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# ERASMUS MUNDUS IN PERCCOM: EDUCATION FOR GREEN INDUSTRY

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## Abstract

*Today environmental safety, green energy, and ecological engineering becomes a top priority as a result of negative impact of human activities on the environment, current rates of industrial development and globalization. Higher education sector has a responsibility to those challenges as a key player in the successful transition to a knowledge-based economy and society. The problems, which the society is facing today, could be mitigated by training highly qualified professionals with expertise in green information and communication technologies.*

*International Erasmus Mundus Master Program in Pervasive Computing and Communications for Sustainable Development (PERCCOM) aims at combining advanced information and communication technologies with environmental awareness. This program provides unique competences for ICT professionals who will be able to build cleaner, greener, more resource and energy efficient cyber-physical systems.*

*This paper defines a cross-disciplinary approach of master degree program in green ICT. The method used for defining the pedagogic program content focuses on competences in order to ensure sustainability of the program in terms of employability.*

*The paper provides a feedback from students, which demonstrates program evaluation results and emphasis issues that need to be improved.*

*This paper covers such aspects as training in the development of tools and software for sustainable development, as well as educating open-minded professionals familiar with international research environment.*

## **Introduction**

We live in a fast changing world, in the age of globalization and rapid development of science and technology. International trade and investment, labour mobility, technologies transfer and fast growth of information technology affects our lifestyle, way of thinking, feeling and acting.

Internationalization of higher education is one of the ways society responds to the impact of globalization. It includes efforts by higher education institutions to establish research and other collaborative links, and to further develop involvement in cross-national education and multilateral initiatives such as the Bologna process (de Wit, 2010). Academic integration provides a diversification of educational and research activities, while openness in education allows making a comparative analysis of methodology and curricula.

Joint degree programs as part of institutions' internationalization strategies have become more and more popular due to demand for more comprehensive international study options. It is obvious that capacity of that process depends on the field of study and areas of research. Therefore, it is reasonable to consider dynamic and demanding fields. A typical example of this trend is green technology.

Today environmental safety and green energy becomes a top priority as a result of negative impact of human activities on the environment, current rates of industrial development and globalization.

The Smart 2020 report (2008) written by the international climate group recommends to intensively deploy Information and Communication Technologies (ICT) both for enhancing the monitoring of environment and human activities (industry, building, transport, etc.) and for distributed smart ICT systems to mitigate the pollution, the waste, food quality and supply, energy constraints, etc.

Higher education sector has a responsibility to address those challenges as a key player in the successful transition to a knowledge-based economy and society. By educating professionals with high expertise in networking, computing and programming, capable to design, develop, deploy and maintain both pervasive computing systems and communication architectures for sustainable development the problems might be solved.

Literature review of educational programs in the related fields shows a growth of disciplines and graduate programs on the environmental topics as well as on ICT in general. However, no international programs is found that has curricula both on ICT and on environmental considerations.

This paper focuses on the experience of an international consortium, which developed and established an international master degree program "Pervasive computing and communications for sustainable development", first Erasmus Mundus Joint Master Degree (EMJMD) program related to green ICT.

The method used for defining the pedagogic program content focuses on the competences in order to ensure sustainability of PERCCOM in terms of employability. Thus, initiation of new curricula is based on the REFLEX study used by Céreqcenter to evaluate the Erasmus Mundus employability (MKW GmbH, 2011) in terms of five key categories of competences.

This paper briefly describes the content of PERCCOM program and provides a discussion on the challenges in the development of an international master program in Green ICT.

## **Literature Review**

Beginning in the early 2000s, different authorities, including the European Commission (Commission of the European Communities, 2009), pointed out the importance of ICT sector in the search for a solution to a problem of energy-efficiency and low-carbon economy. It was an initial step towards

creating a policy framework in order to promote the energy saving potential of ICTs so that it will be widely recognized and exploited. According to this report entitled "Mobilizing Information and Communications Technologies to facilitate the transition to an energy-efficient, low-carbon economy" (Commission of the European Communities, 2009), ICT-enabled improvements in different sectors such as transport, building and energy, could save about 15% of total carbon emissions by 2020 (paragraph 17). The new market demand in sustainable development was also expressed by Organization for Economic Co-operation and Development (OECD) in the reports on "OECD Information Technology Outlook 2010" (2010) and "The 2011 Gartner Scenario: Current States and Future Directions of the IT Industry" (2011). Those reports highlighted ICT producers' responsibilities in minimising environmental impact of their products and operations.

