Typology for ICT Adoption of EU Environmental Policies

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Abstract - Information and Communication Technologies (ICT) have the potential to promote sustainable development as the growth in ICT is associated with environmental planning, research, conservation and planning. The aim of the paper is to create a typology for ICT adoption of EU environmental policies. The level of dependence on ICT solution and the level of complexity of the used ICT solutions by the established environmental policies are examined. The EU environmental policies are classified in three homogenous groups with similar ICT characteristics using K-Means cluster analysis. Regarding the classification according to the criteria, most EU environmental policies demonstrate high rate of ICT adoption and it constitutes a first and very important step for the transition to the new digital era, which is promoted by the European Union.

Key-Words - ICT adoption; environmental policies; European Union; typology; ICT solutions

1. Introduction

Green ICT (Information and Communication Technologies) associates the needs of present generations without compromising the ability and the right of future generations to meet their own needs and at the same time, it involves pollution prevention at the end of a product's use, product stewardship to reduce the carbon footprint during use, and use of clean-green technologies to reduce the use of materials that pollute the environment and develop eco-friendly competencies [1,2]. Green ICT is used as an umbrella term incorporating concepts like cloud computing outsourcing, virtualization, procurement, recycling, power management, etc. [3]. ICT solutions can not only support but also enable the use of Renewable Energy Sources (RES) through approaches such as smart grids, smart lighting, smart heating, etc. [4].

Many researchers have already identified areas in which ICTs have a major effect on the environment, while most of them identify the energy efficiency of buildings and transport substitution and rationalization through the process of dematerialization, tele-work and tele-conferencing, video-conferencing as the main areas of impact based on sectoral energy consumption and application opportunities (e.g. Climate Risk, 2008) [5]. The contribution of the dimensions of Green Informatics to the environmental protection and sustainable development are the following [6]: reduction of energy consumption and carbon dioxide emissions during the manufacturing process and usage in the context of a low carbon economy, growth of environmental awareness through education, training and information diffusion, effective communication for environmental projects and networks, environmental governance for sustainability.

In an attempt to better understand the contribution of ICT and related management practices as tools for dealing with environmental issues, particularly from a developing country perspective, the following ICT application categories are defined [7]: environmental observation, environmental analysis, environmental planning, environmental management and protection, impact and mitigating effects of ICT utilization, environmental capacity building. European Union through the Fifth Framework Programme had replaced the terms 'ICT' and 'telematics' with a new one in a broader sense: Information Society Technologies (IST) [8]. The use of ICT at full potential and efficiency by means

of three ecological measures is proposed [9]:

- Green ICT: reduction of carbon dioxide emissions during the manufacturing process and use of ICT
- Smart ICT: ICT usage in sectors like energy, transportation, buildings, manufacture, logistics and forestry to reduce their carbon footprint
- Community ICT: applying ICTs at community level to reduce energy consumption and substitute for journeys

These three themes underpinned the selection of ten key policy areas and form an overall ICT policy framework for the EU over the next five to ten years [10]:

(1) The knowledge economy: driver of future wealth
(2) Clear leadership: rethinking the EU's policy making process
(3) The knowledge society: participation for all
(4) Online trust: a safe and secure digital world
(5) Green ICT: support for an eco-efficient economy
(6) Revolutionising eGovernment: rethinking delivery of public services
(7) Next generation infrastructure: balancing investment with competition
(8) A single information market: enabling cohesion and growth
(9) SMEs and ICT: supporting Europe's small enterprises
(10) Soft infrastructure: investing in social capital

Europe's productivity and competitiveness crucially are based on its ability to generate, scale-up, and efficiently exploit the innovative digital technologies across all the sectors of economy involving Europe's traditional strengths such as automation, vehicle manufacturing, financial services or machine equipment [11]. EU regions are characterized by considerable differences in terms of economic development and well-being [12]. In times of digitalization and growing complexity of research, international cooperation in research, development and innovation is becoming increasingly important [13]. The OECD's work programme regarding ICT, climate change and environment belongs to the Organisation's development of a wider Green Growth Strategy, results of which have been presented in May 2010 at the OECD Council at Ministerial Level [14]. 'Environmental innovation' are called new or enhanced processes, products and technologies which aim either to reduce or to avoid environmental damage [15, 16].

