.

Source: European Policy Centre (EPC, 2020).

The text discusses how digital transformation in the ICT sector involves the adoption of advanced digital tools and processes to ameliorate operational efficiency, optimize resource usage, and encourage innovation. This digital transformation process is driven by the increasing integration of the following key technologies, including **Artificial Intelligence (AI), Cloud Computing, the Internet of Things (IoT), and Big Data Analytics**.

This paragraph also illustrates how ICT plays a key role in supporting the transition to a Green Economy by enabling key environmental, economic, and social goals. The most significant ones are outlined below:

a) *Improving Energy Efficiency*

b) *Enabling Carbon Emission Reductions*

c) *Facilitating the Circular Economy*

This paragraph shows the challenges, outlooks, and role of ICTs in the digital transformation and Green Economy sectors.

This paragraph provides an overview of digital transformation in the ICT sector. Digital transformation in this field involves leveraging advanced technologies to enhance the delivery of services, improve connectivity, reduce operational costs, and stimulate innovation. The key **drivers** of this process are examined in the context of their effects on various aspects of the ICT industry, including telecommunications, software, hardware, and data management.

Key **drivers** of digital transformation in the ICT sector include:

a) *Increasing demand for data*

b) *Cloud adoption*

c) *Connectivity improvements*

d) *Sustainability goals*

In this paragraph, Case Studies in the digital transformation in the ICT Sector are examined and epitomized, briefly highlighted below:

a) *China Mobile: 5G Rollout and Digital Innovation*

b) *AT&T: Network Virtualization and Cloud Migration*

c) *IBM: Transformation into a Cloud and AI Leader*

d) *Google: Cloud Transformation and AI Integration*

e) *Ericsson: Digital Transformation through 5G and IoT*

f) *Telstra: Smart City Initiatives and IoT Deployment*

g) *Amazon Web Services: Cloud Dominance and AI*

h) *Huawei's Digital Transformation and 5G Leadership*

In the Third Paragraph, the author presents the Green Economy Transition Framework **(GETF)** and highlights the importance of sustainability through the integration of ICT. furthermore, the implementation roadmap of ICT-Enabled Framework (IGE Framework), and pertinent case study to support the presentation.

This paragraph discussed GETF and the successful transition to a Green Economy, which requires a comprehensive and innovative methodology that integrates **economic**, **environmental**, and **social objectives** while ensuring **sustainability**, **inclusivity**, and **resilience**. The Green Economy Transition Framework (GETF) is one such gradual approach that provides a systematic methodology to guide toward achieving a sustainable, Green Economy. This section outlines the **GETF's core principles**, including policy innovation, technological advancements, financial mechanisms, and community engagement, all of which collectively support a seamless transition to a more sustainable future

Brief outlines from Green Economy Transition Framework (GETF)

The Green Economy Transition Framework (GETF) represents an **original** approach to shifting from a conventional economic model to one that emphasizes sustainability, environmental administration, and **social substantive** equity. This framework integrates key sectors - *energy, agriculture, transportation, industry, and urban development - into a cohesive system aimed at achieving long-term sustainability*. By compelling change through a combination of policy innovation, technological advancements, financial mechanisms, and broad-based participation, the **GETF** promotes systemic transformation across multiple dimensions of the economy.

At the core of the GETF is a focus on ***cross-sectoral collaboration***, ***digitalization***, *and* ***equity****, ensuring that the transition is not only environmentally sustainable but also economically inclusive and socially just. This multilateral approach seeks to harmonize the needs of the environment with the demands of economic growth and social well-being, ensuring that the benefits of the Green Economy are shared equitably among all segments of society.*

- ***Key Components of the GETF***

1. Policy Innovation

Policy reform is a cornerstone of the GETF. A supportive policy environment is necessary to help the transition to a Green Economy. A key innovation within this framework is the **Green Policy Accelerator**, a complex mechanism designed to update and refine policies in real time based on environmental and economic data. The following components are central to policy innovation in the GETF:

- **Carbon Pricing and Subsidy Reform***:* Introducing carbon pricing mechanisms, such as carbon taxes or cap-and-trade systems, incentivizes industries to reduce carbon emissions. Coupled with the phase-out of fossil fuel subsidies, these reforms encourage the redirection of financial resources toward green technologies, including renewable energy sources.
- **Regulatory Sandboxes for Green Technologies**: Regulatory "sandboxes" are experimental spaces where companies and start-ups can test new green technologies, such as renewable energy solutions or carbon capture methods, under less stringent regulatory conditions. This supports innovation and accelerates the adoption of environmentally friendly technologies.
- **Green Procurement Policies**: Governments can lead by example through the adoption of green procurement policies. These policies prioritize sustainability across public sector contracts, from infrastructure projects to office supplies, ensuring that all public spending aligns with Green Economy objectives.