The consequences of such demand for European labour market were obvious. Companies also noticed an importance of green ICT projects (Gartner, Inc, 2009). In December 2008, Gartner surveyed 620 respondents who had responsibility for their organisation's green IT programs. Only 10 per cent of them had no green ICT projects at the time of the survey. Respondents were asked a series of questions about the development of their organization, ICT environment programs and also the impact of the recession on green ICT initiatives, including green ICT in semiconductor industry, software industry, etc. According to the survey, in most cases, particularly in Europe and Asia/Pacific, the recession would not change or would increase the priority of green ICT projects.

Gartner (ibid) also asked organizations that had a specific capital expenditure budget for green ICT (22 per cent of respondents), what proportion of total IT capital expenditure this represented. Overall, more than one-third of respondents (46 per cent in Europe, 38 per cent in Asia/Pacific and 36 per cent in the US) anticipated spending more than 15 per cent of their IT capital budgets on green ICT projects.

These new trends are directly reflected in educational market, as higher educational institutions should have been involved in an effort to spur green technology for the ICT industry. Extensive education market research showed growing interest in environmental issues, in particular, increasing number of courses and degree programs. According to OECD (2014) the number of students, graduated in environmental protection and physical sciences, has increased by about 62% since 1998. As claimed, this figure is comparable to growth rates in mathematics and statistics (OECD, 2014). Most degree programs provide students with competencies in different fields relating to ecology and environmental safety. One of the examples is EMAE (European Master in Applied Ecology, n.d.), whose aim is "contribution to conserve environment with regards to business and legislation, and promotion of sustainable growth". Another one is IMETE (International Master of Science in Environmental Technology and Engineering, n.d.), which foster knowledge acquisition in "design and application of state-of-the-art environmental technology and engineering solutions to tackle today's global environmental problems". There are also EWEM (European Wind Energy Master, n.d.), JEMES (Joint European Master Program in Environmental Studies, n.d.), MESPOM (Master of Science in Environmental Sciences, Policy and Management, n.d.), MIND (Erasmus Mundus Master's program in Industrial Ecology, n.d.), SELECT (Environomical Pathways for Sustainable Energy Systems, n.d.), STeDe (Erasmus Mundus Master in Sustainable Territorial Development, n.d.), and STEPS (Erasmus Mundus Master Course in Sustainable Transportation and Electrical Power Systems, n.d.) (See Table 1).

Table 1, EMJMD programs in Environmental Issues

Nº	Title	Key Aspects of Curricula	Website
1	EMAE	- Business and legislative aspects of conservation of environment; integration of the growing needs of citizens, public authorities, and industry.	<a href="http://www.emmc-imae.org">http://www.emmc-imae.org</a>
2	IMETE	- Design and application of state-of-the-art environmental technology and engineering solutions to tackle global environmental problems.	<a href="http://www.imete.ugent.be">http://www.imete.ugent.be</a>
3	EWEM	- Wind Physics; - Rotor Design; - Electric Power Systems; - Offshore Engineering	<a href="http://ewem.tudelft.nl">http://ewem.tudelft.nl</a>
4	JEMES	- Complex urban processes and problems across international, cultural and disciplinary boundaries	<a href="http://www.jemes-cisu.eu/">http://www.jemes-cisu.eu/</a>
5	MESPOM	- Identification and implementation solutions to complex environmental sustainability challenges, - Management of diverse environmental issues in various social contexts.	<a href="http://mespom.eu">http://mespom.eu</a>
6	MIND	- Industrial ecology analyses of complex sustainability problems; - Industrial ecology solutions for complex sustainability problems; - Development of implementation strategies for solutions identified.	<a href="http://www.emmind.eu">http://www.emmind.eu</a>
7	STEPS	- New energy sources and their implications to the power systems - Reduction of CO <sub>2</sub> emissions by increasing energy efficiency and the share of clean energies - Incorporation of electric transportation as an alternative to vehicles using combustion engines.	<a href="http://www.emmcsteps.eu/">http://www.emmcsteps.eu /</a>