The Global e-Sustainability Initiative report is widely referred to as SMART 2020 report supports that ICT are supposed to increase a 2.8% of total global CO2 emissions by 2020 but on the other hand, ICT are supposed to reduce CO2 emissions by 15% of the estimated total global CO2 emissions [17, 18]. The definition of sustainable development, known as the "Brundtland definition", combines two ethical claims [19]: intra-generational justice (meeting the needs of the present) and inter-generational justice (not compromising the ability and the right of future generations to meet their own needs). During the past decades, the rise of urban expansion and sprawl processes joined many urban layouts with different morphological characteristics and a common lack of environmental solutions and alternative energy [20]. The EU's main environmental goals of greening the economy in line with the sustainable development goals, protecting the natural environment and safeguarding health, wellbeing and human rights across the EU [21] are completely undermined unless EU member states implement these policies [22]. Climate Change Mitigation (CCM) policy analysis is non-trivial, since multiple policy levels (community-level, provincial-level, national, EU, international), stakeholders (entrepreneurs, politicians, governors, society) and actors are getting involved [23].

Environmental Policy Integration (EPI) refers to the incorporation of environmental objectives in non-environmental policy sectors, such as agriculture, energy and transport, with the aim to target the underlying driving forces, rather than merely symptoms, of environmental degradation [24-27]. EPI is closely related to the concept of sustainable development, which began to shape the general thinking of environmental protection since the publication in 1987 of the report of the United Nations' World Commission on Environment and Development, entitled Our Common Future and commonly referred to as Brundtland Report [28, 29]. While the Brundtland Report efficiently limits EPI to the integration of environmental concerns in economic decision-making, the Rio Declaration and Agenda 21 discuss integration of environmental concerns across a broader spectrum of sectors [24]. The EU assumed a leading role in promoting ecosystem services and natural capital as a conceptual framework with practical implications for policy-making [30].

The aim of the paper is to create a typology for ICT adoption of EU environmental policies. The level of dependence on ICT solution and the level of complexity of the used ICT solutions by the established environmental policies are examined.

The EU environmental policies are classified in three homogenous groups with similar ICT characteristics using K-Means cluster analysis.

2. Methodology

The methodology approach concerns the study of the ICT adoption of the EU environmental policies and in particular, the examination of the level of dependence on ICT solution and the complexity of the used ICT solutions by the established environmental policies through their classification in the existing models. The data were collected from the official European Union website (www.europa.eu). The sub-topics of the EU environmental policies are the following: tackling climate change, general provisions, sustainable development, waste management, air pollution, water protection and management, nature and biodiversity protection, soil protection, civil defence, noise pollution, cooperation with third countries. At first, the regulations, the directives, the decisions, the communications and other acts regarding the environmental issues were recorded.

Additionally, a 2-dimentional table was developed in order to examine the existence of the criteria that European Commission uses to assess ICT implications of EU legislation since 2010 [31] (Table 1). These criteria constitute the variables x1, x2, ..., xn. The level of dependence of the EU environmental policies policies on the ICT solutions and the level of complexity of the ICT solutions may be low, medium and high (1, 2 and 3 respectively).

Table 1. Criteria.