2. Technological Innovation and Digitalization

Technological innovation plays an important role in the Green Economy transition. Advancements in digital technologies such as **artificial intelligence (AI)**, **blockchain**, and the **Internet of Things (IoT)** offer unprecedented opportunities to improve resource use, reduce emissions, and spur innovation. *The following technological innovations are central to the GETF:*

- **Smart Grids and Renewable Energy Integration**: The implementation of smart grids enables more efficient energy distribution and facilitates the integration of renewable energy sources like solar and wind. This optimizes energy use, reduces waste, and lowers carbon emissions.
- **Blockchain for Transparency in Sustainability**: Blockchain technology improved transparency in environmental impact reporting. It can be used to track carbon credits or the lifecycle of products, ensuring that businesses adhere to green standards and providing consumers with verifiable sustainability information.
- **Precision Agriculture with IoT and AI**: Smart agricultural techniques leveraging IoT devices and AI-driven analytics help improve water usage, reduce the need for chemical fertilizers, and increase crop yields while minimizing environmental impact. This promotes sustainable agricultural practices, a critical pillar of the Green Economy.

3. Financial Innovation and Green Investment Models

Innovative financing models are essential to scale the Green Economy. Financial institutions, governments, and private sector entities must collaborate to create sustainable investment strategies. The following financial innovations are key to the GETF:

- **Green Bonds and Climate Bonds**: These financial instruments allow governments and corporations to raise capital for projects that support environmental sustainability, such as renewable energy installations, energy-efficient infrastructure, and sustainable transportation systems.
- **Blended Finance Models**: Blended finance combines public and private investment, reducing the financial risk for private investors. This approach enables the funding of green projects that might otherwise be considered too risky, thereby encouraging private sector participation in the transition to a Green Economy.

- **Impact Investing and Socially Responsible Investment Funds**: Encouraging institutional investors to prioritize **Environmental, Social, and Governance (ESG)** criteria can help establish investment funds focused on green and socially responsible initiatives. These funds aim to generate both financial returns and positive social and environmental outcomes.

4. Multi-Stakeholder and Community Engagement

Transitioning to a Green Economy requires active engagement from all stakeholders, ranging from governments to local communities. The following strategies help in inclusive participation in the Green Economy:

- **Participatory Governance and Co-Creation**: Governments should establish platforms for collaboration where stakeholders - including businesses, scientists, local communities, and non-profit organizations - can contribute to the policymaking process. This ensures that the transition reflects the needs and aspirations of society at large.
- **Public Awareness Campaigns and Green Education**: Large-scale public awareness campaigns can educate citizens about the benefits of the Green Economy and the role they can play in supporting sustainability. Besides, integrating environmental education into national curricula encourages a generation of environmentally-conscious citizens.
- **Green Job Training and Reskilling**: The Green Economy will require a new skillset in areas such as renewable energy, energy efficiency, sustainable agriculture, and green manufacturing. Governments should invest in reskilling programs to help workers transition from declining industries to green job opportunities.

5. Monitoring and Adaptive Management

A unique feature of the GETF is its reliance on **adaptive management**, a feedback-driven approach that allows policies and projects to adjust continually in response to new data. The following innovations improve monitoring and adaptive management in the GETF:

- **Real-Time Environmental and Economic Monitoring**: Using data analytics and AI, governments can monitor key environmental and economic indicators -

such as carbon emissions, biodiversity loss, and GDP growth - in real time. This data enables timely adjustments to policies, investment strategies, and projects, ensuring that the transition remains on track.

- **Transparent Progress Reporting**: Regular and transparent reporting of progress is essential for building public trust. Blockchain can improve this process by ensuring that environmental impact data is tamper-proof and easily verifiable.