There are also different international programs proposed and implemented in the Erasmus Mundus Program, which cover the disciplines of computer science and ICT in general, such as DESEM (Erasmus Mundus MSc in Dependable Software Systems, n.d.), EMDC (European Master in Distributed Computing, n.d.), EMECS (European Master Embedded Computing Systems, n.d.), MERIT (Master of Science in Research on Information and Communication Technologies, n.d.), NORDSECMOB (Master's program in Security and Mobile Computing, n.d.).

Some Universities propose or initiate the first Masters in green ICT like Leeds Beckett University and its MSc "Sustainable Computing" (Leeds Beckett University, n.d.), or have begun to incorporate courses in Green ICT to educational curricula, like Australian National University and "ICT Sustainability" as part of its Information technology and engineering masters programs (Australian National University, n.d.).

However environmental issues should be studied in a global way by integrating different national point of views. At the international level, there is still a significant gap between ICT skills and environmental considerations. In order to fill this gap it is necessary to provide a quality advanced education to students. Educational programs should have a more focused state of the art vision on green and sustainable ICT covering networking, mobile computing, energy efficient sensors, sustainable and smart system engineering, software and services, environmental awareness and legislation.



## **Research Review and Methodology**

The aim of this paper is to define a cross-disciplinary approach (including courses in ICT, eco-design, ecology, culture,...) of master degree program in green ICT based on the case study of Erasmus Mundus Master in Pervasive computing and communications for sustainable development.

## **Research Method**

The research method is decomposed in four steps. (1) The previous section defined the gap in Green ICT education, (2) The design and the implementation of an international master in Green ICT based on competences required by companies, (3) the students' assessment regarding competences and (4) the analysis of results for improving the master.

## **Development of Master in Green ICT Based on Competences**

Work on curriculum development in the field of sustainability has been carried out for a long period of time. One of the examples is a project on the Definition and Selection of Key Competencies (DeSeCo) initiated by OECD to create a common framework for the identification of main competencies for education for sustainable development (OECD, n.d.). However, framework developed by DeSeCo would refer to broad sustainable development concepts.

The emerging discipline of green ICT and sustainability brings together computer science, sustainable development and management science. This aims to provide contemporary IT professionals the opportunity to gain advanced knowledge in development of cleaner, greener, more resource and energy efficient cyber-physical systems.

Development of the new curriculum was based on REFLEX study (Allen et al., 2005) used by Céreqcenter to evaluate the Erasmus Mundus employability (MKW GmbH, 2011). The objective was not to design a Master only oriented on an ICT technical expertise, but to develop courses around competences useful in companies. According to the REFLEX study, the competences required for engineer and executive positions are divided into five categories, which are used to prepare PERCCOM students in their future career: Professional expertise, Functional flexibility, Mobilization of human resources, Innovation and knowledge management, International orientation. The organization of the courses aims to equip students with this set of competences.

### **- Category 1. Professional Expertise:**

- (a) Mastery of own field or discipline: PERCCOM is a master in ICT area; therefore, graduates should be expert in different domains of ICT, including Computer, Software, and Network.
- (b) Knowledge of other fields or disciplines: Green ICT is studied in a systemic way. The student should be open-minded in order to appreciate the global context of work environment. The student has courses in sustainable development, circular economy, engineering system, and management.
- (c) Analytical thinking and critical reflection: System engineering enables students to analyze, criticize, compare and assess different solutions and proposals. Courses on green ICT (for example carbon emission, obsolescence in considering the whole life cycle of ICT product) are appropriate for the development of critical reflection.
- (d) Ability to rapidly acquire new knowledge: The students have fundamental courses in ICT to improve their adaptability to the rapid development of new ICT technologies.

