Education in Green ICT and Control of Smart Systems : A First Hand Experience from the International PERCCOM Masters Programme

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Abstract: PERCCOM (PERvasive Computing and COMmunications in sustainable development) Masters is the first innovative international programme in Green ICT for educating and equipping new IT engineers with Green IT skills for sustainable digital applications design and implementation. After five years of running the PERCCOM programme, this paper provides an assessment of skills and employability in the context of Green jobs and skills. The paper ends with a list of recommendations for the development of environment related education curricula.

Keywords: Green ICT, Environment Control Systems, Green Jobs, Green Skills, Green Economy, Sustainable Development

1. INTRODUCTION

The increased proliferation of new academic programmes in sustainable development is primarily justified by the need to create a new category of occupations commonly known as Green Jobs. This is a response to UN and EU 2030 Agenda for Sustainable Development (UN, nda) that is a plan of action for people, planet, and prosperity that encompasses 17 Sustainable Development Goals and 169 targets. The United Nations *Decade of Education for Sustainable Development* (2005-2014) aimed to integrate sustainable development principles and practices into all aspects of teaching and learning for a more sustainable society and environment (UN, 2014). UNESCO developed a *Teaching and Learning for a Sustainable Future* (UNESCO, nd) programme to support UN's initiative. This programme outlines modules corresponding to four themes namely: Theme 1 – *Curriculum Rationale*; Theme 2 - *Sustainable Development Across the Curriculum*; Theme 3 – *Contemporary Issues*; Theme 4 – *Teaching and Learning Strategies*. The strategy for sustainable development programme is to equip learners with knowledge, competences, skills, and capacity in sustainable development (UN, 2005; UNECE, nd). Such type of education programme aims to promote mental paradigm shift towards a safer, healthier, and more prosperous world to support a better quality of life (UN, 2005) and sustainable future (University World News, 07/09/2018). Higher Education Institutions play a pivotal role in supporting UN's Education for Sustainable Development initiative and consequently, an increasing number of universities are offering degree and certificate programmes in sustainable development (ibid). They are invited to join UN Higher Education Sustainability Initiatives (UN, ndb) where the United Nations University provides replicable sustainability in action use cases (University World News, 07/09/2018).

In this context, seven years ago (i.e. 2012), a new Joint European Masters in Pervasive Computing and COMmunications for sustainable development (PERCCOM) was funded by Erasmus+ programme (PERCCOM, nd; Porras et. al., 2016). The primary goal of PERCCOM Masters programme is to provide world class ICT education with integrated sustainable design environmental

sustainability awareness. Two broad categories of learning objectives to support this goal are to: (1) develop eco-friendly digital services (on energy efficient ICT infrastructures) through optimized energy efficient data processing, storage and transportation. This subsumes under the term Greening of ICT where details and overview of the terms could be found in Pattinson and Kor (2014); (2) develop digital services to environment control systems (see IFAC TC 8.3) in various sectors (e.g. smart transportation, smart buildings, smart grid, smart logistics, etc… - see details in GESI (2008)). This approach is typically known as *Greening (or enabling) by ICT* which aims to mitigate pollution through the reduction of carbon footprints, and energy use across a range of sectors (e.g. power, transportation, manufacturing, agriculture, building, service and consumer – details see GESI (2012)). The crux in the Smarter 2030 report (GESI, 2015) could be summarized as follows: "*ICT has the potential to enable a 20% reduction of global CO_2e emissions by 2030, hold emissions at 2015 levels and effectively decouple economic growth from emissions growth*". The report discusses an assessment conducted for eight economic sectors (i.e. mobility and logistics, manufacturing, food, buildings, energy, work and business, health, and learning) reveals an estimated annual generation of $11 trillions of economic benefits by 2030 due to *Greening (or Enabling) by ICT*. On the other hand, ICT footprint (measured as a percentage of global emissions) is predicted to decrease over time (i.e. 1.25 Gt CO_2e in 2030 or 1.97% of global emissions (Smarter 2030 report); 1.27 Gt CO_2e in 2020 or 1.27% of global emissions (Smarter 2020 report); 1.43 Gt CO_2e in 2030 or 1.43% of global emissions (Smart 2020 report). To reiterate, the initial goal of the PERCCOM Masters programme was to train new Green ICT engineers and decision makers for promoting sustainability in digital sectors. However, in this paper, we aim to analyse the vocation of PERCCOM Alumni to appreciate the extent this initial goal has been realised.

This paper is organised as follows: Section 2 presents a literature review on green jobs; Section 3 describes the PERCCOM Masters programme; Section 4 discusses the results of the analyses of PERCCOM Alumni vocation (from

Cohorts 1 to 4); Section 5 provides conclusions and critical perspectives of green jobs.