➢ ***Challenges and Solutions in the Green Economy Transition***

While the transition to a Green Economy presents significant opportunities, it also faces several challenges. These include resistance from entrenched industries, high upfront costs of green infrastructure, and the potential for social inequalities arising from the transition. There are several strategies to overcome these obstacles:

- **Strong Political Will and Leadership**: Governments must demonstrate an evident commitment to sustainability through strong leadership and policies. Political will is important in overcoming resistance from traditional sectors, such as fossil fuel industries.
- **International Collaboration**: Developing countries may face financial and technical barriers to green technology adoption. International partnerships that provide climate finance, technology transfers, and capacity building are essential for enabling these countries to transition to a Green Economy.

The Green Economy Transition Framework offers a complete and adaptable pathway for countries seeking to transition from traditional economic models to sustainable, green economies. By emphasizing policy innovation, technological advancements, financial mechanisms, and broad-based community participation, the GETF provides an integrated approach to achieving environmental, social, and economic sustainability.

The Case Study of Costa Rica's Green Economy implementation exemplifies the potential for success when these strategies are effectively implemented.

The paragraphs 2.3.1 and 2.3.2 presented and discussed the Green Economy Transition Framework (GETF) as a pathway to sustainability with ICT Integration. Central to the GETF is the inclusion of **ICT tools** (**Artificial Intelligence (AI), big data, the**

Internet of Things (IoT), blockchain, and **Cloud Computing**) that improve cross-sectoral collaboration, digitalization, and equity.

- ***Key Components of the GETF with ICT Integration***

Policy Innovation and ICT: ICT plays a critical role in the progress and implementation of these policies by enabling real-time data collection and analysis, providing transparency, and ensuring accountability. Key policy innovations supported by ICT **include:**

- *Carbon Pricing and ICT-Enabled Monitoring*
- *Regulatory Sandboxes for Green Technologies*
- *Green Procurement Policies with Digital Tools*
- *Technological Innovation and ICT Integration*
- *Smart Grids and Renewable Energy Integration*
- *Blockchain for Transparency in Sustainability*
- *Precision Agriculture with IoT and AI*

- ***Financial Innovation and Green Investment Models with ICT***

Financial innovations are necessary to scale the Green Economy, and ICT is important for these new financing models. Through digital tools, green investment can be monitored and improved, ensuring that funds can be channelled toward projects that contribute to sustainability. Key financial innovations facilitated by ICT include:

- *Green Bonds and Climate Bonds with Digital Platforms*
- *Blended Finance Models and Digital Risk Assessment*
- *Impact Investing with ICT-enabled Transparency:* Impact investing and socially responsible investment funds.

- ***Multi-Stakeholder and Community Engagement with ICT***

The Green Economy transition requires active participation from all sectors of society, and ICT plays an important role in facilitating communication, collaboration, and public engagement through:

- *Participatory Governance and Co-Creation Platforms*
- *Public Awareness Campaigns and Digital Education*

- *Green Job Training and Digital Reskilling Platforms*

➢ ***Monitoring and Adaptive Management with ICT***

One of the distinctive features of the GETF is its use of **adaptive management**, which relies on feedback loops to ensure that policies and projects remain effective and responsive:

- *Real-time environmental and Economic Monitoring with AI and IoT*
- *Transparent Reporting with Blockchain*

The successful transition to a Green Economy leveraging information and communication technology (ICT) requires a perceptible, structured, and phased approach, such is the **ICT-enabled Green Economy Framework (IGE Framework)**.

This paragraph also presents a **phase-wise implementation roadmap** of the ***objectives***, ***key activities,*** and ***expected outcomes*** of the ICT-enabled Green Economy Framework (IGE Framework). The paragraph also discussed the ***challenges and solutions for implementing the ICT-enabled Green Economy Framework (IGE Framework)***.

The Fourth Paragraph presents the author's presentation *about methodologies for reducing the carbon footprint* and emphasizing the role of ICT in shaping the Green and sustainable energy Economy with a focus on Bulgaria. Additionally, it also discusses the five case studies for Bulgaria's green transition.