### **- Category 2. Functional Flexibility:**

- (e) Ability to negotiate effectively, (f) Ability to perform well under pressure, (g) Ability to coordinate activities, (h) Ability to work productively with others.

### **- Category 3. Mobilization of Human Resources:**

(i) Ability to clearly express their opinion, (j) Ability to mobilize the human resources and the capacities of others (for example, in the context of collective work, the students should be able to identify the strengths and weaknesses of each to quickly solve a problem), (k) Ability to exercise their authority, (l) Ability to use time efficiently.

For assessing the competences in the categories 2 and 3, the students work on team projects. The objective of these projects is to develop project management skills (i.e. define tasks, manage time, scheduling, negotiate the client requirements), to understand customer requirements, and to work with their colleagues. The projects encompass academic projects, industrial projects and student contests. Student contests help to assess competencies (f), (g), (h) and (l). For example, the students have participated in Green ICT Student Contests such as Green Code Lab Challenge (<http://www.greencodelab-challenge.org/>). Specific Courses are provided in system engineering, in agile method (scrum) and in project management for equipping students with skills for the elicitation of stakeholders' requirements and scheduling of project activities. Seminars with industrials are organized so that students will be exposed to practices relating to human resource management in projects.

### **- Category 4. Innovation and Knowledge Management:**

(m) Ability to come up with new ideas and solutions, (n) Willingness to question their own and others' ideas, (o) Ability to present products, (p) Ability to present ideas or reports to an audience, (q) Ability to write reports, memos or documents.

Competencies (m) and (n) are very important in educational programs. It is necessary to include in green ICT and in ICT courses information about environment, performance and cost. The Master thesis projects enable students to apply acquired knowledge for the development of innovative green ICT solutions. The students should also present the results of the project orally and in written reports.

In summary, the scoring tool applied in the project, assesses the students with regard to three dimensions: the knowledge, the know-how and the self-management skills.

Moreover, professional work relating to sustainable development must respect the general code of Ethics. The students are also assessed based on their attendance, loyalty, honesty, attitude, behaviour in teamwork, and interaction with others.

### **- Category 5. International Orientation:**

(r) Ability to write and speak in a foreign language, (s) Professional knowledge of other countries, (t) Understanding of international differences in culture and society.

Each semester, the students follow courses on local language and culture. The collective projects involving students coming from different countries are a good way for improving the cultural integration. Concerning competence (s), industrial seminars are organized with international enterprises such as Cisco, Orange, Ericsson AB, Facebook, RUSSOFT etc.

## **Results and Contributions**

### **PERCCOM Program Description.**

The program was designed by an international consortium. Geographical location of the consortium's territory stretches across a wide variety of countries and even continents. Full partners are presented by four universities: University of Lorraine, France, Lappeenranta University of Technology, Finland, Luleå University of Technology, Sweden and ITMO University, Russia. Associated partners include Leeds Beckett University, United Kingdom, Bremen University, Harz University of Applied Sciences, both – Germany, and CSIRO, Australia.

Apart from academic and research partners, several industrial companies participates in seminars and workshops organised by PERCCOM consortium. Cisco, Ericsson AB and Orange makes significant impact in a field of green ICT and Ellen Mac Arthur Foundation in a field of circular economy.

All of them have experience and required expertise in green technology. Research conducted by Tomala (2014), shows that the Nordic countries are world leaders in utilizing ICT, and the market potential for ICT business in this region is very high. For example, NRI (Network Readiness Index) for Sweden and Finland is equal to 5,94 and 5,81 respectively, which allows them to occupy first and third positions in NRI-ranking. Situation in France is different. According to The Global Information Technology Report 2012 (Dutta, Bilbao-Osorio, 2012), France occupies 23<sup>rd</sup> position in NRI- ranking. Moreover, French industrial companies operating in ICT sector highlighted a skills gap of 3,000 master level professionals per year. This situation lasted for the past 20 years (Empirica, 2014). Therefore, the program in green ICT would help to contribute to the solution of the problem.