Variable	Criterion
$\mathbf{X_1}$	Does the legislation require the design of information rich processes?
$\mathbf{X_2}$	Does the legislation require the design of new business processes?
$\mathbf{X_3}$	Are large amounts of data gathering required in these processes?
$\mathbf{X_4}$	Is collaboration between ICT systems of multiple DG's or institutions/ organizations required?
$\mathbf{X_5}$	Is the legislation concerning ICT systems or is ICT a supporting function of the legislation?
$\mathbf{X_6}$	Does the legislation require new ICT solutions or can existing applications fulfill the requirements?
$\mathbf{X_7}$	Are there any legacy systems which might hamper the implementation?
$\mathbf{X_8}$	Does the legislation impose authentication requirements?
$\mathbf{X_9}$	Is a large amount of data exchange between Member States and/or the Commission required?
$\mathbf{X_{10}}$	What is the required lead -time of the implementation (urgency)?
$\mathbf{X_{11}}$	Are new interoperability specifications required?
$\mathbf{X_{12}}$	Does the initiative impose high security requirements on the ICT solution?

The EU environmental policies were classified in three homogenous groups with similar ICT characteristics using K-Means cluster analysis. The most popular hierarchical algorithms are single-link and complete-link; the most popular and the simplest partitional algorithm is K-means [32]. K-means clustering [33] is a method commonly used to automatically partition a data set into k groups [34]. K-means requires no prior information about the associations of data points with clusters [35-39]. The K-Means algorithm is an excellent choice due to its convergence properties [40].

A generic outline that describes all k-means algorithms is presented below [41-44]:

(1) Initialize the seed values for a prespecified number (k) of clusters. These seed values represent the cluster centroids. If computationally feasible, cluster centroids from a prior hierarchical cluster analysis

(e.g. Ward's method or group average) can be used as seeds. This method of initializing the k-means seed values has been recommended by Milligan, who – when summarizing the findings of a previous Monte Carlo study – concluded that "the k-means algorithms do no seem to be very desirable if random starting seeds must be used"

(2) Allocate each data point in the sample to the cluster with the nearest centroid. Proximity is defined using Euclidean distances.
(3) If a cluster increased in size during the last data pass, that is, if new data points were allocated to the cluster, then recomputed the cluster centroid.
(4) Alternate steps 2 and 3 until no data points change clusters.

The initial cluster centers constitute the vectors with their values based on the 12 variables, which refer to the three clusters. These 3 clusters are at maximum index distance from each other. The results from this method are presented in a large table that shows members of clusters and their distances from respective cluster centers [45].

3. Results

The research in the official European Union website (www.europa.eu) resulted in the retrieval of 227 environmental policies. According to the findings, at the criterion "Does the legislation require the design of information rich processes?", 79 EU environmental policies present low dependence on ICT solution, 94 EU environmental policies present medium dependence on ICT solution and 54 EU environmental policies present high dependence on ICT solution. Regarding the variable X2, "Does the legislation require the design of new business processes?", 21 EU environmental policies are low dependent on ICT solution, 120 policies are medium dependent on ICT solution and 86 policies are highly dependence on ICT solution. As for variable X3, "Are large amounts of data gathering required in these processes?", 83 EU environmental policies have low dependence on ICT solution, 91 policies have medium dependence on ICT solution and 53 policies have high dependence on ICT solution. Figure 1 shows the results regarding the variable X4, "Is collaboration between ICT systems of multiple DG's or institutions/organisations required?".

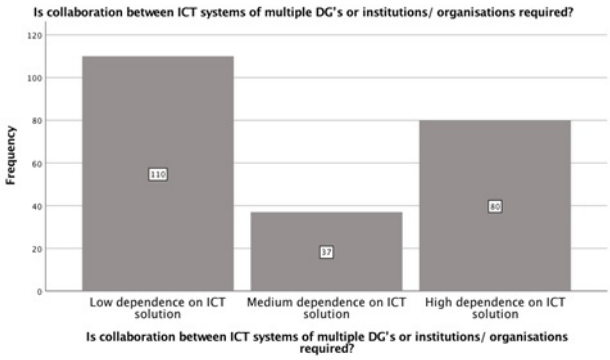

Figure 1. Level of dependence on ICT solution of EU environmental policies regarding the criterion "Is collaboration between ICT systems of multiple DG's or institutions/organisations required?"