Carbon footprint reduction requires systematic approaches by industry, households, and governments. This requires a combination of technology, behavioural change, policy intervention, and optimized use of resources. Some highlights are mentioned below:

a) *Energy Transition to Renewable Sources*

b) *Improving Energy Efficiency*

c) *Carbon Sequestration (Afforestation and Reforestation)*

d) *Sustainable Agriculture and Soil Carbon Sequestration*

e) *Behavioural Change and Consumption Patterns*

f) *Carbon Pricing and Policy Interventions*

Several case studies are relevant to the integration of Information and Communication Technology and the Green Economy, particularly in the context of smart

cities, renewable energy, and agriculture. Here are a few noteworthy examples that can serve as case studies for Bulgaria's potential plans:

1. *The Smart City of Barcelona, Spain (Ferrer, 2017)*
2. *Khyber Pakhtunkhwa Billion Tree Tsunami Project, Pakistan (UNEP, 2019)*
3. *Finland's Renewable Energy and ICT Synergy (Sipilä, 2022)*
4. *Smart Agriculture in the Netherlands (RTHINK, 2020)*
5. *Estonia's e-Government and Digitalization for Green Initiatives* (Estonia, 2023)

Chapter Two extends the theoretical fundamentals discussed in Chapter One by providing practical insights into the role of ICT in facilitating the Green Economy's transition.

Chapter Three transitions from theoretical discussion to practical applications, emphasizing the role of ICT in supporting Bulgaria's transition to a Green Economy. It examines the role and potential of green ICT solutions in both developed countries and Bulgaria. The final chapter focuses on a practical exploration of the transition to an ICT-enabled Green Economy within the Bulgarian context. It presented practical examples of how ICT is integrated into large-scale environmental projects, such as reforestation, and provides a blueprint for applying technology to sustainability strategies. The chapter underscores the potential for ICT to drive both environmental and social progress, paving the way for a more sustainable future.

Building on the theoretical foundation established in the earlier chapters, this chapter presents a modified version of mathematical representation for ICT integration and data analytics optimizations. This mathematical framework has been adapted to improve the implementation of ICT solutions in environmental management. One of the key contributions of this chapter is the proposed methodology for implementing ICT-driven Green Economy models in Bulgaria.

The First Paragraph exemplifies Green Economy indicators and global trends influencing its adaptation. The **Green Economy** *aims to improve human well-being and social equity while reducing environmental risks and ecological scarcities. To monitor progress toward a Green Economy, a set of indicators is applied*. These indicators assess

the *economic, environmental*, and *social dimensions* that are integral to sustainable development. This illustration lays the foundation for the practical implementation of the project.

The Second Paragraph defines greening ICT and its solutions for well-being in the context of the Green Economy with the case study as an illustration. The following are the ways the Green Economy contributes to human well-being, supported by facts and a case study to illustrate its practical applications.

- *Environmental Protection and Climate Resilience*
- *Job Creation and Economic Growth*
- *Resource Efficiency and Circular Economy*
- *Poverty Alleviation and Social Inclusion*

The reason for choosing the Green Economy as part of the project is explained briefly as the Green Economy contributes to **human well-being** by supporting healthier environments, improving social conditions, and providing economic opportunities. Well-being is a concept encompassing physical health, mental well-being, economic stability, social inclusion, and environmental quality and is briefly explained as under:

- *Physical Health*
- *Mental Well-Being*
- *Economic Stability and Livelihoods*
- *Social Inclusion and Equity*
- *Environmental Quality*

The case study of Germany's Energiewende for energy transition is a prime example in this regard.

The Third Paragraph explains the Bulgarian position regarding ICT and the Green Economy with detailed facts and figures to support the fact that Bulgaria is ready for the Implementation of an ICT-driven Green Economy and with case studies showing *the appropriate green practices for Bulgaria*.

This paragraph explains the challenges and opportunities in adopting green ICTs in Bulgaria. Bulgaria, as a member of the European Union, is aligning its policies with the

EU Green Deal - a framework aimed at achieving carbon neutrality by 2050. Bulgaria's transition is marked by both progress and challenges, which can be used as an opportunity for an ICT-driven Green Economy in Bulgaria, and some of the highlights regarding it are listed below:

- *Energy Transition*
- *Green Jobs and Innovation*
- *Environmental Governance*
- *Smart City Initiatives in Bulgaria*
- *Renewable Energy Integration and ICT*

In this paragraph, *appropriate case study green practices for Bulgaria* are discussed as an example:

- *Nicosia Smart City (Cyprus)*
- *Amsterdam Smart City*

The **Fourth Paragraph** of the final chapter presented *the method for the implementation of ICT's driven Green Economy model in Plovdiv, Bulgaria*, with the *mathematical representation*, *ICT integration, and data analytics optimization.*

There are various methodologies available for conducting research, each with its strengths and weaknesses. After careful consideration, the researchers used a qualitative research methodology with a case study approach. This decision stems from the desire to gain a deeper understanding of complex phenomena and data analyses, which other methods may not fully capture.