The structure of the program (see Figure 1) enables students to get an MSc degree in this area to meet the aspirations of information technology professionals. Program courses expose students to the interdisciplinary and integrated nature of green ICT as well as current research results and challenges of the field. Program is divided into three sections that correspond to the three objectives:

- Sustainable Computer Network Engineering, which aims at providing students with fundamental knowledge in computer networks and in eco-design. This section is delivered during the first term in University of Lorraine (France).
- Sustainable Software and Services which aims at providing students with knowledge in software engineering, service engineering, and cloud computer aspects that may result in sustainable solutions. This section is delivered during the second term in Lappeenranta University of Technology, Finland, and during a seminar in ITMO University, Russia.
- Resource Efficient Pervasive Computing Systems and Communications which aims at providing students with knowledge in advanced issues of mobile networks, distributed systems, energy efficient sensor networks, pervasive computing and mobile software. This section is delivered during the third term in Luleå University of Technology, Sweden.

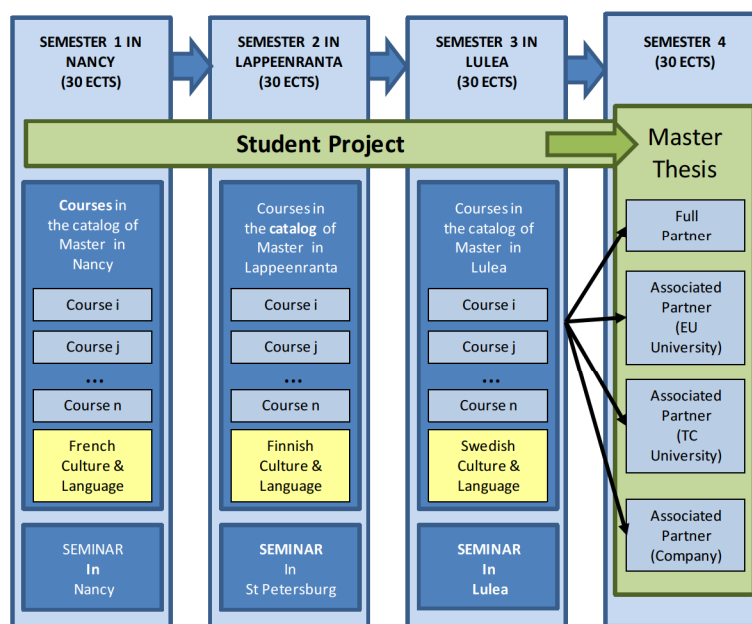


Figure 1, Curriculum of PERCCOM program



The figure 1 shows four kinds of courses, which cover all relevant competences (Table 2):

- The courses i, j,... correspond to the core of the program (ICT, Green ICT,...) mainly taught by local professors.
- The seminars involve professors from other Universities (Leeds Beckett University, University of Bremen,...), engineers from international companies (Orange, Cisco, Facebook, Ericsson,...), people from non-profit organization (Ellen Mac Arthur Foundation,...). The objective is to expose students to all appropriate facets of green ICT,
- The student projects are the Master theses assigned at the beginning of master program. Traditionally, the students in a master program only work on their master thesis during the last semester. In PERCCOM, the students can start the master thesis from the first semester. The objective is to offer more time to students for preparing the bibliography, for anticipating technical issues, for developing a work plan, for re-orienting, refining the initial topic,...
- Courses on culture and language include museum visits, local traditional activities and company visits such as datacentres (Orange, Facebook,...). The objective of these courses is to reinforce the students' open-mindedness.