Figure 2 shows the level of dependence on ICT solution of the EU environmental policies regarding the variable X5, "Is the legislation concerning ICT systems or is ICT systems a supporting function of the legislation?".

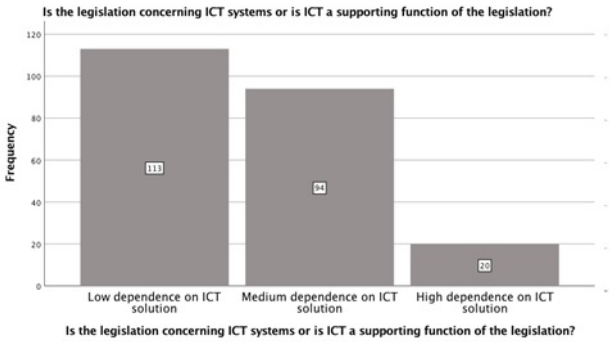

Figure 2. Level of dependence on ICT solution of EU environmental policies regarding the criterion "Is the legislation concerning ICT systems or is ICT systems a supporting function of the legislation?"

In Figure 3, the level of complexity of the ICT solutions that are implemented by the EU environmental policies regarding the variable X6, "Does the legislation require new ICT solutions or can existing applications fulfil the requirements?" is presented.

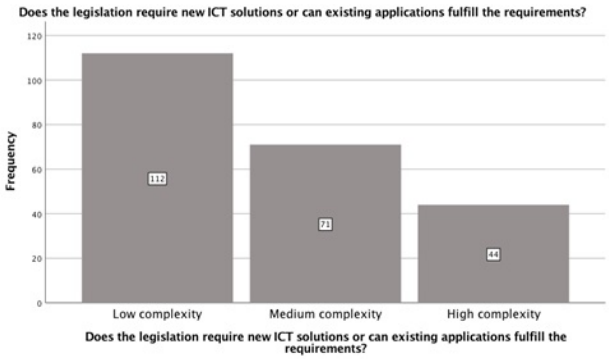

Figure 3. Level of complexity of the ICT solutions of EU environmental policies regarding the criterion "Does the legislation require new ICT solutions or can existing applications fulfil the requirements?"

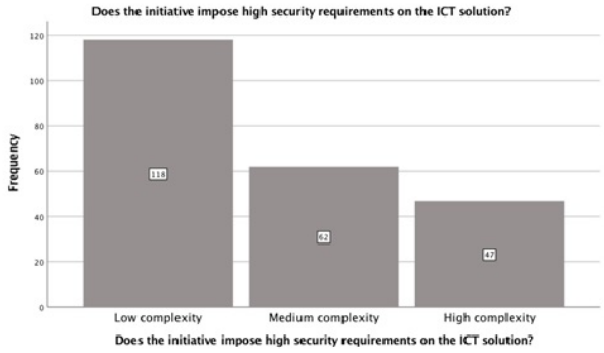

Figure 4. Level of complexity of the ICT solutions of EU environmental policies regarding the criterion "Does the initiative impose high security requirements on the ICT solution?"

Regarding the variable X7, "Are there any legacy systems which might hamper the implementation?", 160 EU environmental policies present low complexity of ICT solutions, while 67 policies present medium complexity of ICT solutions. As for the variable X8, "Does the legislation impose authentication requirements?", 86 EU environmental policies have low complexity of ICT solutions, 48 policies have medium complexity of ICT solutions and 93 EU environmental policies have high complexity of ICT solutions. Regarding the variable X9, "Is a large amount of data exchange between Member States and/or the Commission required?", 86 EU environmental policies indicate low complexity of ICT solutions, 86 policies indicate medium complexity of ICT solutions and 55 EU environmental policies indicate high complexity of ICT solutions. As for the variable X10, "What is the required lead-time of the implementation (urgency)?", 36 EU environmental policies perform ICT solutions with low complexity, 20 policies perform ICT solutions with medium complexity and 171 EU environmental policies perform ICT solutions with high complexity. Regarding the variable X11, "Are new interoperability specifications required?", 73 EU environmental policies present low complexity of ICT solutions, 119 policies present medium complexity of ICT solutions and 35 EU environmental policies present high complexity of ICT solutions. Figure 4 shows the level of complexity of the ICT solutions that are implemented by the EU environmental policies regarding the variable X12, "Does the initiative impose high security requirements on the ICT solution?".