For this research, Plovdiv was selected as the primary case study. Plovdiv, as one of Bulgaria's largest and most historically rich cities, presents a unique context for exploring the intersection of Information and Communication Technology and sustainable economic practices. The goal of this research is to provide an in-depth perspective that is informed by both an extensive literature review and a detailed case study analysis. By focusing on Plovdiv, the aim is to uncover specific local progress, challenges, and opportunities that can inform the development of a customized strategy for an ICT-driven Green Economy in Bulgaria.

The justification for selecting Plovdiv as the primary purpose of this study is diverse. The city is becoming recognized as a centre for innovation and technology, making it an ideal place to investigate how ICT may assist the transition to a Green Economy. Through an analysis of the local context, to identify best practices and potential barriers that could influence the successful implementation of sustainable initiatives.

This paragraph justifies and puts the case forward about the adaptation success of the Case Study of Billion Tree Tsunami project in the city of Plovdiv. A brief introduction about the summarization of the project is in the section below.

Th**e Khyber Pakhtunkhwa (KP) Billion Tree Tsunami project** (kpGov, 2023) is an excellent case study for Plovdiv's Green Economy, especially for sustainable forestry management and leveraging **information and communication technology**. Here are brief into why it holds relevance as explained detailed in the thesis as follows:

- *Scale and Success in Reforestation*
- *Carbon Sequestration and Climate Mitigation*
- *Economic and Job Creation Benefits*
- *Role of ICT for Monitoring and Transparency*
- *Community Involvement and Policy Integration*

Key Outcomes of KP's Billion Tree Tsunami

- **Carbon Sequestration:** It estimated that the project could sequester up to 140 million tons of CO_2 over the next 20 years
- **Cost:** $223 million investment from the provincial government and international donors (IUCN, 2017)
- **Community Engagement:** Over 500,000 green jobs created, including tree planting and nursery development
- **Ecosystem Restoration:** 350,000 hectares reforested with indigenous and fast-growing species to ensure sustainable growth

Positive Reviews and Recognition of Billion Tree Tsunami

- **World Economic Forum**: The project planted trees across 350,000 hectares in KP, leading to significant environmental restoration, combating deforestation, and reducing the risk of flooding and landslides. It also generated green jobs, benefiting local communities, particularly youth and women. The project exceeded KP's commitment to the Bonn Challenge, restoring degraded lands globally (WEF, 2024).
- **UN Environment Programme (UNEP)**: The Billion Tree Tsunami was hailed as a significant effort in ecosystem restoration. UNEP Regional Director for Asia-Pacific, Dechen Tsering, praised Pakistan's leadership in addressing climate change and contributing to the UN Decade on Ecosystem Restoration (UNEP, 2024).
- **International Union for Conservation of Nature (IUCN)**: Inger Andersen, former head of IUCN, described the project as "a true conservation success story" due to its role in rehabilitating ecosystems and surpassing global restoration goals (WEF, 2024).
- **United Nations Development Programme (UNDP)**: The project was lauded for its role in mitigating climate change. UNDP's Resident Representative in Pakistan, Knut Ostby, emphasized the importance of the project in addressing carbon emissions and creating employment (Radio PK, 2024).
- **WWF-Pakistan**: An independent audit by WWF-Pakistan declared the project a success in terms of environmental, social, and economic impacts, underscoring its role in creating sustainable livelihoods through reforestation (WEF, 2024).
- **Local Impact and Testimonials**: Villagers in KP have shared their positive experiences, noting how the project created tree nurseries that boosted incomes. Community members were employed to care for the saplings, making it a locally driven initiative (Dawn News, 2023).
- **Media and Public Support**: The project was praised by the public and media for its long-term vision. Supporters highlighted that the government's focus on such green initiatives sets a precedent for future generations, ensuring that reforestation efforts benefit both the environment and local economies (Dawn News, 2023).

In this paragraph, a detailed phased-wise methodology is discussed and implemented, and below is a summarized part about the phase-wise approach:

Table 1. Implementation Phases of the Project.