Table 2, Relation between course elements and competences

		Professional Expertise				Functional Flexibility				Mobilization of Human Resources				Innovation and Knowledge Management				International Orientation			
		a	b	C	d	e	f	g	h	i	j	k	l	m	n	o	p	q	R	s	T
Course 1	Communication Protocols	x		X						x			x					x	x	x	
Course 2	Quality of Sustainable Service	x		X						x			x					x	x	x	
Course 3	Automatic Control for Sustainable Development	x	x	X						x			x					x	x	x	
Course 4	Systems Engineering (Eco Design)		x	X		x		x	x	x	x	x	x	x	x	x	x	x	x	x	
Course 5	Sustainable Development and Circular Economy	x	x	X						x			x					x	x	x	
Course 6	Master Thesis Project	x	x	X	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
Course 7	French Culture and Literature									x							x	x	x		X
Course 8	Green IT& Sustainable Computing	x		X						x			x					x	x	x	
Course 9	Code Camp on Communication Engineering	x		x						x			x					x	x	x	
Course 10	Architecture in Systems and Software Development	x		x						x			x					x	x	x	
Course 11	Research Methods Laboratory Project	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
Course 12	Finnish Society and Culture		x	x						x							x	x	x		X
Course 13	Towards Semester 3		x														x	x	x		X
Course 14	Network programming and Distributed Applications	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
Course 15	Wireless Sensor Networks/ Wireless Mobile Networks	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
Course 16	Multimedia Systems	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
Course 17	Special Studies in Pervasive and Mobile Computing	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
Course 18	Swedish for Beginners									x								x	x		X
	Master Thesis	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	X

### **PERCCOM Program Assessment by Students**

As it is indicated by ENQA (2010), “students have increasingly become involved in the improvement and enhancement of their own learning experiences”. The objective of this section is to get a first feedback from students who are finalizing their semester 4. For that a student survey was developed. The indicators used in the assessment are the competences which were previously defined (see the letters (a,b,c,...)) in the table 2. The survey is anonymous and the students must define their competence before and after the program by using the following scale: No Competence, Low, Good, Very good and Expert. This evaluation is totally subjective. However, the first interest of this survey is to investigate the score deviation before and after PERCCOM program. That helps to understand the progress of students regarding the different competences and identify the ways of improvements. The

second interest is to analyse the final absolute scores to appreciate the self-confidence of students to find a job after program graduation. The figures 2-5 show the results of the survey collecting 16 answers from a cohort of 17 students. The general objective for a Master program is to form excellent professionals (Expert or with very good competences). The results indicate that improvements should be proposed to reinforce the quality of the program even if the global results are extremely positive.

### **Discussion about PERCCOM Program**

**Category “Professional expertise”:** The students selected in PERCCOM program should demonstrate relevant background knowledge in ICT. As it is seen from the figure 2, their initial competences vary between good and very good. The majority of students, however, did not have relevant background in sustainable development. Only two students consider their initial expertise in sustainable development as good or very good. The second chart indicates that courses in Green ICT still need to be improved as only 35% of respondents assess their expertise in sustainable development as very good or expert.

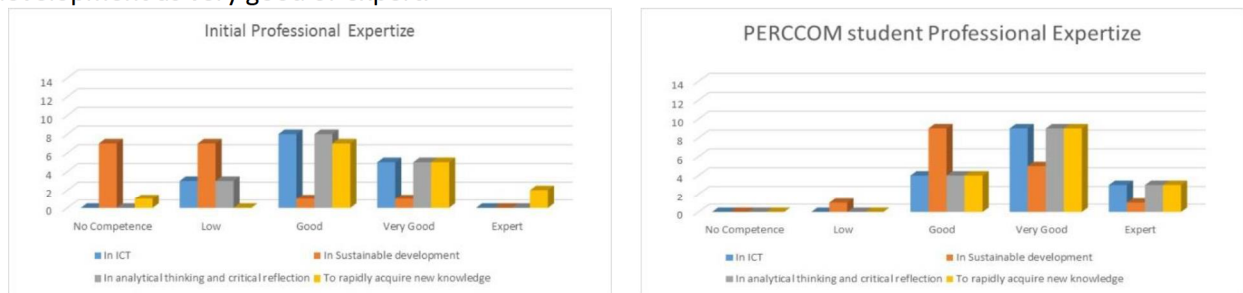


Figure 2, Professional Expertise

The actions proposed to improve this category are the following:

1) *To improve courses in ICT eco-design:* Table 2 shows relationships between course elements and competences described in Research Method section. As PERCCOM objective is to educate experts in green ICT, students should follow the program both in a traditional ICT master program and study courses on sustainable development and in eco-design. For eco-design of ICT solutions, PERCCOM program includes course in System Engineering (see course 4, table 2), which is essential to analyze Green ICT systems with a systemic approach in order to collect the whole stakeholder’s requirements and to be able to validate, verify and compare all solutions proposed by ICT Engineers (Rondeau et al, 2014). However, System Engineering could be a full Master program and one of PERCCOM challenges is to develop pedagogy around System Engineering for the larger public and for students in ICT. Currently, the objective is to simplify the course in System Engineering by illustrating the eco-design approach on a simple and pedagogic application. This application is about a system for monitoring indoor air quality with a double objective: (1) to reduce the pollution by using ICT (2) the most environmentally friendly.