Furthermore, K-means analysis was implemented in order to identify homogenous groups of EU environmental policies that have similar ICT characteristics but are distinctively different from other EU environmental policies. In Table 2 we can see the number of the iterations and the changes in the cluster centers. In the fifth iteration the process of redistribution of the units stops because there are no changes in the cluster centers. The maximum absolute coordinate change for any center is .000. The current iteration is 5. The minimum distance between initial centers is 4.690.

Table 2. Iteration history

Iteration	Change in Cluster Centers		
	1	2	3
1	2,212	1,775	2,005
2	,105	,255	,247
3	,028	,164	,190
4	,000	,037	,044
5	,000	,000	,000

Some of the results are presented in Table 3, where each environmental policy belongs to a cluster formed by the new cluster centers.

Table 3. Cluster membership

EU environmental policy	Cluster	Distance
Reg.401/2009	1	1,682
Reg.166/2006	3	1,923
Reg.1221/2009	1	1,852
Dec.98/685	3	1,349
Dec.2015/1339	3	1,349
Dec.2016/1841	2	,942
Direct.2003/87	3	1,349
Direct.2007/60	1	1,375
Reg.1493/93	1	2,405
Reg.1005/2009	2	2,037
COM(2005)670	3	1,249
COM(2009)162	1	1,563
COM(2008)400	2	,578
COM(1999)640	3	2,213
COM(2000)576	2	,578
COM(2002)511	2	,578
COM(2000)264	3	2,244
Reg.66/2010	2	1,048
Reg.691/2011	3	2,099
Reg.1907/2006	1	1,362

In Appendix, the final cluster centers and the profile of the three clusters are presented. According to the findings, it can be said that Cluster 1 represents the group of EU environmental policies with "High rate of ICT adoption", Cluster 3 represents the group of EU environmental policies with "Medium rate of ICT adoption" and Cluster 2 represents the group of EU environmental policies with "Low rate of ICT adoption". Table 4 is a detailed look at the distances among the cluster centers.

Table 4. Distances between final cluster centers

Cluster	1	2	3
1		4,424	2,702
2	4,424		2,035
3	2,702	2,035	

In Figure 5, the data about the number of units in each cluster are presented. According to the results, 85 EU environmental policies have been classified in Cluster 1 "High rate of ICT adoption", 76 EU environmental policies have been classified in Cluster 2 "Low rate of ICT adoption" and 66 EU environmental policies are included in Cluster 3 "Medium rate of ICT adoption".