Phase	Objective	ICT Tools Involved	Actions	Timeframe	Estimated Costs
1. Feasibility Study and Site Selection	Identify suitable sites for afforestation and assess environmental impact using data-driven approaches.	GIS, Remote Sensing, AI	- Use GIS and satellite data to identify degraded lands and industrial zones. - AI to analyse environmental data and predict optimal planting sites.	3 months	€300,000
2. Tree Nursery Development	Set up ICT-enabled tree nurseries to monitor tree growth and health before planting.	IoT Sensors, AI	- IoT sensors to monitor soil, humidity, and temperature in nurseries. - AI to predict nursery capacity and plant growth potential.	6 months	€400,000
3. Pilot Afforestation in Industrial Zones	Initiate tree planting in high-emission zones.	Drones, GIS, IoT	- Drones to assist with tree planting in difficult terrains. - GIS to map tree planting locations and track growth. - IoT for real-time monitoring of soil and tree health.	1 year	€3 million
4. Community Engagement and Awareness	Involve the local community using mobile technology for participation in tree planting and monitoring.	Mobile Applications, Blockchain	- Develop a mobile app for public engagement. - Use blockchain for crowdfunding and transparency in project transactions.	6 months	€500,000

5. Large-Scale Expansion	Scale afforestation efforts to cover urban and peri-urban areas.	Drones, IoT, Remote Sensing	- Use drones and IoT sensors to expand afforestation to larger areas. - Remote sensing to monitor overall forest cover.	2 years	€5 million
6. Monitoring and Maintenance	Ensure sustainability and growth of the forest using real-time data and long-term monitoring.	IoT, AI, Drones	- IoT sensors to monitor tree growth, soil conditions, and CO_2 absorption. - AI to improve irrigation and resource allocation. - Drones for aerial monitoring.	5 years	€2 million per year

Total Estimated Cost: ***€14.2 million*** *(excluding long-term monitoring)*
Source: Author's summary.

Paragraph 3.4.4 details the ICT solutions to adapt the Billion Tree Tsunami project. The integration of IoT sensors, drone technologies, geolocation systems, AI, data analytics platforms, and community engagement tools creates a robust ICT solution for managing the Billion Tree Tsunami Project. These technologies ensure effective monitoring, resource optimization, and data transparency, raising both environmental sustainability and community participation. By employing these tools, the project can improve its impact and achieve its long-term goal of ecological restoration after reforestation, contributing to a Green Economy and sustainable development.

In this section of the paragraph that discusses the project in the context of ***Plovdiv* and similar *European Union (EU)* reforestation and environmental sustainability initiatives**, it is shown how the ICT-based reforestation plan for the Khyber Pakhtunkhwa billion-tree project can draw inspiration from successful projects and technologies already implemented in the EU. This includes leveraging best practices, equipment, and strategies from Europe's green initiatives, smart forestry projects, and urban reforestation efforts.

In the last paragraph, 3.4.5 presented the *mathematical frame representation, ICT integration, and data analytics optimization, as mentioned briefly below.*

To estimate the optimal number of trees to plant in specific zones, we can define a model as follows:

Let:

- A = Area available for afforestation (in hectares)
- N= Total number of trees to plant
- T = Number of trees per hectare (planting density)
- C_s= Average CO_2 sequestration per tree (kg/tree/year)

The total number of trees $\boldsymbol{N}$ This can be calculated as:

$$\boldsymbol{N = A \times T}$$

The carbon sequestration potential **S** for the planted area will be:

$$\boldsymbol{S = N \times C_s = A \times T \times C_s}$$

This equation helps determine the expected reduction in CO_2 emissions, guiding planting efforts.

- *Carbon Sequestration Model for Plovdiv*

Let us define the components involved in the tree planting project:

Parameters:

- A = Total afforestation area in hectares (ha)
- T_d = Tree density, i.e., number of trees per hectare (trees/ha)
- C_s = Carbon sequestration per tree per year (kg CO_2/tree/year)
- t= Time in years
- $M(t)$ = Mortality rate of trees at time tFraction of total planted trees that die)
- $S(t)$ = Net carbon sequestration at time t (kg CO_2/year)
- ICT_f = ICT efficiency factor (improvement in planting, monitoring, and survival rate due to ICT tools)

Now, let us break down the equation:

1. **Number of Trees Surviving Over Time**

After accounting for tree mortality, the number of trees surviving at year t is given by:

$$N_{surv}(t) = A \times T_d \times \big(1 - M(t)\big)$$

2. **Carbon Sequestration of Surviving Trees[2]**

Each tree sequesters $\boldsymbol{C_s}$Kg of CO_2 per year. The total carbon sequestration at the time of considering the number of surviving trees is:

$$\mathbf{S(t) = N_{surv}(t) \times C_s}$$

Substituting $\boldsymbol{N_{surv}\ (t)}$**From** the previous equation, we get:

$$\mathbf{S(t) = A \times T_d \times (1 - M(t)) \times C_s}$$

CONCLUSIONS

This thesis has explored the potential of information and communication technologies in the transition towards a Green Economy, demonstrating how ICT can support sustainable development, enhance resource use, and promote environmental

[2] CO2 Sequestration per Tree: Research shows that on average, a mature tree absorbs about 21.77 kg of CO2 per year in temperate climates. See: Nowak, D. J., and Crane, D. E. "Carbon storage and sequestration by urban trees in the USA." Environmental Pollution, vol. 116, no. 3, 2002, pp. 381-389.

sustainability alongside economic viability. *Through a complete analysis of the theoretical frameworks, challenges, and practical applications, this research has examined and explored the transformative role of ICT in assisting the shift from traditional economic models to green, more sustainable practices*.

The theoretical nucleus of this thesis is presented in chapter one: *"A Green Economy is an economic model that prioritizes sustainable development by encouraging the efficient use of renewable resources, the conservation of natural capital, and the integration of* ***information and communication technologies (ICT)*** *to support ecologically responsible practices. It aims to achieve long-term economic growth while minimizing* ***environmental degradation***, ***supporting substantive equality***, *and ensuring that all ecosystem components are preserved and* ***interconnected***. *The Green Economy seeks to* ***decouple economic growth from environmental harm***, *reduce poverty, and create a more equitable and sustainable future"*.

The Green Economy Transition Framework (GETF) serves as a shell of this thesis with its **Green Economy Transition Framework (GETF)** ICT pathway implementation.

The mathematical framework for optimizing ICT integration with the case studies forms the base of the practical implementation of the thesis.

The Billion Tree Tsunami Project showed promising results, and these results presented the case of a success story. The implementation of the project with ICT allows us to be a success story. The implementation phase-wise, the technology needs, and cost utilization were thoroughly discussed in that thesis and presented for the implementation.

An ICT-based Green Economy project with inclusiveness is the need of the hour, as it balances technology with sustainability to create equitable growth. By exploiting Information and Communication Technology (ICT), such projects can promote efficient resource use, reduce carbon footprints, and encourage green innovation. ICT Green Economy inclusiveness ensures that all individuals and groups, regardless of their background, have equal access to opportunities, resources, and benefits to bridge the digital divide while increasing economic opportunities.

In this project case, the user (author) does not measure the values and data himself but accepts the assessment of the nationally and internationally recognized organizations (UN, EEA, IRENA, OECD, etc.).

Applicability and utility

The research with the title "The Potential of Information and Communication Technologies in the Transition towards Green Economy" can play an important role in many fields in the move towards a Green Economy, including:

- *Energy Efficiency and Smart Grids*
- *Sustainable Urban Development and Smart Cities*
- *Circular Economy and Resource Optimization*
- *Environmental Monitoring and Data-Driven Decision Making*
- *Promoting Sustainable Consumption and Production*

In accordance with the goal and set tasks of the dissertation research, the following main results were obtained:

1. The principles of the Green Economy are defined and established, expressing it as an economic model that promotes growth within the boundaries of the environment while ensuring social justice.
2. The strong link between the Green Economy and the Circular Economy is highlighted, and the importance of the framework approach to sustainability is demonstrated.
3. Centering ICT in sustainability analysis shows how technology improves energy efficiency, optimizes resource use, and reduces waste – important elements for achieving global sustainability goals.
4. The important role of ICTs is highlighted by their coalition with several key Sustainable Development Goals (SDGs), especially those focused on climate action, responsible consumption, and clean energy.
5. The model of the Linear Economy is critically examined by discussing structural issues.
6. The role of information and communication technologies (ICTs) has been identified as a key enabler for the Green Economy.
7. It is shown how the integration of ICT and sustainability goals in different industries and sectors of the Green Economy can reduce environmental damage and improve economic competitiveness.
8. A methodological approach has been introduced to reduce the carbon footprint in specific ICTs and in the ICT sector itself.