2) *To reinforce the interest of green ICT in Economic environment:* The participation of companies in PERCCOM program is essential to make aware students about ecology aspects. Currently, the students visited different Datacenters (Orange, Facebook) to show concrete solutions to mitigate energy consumption. Other aspects should be also considered as the recycling, the obsolescence of ICT products,... Currently, the objective is to integrate new industrial partners in PERCCOM consortium such as Kaliterre, a company developing new tools or monitoring software energy consumption, the green IT alliance, an French association of companies working on green ICT,...

The main difficulty on this category of competences is that Green ICT is a new approach which uses immature technical solutions. For example, new protocols (Cisco EnergyWise, IEEE 1888,...) and new functionalities (EEE (Energy Efficient Ethernet) standard, hibernate mode in network devices,...) have been recently developed to provide additional services to improve ICT energy-efficiency and this trend should continue in the future. Moreover, the optimization of ICT with environmental considerations should be based on standardized green metrics. However, as mentioned by ITU-T report (2012), there are currently many initiatives (green grid, ITU-T SG5, European Telecommunication Standards Institute

(ETSI),...) that define Green KPI (Key Performance Indicators), which results in disharmony. The consequence of this instable period is that the course content is/should be updated by 25-20% every 2-3 years, which creates challenges for lecturers. However, quality and up-to-date-ness should prevail. Nevertheless, the issue of perpetual changes of technology landscape is well-known by ICT teachers.

Categories “Functional flexibility” and “Mobilization of human resources”: Figures for these two categories of competences are similar and demonstrate good results (see figure 3). It could be explained by a large number of team projects, which PERCCOM program proposes to students. In particular, as it could be observed from table 2, disciplines taught in Luleå University of Technology are mainly based on project work. That facilitates the assessment of the capacities of students with respect to all aspects of competences. For example courses 14, 15, 16 and 17 required for the students to apply knowledge acquired in both semester 1 (Network) and semester 2 (Software).