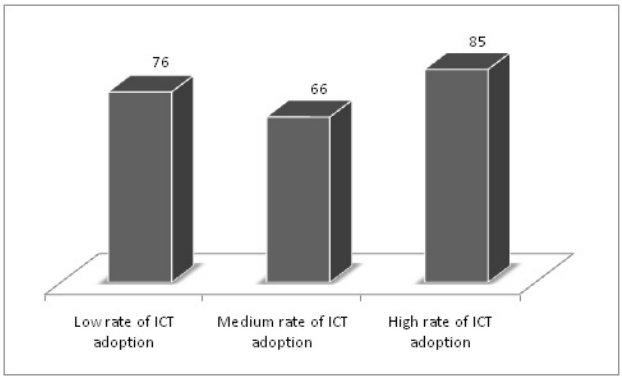

Figure 5. Number of cases in each cluster

4. Conclusion

The EU environmental policies have been distinguished and classified. According to the results, in most EU environmental policies, the legislation doesn't require the design of information rich processes although it requires the design of new business processes. Also, most EU environmental policies are noticed to have medium dependence on ICT solution through the process of large amounts of data gathering. There isn't required so strong collaboration between ICT systems of multiple DG's or institutions/organisations. Most EU environmental policies indicate that ICT systems constitute a supporting function of the legislation. Furthermore, as for the complexity of the implemented ICT solutions by the EU environmental policies, in most cases, the legislation doesn't require new ICT solutions while the existing applications can fulfill the requirements. However, there are not any legacy systems which might hamper the implementation but the legislation almost always imposes authentication requirements. There isn't required a large amount of data exchange between Member States and/or the Commission. In most cases, the required lead-time of the implementation is maximum three years and new interoperability specifications are required. In most cases, the initiative doesn't impose high security requirements on the ICT solution.

Regarding the classification according to the 12 criteria, most EU environmental policies (85) demonstrate high rate of ICT adoption. The environmental policies that belong to this group achieve high level of ICT integration at eight criteria and medium level of ICT integration at four criteria. On the other hand, the group with medium rate of ICT adoption consists of the environmental policies (66) that present high level of ICT integration at one

criterion, medium level of ICT integration at six criteria and low level of ICT integration at five criteria. Very important is also the percentage of the EU environmental policies (76) that perform low rate of ICT adoption, in which the policies indicate high and medium level of ICT integration at only two criteria and low level of ICT integration at 10 criteria.

The status of ICT adoption of an economy is an indicator of its potential ability to exploit the economic opportunities afforded by the new technologies or more generally its prospects for transition to the new economy [46, 47]. Some of the key issues for emerging and developing economies include [48]: access to the broadband networks and ICT equipment and services necessary to enable their operation, access to data and how the masses of data collected can be brought together to provide a holistic picture of an eco-system or environment, affordability and how emerging and new technologies can be implemented in contexts of severe budgetary constraint. On the European Union level a set of Directives, Regulations and Communications affects the impact of ICTs on sustainability [49]. To prepare for and to take account of the ICT aspects of the EU policies, stakeholders involved in the drafting and the implementation of legislative proposals must be more aware of the ICT exploitation of such proposals [50]. The management of sustainability issues requires attention from actors at different levels, and challenges how contemporary planning practices plan for development [51]. However, the high and medium rate of ICT adoption by the 66% of the EU environmental policies constitutes a first and very important step for the transition to the new digital era. The new digital era is promoted by the eEurope Action Plan aims to ensure the EU fully benefits from the changes the Information Society is bringing and plans to create a digitally literate Europe [52].

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APPENDIX

Table 5. Final cluster centers

Category	Variable	Criterion	Cluster		
			1	2	3
Dependence on the ICT solutions	X_1	Does the legislation require the design of information rich processes?	Medium	Low	Medium
	X_2	Does the legislation require the design of new business processes?	High	Medium	Medium
	X_3	Are large amounts of data gathering required in these processes?	High	Low	Medium
	X_4	Is collaboration between ICT systems of multiple DG's or institutions required?	High	Low	Medium
	X_5	Is the legislation concerning ICT systems or is ICT a supporting function of the legislation?	Medium	Low	Low
Complexity of the ICT solutions	X_6	Does the legislation require new ICT solutions or can existing applications fulfill the requirements?	High	Low	Low
	X_7	Are there any legacy systems which might hamper the implementation?	Medium	Low	Low
	X_8	Does the legislation impose authentication requirements?	High	Low	Low
	X_9	Is a large amount of data exchange between Member States and/or the Commission required?	Medium	Low	Low
	X_{10}	What is the required lead -time of the implementation?	High	Low	Medium
	X_{11}	Are new interoperability specifications required?	High	Low	Medium
	X_{12}	Does the initiative impose high security requirements on the ICT solution?	High	High	High