9. A conceptual model of a framework for the transition to a Green Economy (GETF) has been introduced, outlining the path to achieve sustainability through the integration of information and communication technologies (ICT).

10. The possibility of integrating ICT in the framework of the Green Economy through case studies of relevance for Bulgaria is emphasized.

11. Framework for future research and policy development for future exploration of green technologies is established.

12. Efforts to achieve sustainability with the help of ICT are optimized by improving energy use, waste management and resource conservation.

13. It is shown how the approbation of the Billion Tree Tsunami Project can serve as a model for ICT-stimulated large-scale environmental initiatives.

14. The application of ICT in urban resilience projects with the help of the case study Billion Tree Tsunami is demonstrated.

15. A mathematical framework has been introduced to optimise the integration of ICT in sustainability projects.

The conclusion of the dissertation demonstrates that ICTs are not only a powerful tool for improving environmental sustainability, but also a decisive factor for the transition to a Green Economy, supporting energy efficiency, optimizing resources and reducing environmental impact.

The contributions of this thesis contributed to the development of new theoretical frameworks and practical methodologies for integrating ICT and the Green Economy in the following directions:

1. A solid basis has been created for understanding the role of ICT in sustainable development with an alternative understanding of the Green Economy, helping policymakers and businesses navigate the complexity of the green transition.

2. The reviewed case studies applicable to Bulgaria, a methodology for reducing the carbon footprint in ICT and a modified mathematical representation for integrating ICT with the Green Economy Transition Framework (GETF) provide a structured path to align ICT with the broader sustainability goals.

3. The proposed existing tools for optimising data-driven environmental solutions in the Billion Tree Tsunami project serve as a successful example of how ICT can support large-scale environmental initiatives, and how its adaptation in Bulgaria can be

a key driver of national sustainability efforts and unlock the potential of information and communication technologies in the transition to a Green Economy.

While this thesis has highlighted the importance of ICT in supporting the Green Economy, **it also acknowledges their certain limitations**.

The practical challenges of implementing ICT solutions, particularly in terms of infrastructure, policy alignment, and technological access, need to address for broader adoption. Future research could further examine the potential of ICT to drive innovation in areas such as renewable energy integration, sustainable agriculture, and waste management. Comparative studies across different contexts could provide valuable insights into the scalability of ICT-driven Green Economy models and further refine the mathematical models introduced in this study.

The scientific results obtained during the research can be applied in the activities of the Academy of Economics, Ministry of Education and Culture, as well as other departments and organizations.

IV. DISSERTATION CONTRIBUTIONS REFERENCE

The theoretical and practical significance of the work and its main contributions are expressed in the following:

- *in theoretical aspect:*

1) A new author's definition of the concept of Green Economy is proposed, expanding the traditional concept of sustainability by integrating the principles of cooperation, inclusion, sustainability and integration of information and communication technologies.

2) The structural shortcomings of the Linear Economy are identified in the context of case studies highlighting the important role of information and communication technologies in the transition to a Green Economy.

3) A conceptual framework for the transition to a Green Economy has been developed, which positions information and communication technologies as a major transformative factor for resource optimization, energy efficiency and transition to a low-carbon, Circular Economy.

- *in practical aspect:*

4) A methodology for reducing the carbon footprint in information and communication technologies has been introduced and strategies suitable for Bulgarian practice for energy-efficient design and operation of digital technologies have been proposed.

5) A mathematical framework has been introduced to optimize the integration of information and communication technologies in the technology sector of the Green Economy of Bulgaria in order to improve the analysis of environmental data.

6) The concept of the "Billion Tree Tsunami Project" has been adapted to the Bulgarian practice as a potential opportunity to accelerate the green transition of the city of Plovdiv in the direction of increasing the urban forest cover, improving air quality, increasing community resilience and promoting local biodiversity.

V. LIST OF DISSERTATION PUBLICATIONS

Ashraf, A. & Marinova, N. (2022, October). Coalescence of the Society 5.0 with Circular Economy for Social Well-being. *International Scientific and Practical Conference Circular Economy in the Context of the Relationship Industry 4.0 – Society 5.0 (CERIS)*, 186-193. Svishtov: Publishing House "Tsenov".

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Ashraf, A. (2024). Leveraging Digital Twins for Ecosystem Restoration and Biodiversity Conservation in the Green Economy Framework. *Annual Almanac "Scientific Research of PhD Students", 20*. (under print)