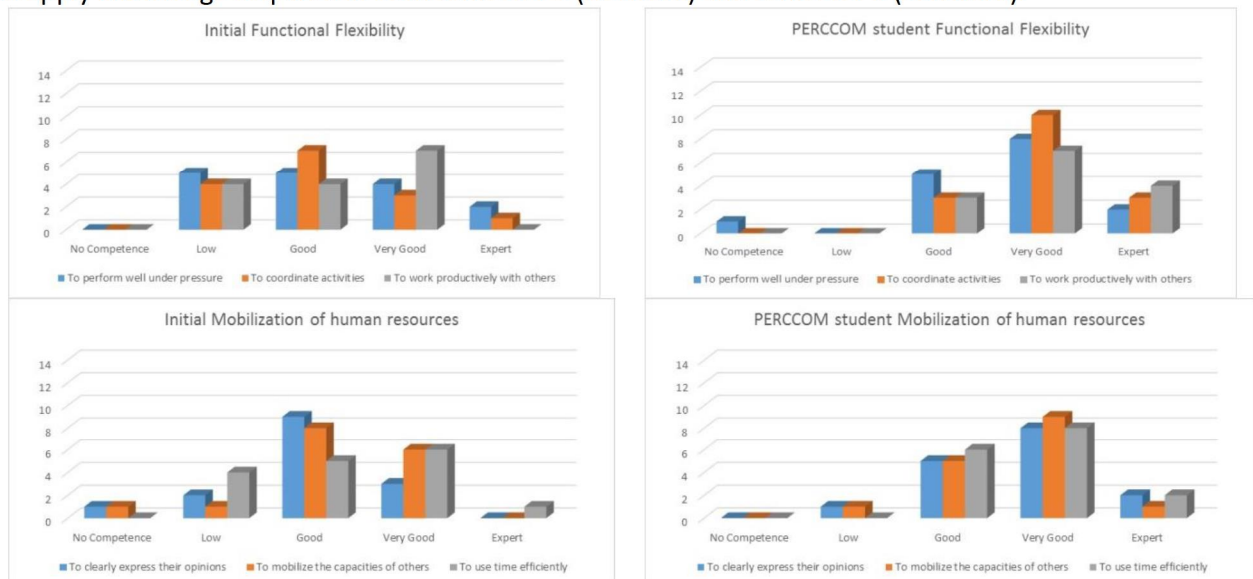


Figure 3, Functional Flexibility and Mobilization of Human Resources

The action proposed to improve these two categories of competences is:

- 1) *To provide more information about Ethic considerations* corresponding to one of three pillars of sustainable development (Ethic, Ecology and Economy). Lectures on computer Ethics (Grupe et al., 2002) will be added in the program. The goal is that in the different projects, the students should better analyze ICT solutions in taking into account their impact on the customers, employers and more generally on the society.

Category “Innovation and knowledge management”

Figure 4 indicates that at the end of PERCCOM program the students are able to both develop new ideas and to share their knowledge in different ways (by written report and oral presentation). Concerning communication, the students must be able to defend their propositions and solutions developed in a context of many projects. Thus, they continually receive feedbacks about their communication performances. For innovation, the students have courses on the way to conduct a research (semesters 1 and 2), moreover, work on the master thesis is mainly research-oriented. Students are hosted by research laboratories, cooperate with researchers’ teams and participate to research meetings. The competences in innovation are crucial in Green ICT, because this field is newly developed.





Figure 4, Innovation and Knowledge Management  
One action it integrate:

1) *Seminars on general ecology concepts* such as circular economy, biomimicry approach (Drouant et al., 2014) in order to engage discussions on the applicability or the transfer of these concepts in ICT area.

Category “International Orientation”:



Figure 5, International Orientation

ICT companies usually work in an international context; therefore, employees should have a strong knowledge of the culture of participant countries and be able to develop strong links between ICT professionals. The survey shows that competence in international orientation after PERCCOM graduation varies from good to expert. Students experience different European cultures: Finnish, Swedish, French and Russian. Moreover, geographical aspect of the program is not limited to these four countries. As mentioned in a section “PERCCOM Program Description”, visiting lectures are delivered by teaching staff from associated partners who also add the international element to students’ experiences. Another significant aspect is the international diversification of students. In particular, three program cohorts are represented by more than 30 nationalities from four continents. Their collaborative work helps to go beyond the cultural differences between countries. This processes aim at improving the understanding of issues at different levels (local, regional, national, supranational, European, International) and also at trying to give a more coherent and common solution to sustainable and long-term future to European economy. For the international orientation, the action is:

1) *to add more partners in PERCCOM consortium* to offer the possibility to students to discover more countries.

## **Conclusion**

Development of green ICT master programs is very important to educate new generations in the area of sustainable development. In the context of the next international meeting in Paris 2015 on the climate change, it is urgent to have new engineers capable of considering environmental issues when developing new ICT solutions. However, the green ICT master program is also a good way to develop other competences to form open-minded people with the objectives to develop international skills, to increase the number of women in ICT domain, to consider Ethics in ICT, to rethink ICT globally and differently and not only reduce ICT activities in the race of Moore's law. Even if PERCCOM follows European Commission recommendations (2008) in creating the new 'green-collar' jobs, the current main question is to know in the next year how their green ICT competences will be really implemented in their future career.

In perspective, PERCCOM consortium is creating an international doctoral school in the area of green ICT. This initiative is managed by Leeds Beckett University. Indeed, PERCCOM master is a part of value-chain, which should start with green education in schools continue with Bachelors degree, masters, PhD and continuing education awarding course certificates. Finally, PERCCOM graduates will become green ambassadors and will run short courses wherever they continue their careers.

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