2. LITERATURE REVIEW ON GREEN JOBS

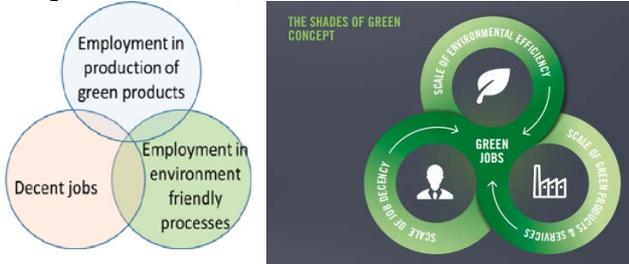Literature reviewed for this paper is coded into the following categories: Green Jobs; and Green Skills.
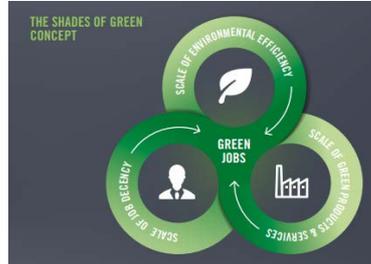

Fig. 1a: Green Jobs (ILO, 2016a)

Fig. 1b: Shades of Green Jobs (ILO, 2016b)

2.1. Green Jobs

According to ILO, green jobs is the pivot of sustainable development (ILO, nda) that aim to preserve or restore the environment (World Watch Institute, 2008; ILO, 2016a). However, OECD (2014) highlights that green jobs are not guaranteed to be good and decent jobs. Note that ILO (2012) has defined decent work "as opportunities for women and men to obtain decent and productive work in conditions of freedom, equity, security and human dignity". ILO has strived to promote greening of enterprises and green decent jobs to: *enhance energy and resource efficiency*; *limit GHG emissions*; *minimise waste and pollution*; *protect and restore ecosystems*; *mitigate effects of climate change; enable adaptability to climate change* (UNEP, 2008; ILO, 2016a). ILO (2012) estimates at least half of the global workforce (i.e. ≈ 1.5 billion people) is affected by the transition to a greener economy. This shift to a greener economy would provide a significant opportunity to create green jobs, improve social inclusion as well as maintaining a sustainable global economy path. Thus, greening of economies will help enhance sustainable natural resources control, increase energy efficiency, reduce waste, and enhance resilience while addressing inequalities (ILO, 2015). However, OECD (June 2017) highlight the fact that '*the size of the overall job turnover created by green growth is likely to be relatively small compared to overall labour movements*". Green jobs could be depicted by Venn diagrams shown in Figure 1a (i.e. Employment in production of green products and services and/or Employment in environment friendly processes) (ILO, 2012) and the different shades of green jobs concept is depicted in Figure 1b. OECD (June 2016, Feb 2018) emphasises that green growth policies will drive a change of employment in terms of increasing the creation of the number green jobs depicted in Figure 1a, and destruction of some decent jobs with large environmental footprints (i.e. 'brown' sectors that are replaced with green activities. According to Worldwatch Institute (2008), the green innovation, design, and technology sector is most likely to retain and create new green jobs. This is possible if it is aligned to one of priorities of OECD's green growth policies (OECD, 2018) that is related to the provision of eco-innovation support and diffusion of green technologies through an enhanced education. The ILO *Green Jobs Programme* (2016b) offers support to policy makers in the formulation of effective policies and development of national green jobs assessment using assessment methodologies developed by the Green Jobs Assessment Institutions Network (GAIN) (ILO, Aug 2018; ILO, Jul 2017). Overview of the methodologies could be found in here (ILO, Feb 2013). Cedefop (April, 2013) highlights the need for a better coherence and alignment amongst education (or training), employments and policies (i.e. climate and energy). Next, we shall look at Green Jobs statistics and trend. According to ILO (2018), by 2030, 24 million new jobs will be created (and 6 millions will be lost) globally if right green policies are in place. The number of green jobs in Europe is estimated to be 4.2 millions (in the year 2014). Green jobs could be coded into broad categories such as environmental protection (e.g. prevention, reduction, or elimination of pollution or environmental degradation) and resource control and management (e.g. preservation, maintenance, safeguard against depletion of natural resources) (Eurostat, 25th Sept 2018) or following sectors: energy (e.g. energy mix, electric vehicles, etc…); ecosystem services (e.g. fishing, farming, forestry, etc…) (ibid); built environment (e.g. smart meters, retrofitting, etc…)(World Economic Forum, Jan 2016). UNEP (2011) has listed annual green economy investment by sector while CNBC (21 Aug 2018), ranked green jobs that are growing in popularity in the US and they are: Environmental Engineer; Wind Turbine Technician; Environmental Scientist; Recycling Worker; Solar Photovoltaic (PV) Installers.

2.2. Green Skills

OECD (2014) define green skills as "*skills needed to adapt products, services and processes to climate change and the related environmental requirements and regulations*". Green jobs and green skills are essential for an effective transition to low-carbon economies which have to be well managed as well as contribute to equal decent job opportunities for all (ILO, 2015). OECD (May, 2015) has conducted a research project on "Boosting skills ecosystems for greener jobs" that focuses on the analysis of skills dimension in the transition and findings reveal that skills necessary for the transition to a green economy are not distinctly "green skills" but rather more appropriate technical skills. Categories of skills needed for green economy are: (i) General skillset (Consoli and colleagues (2016)) – high level cognitive skills; technical skills; specialised and generic green skills; and generic skills (e.g. problem-solving skills, resilience, etc…); (ii) Specific skillset – skills to support resource efficiency; skills to support low carbon industry; skills to support climate resilience; skills to manage natural assets (HM Government, 2011). One of the recommendations brought forward by Cedefop (2015) is to provide specific tertiary training (targeted at architecture and engineering students) to bring about enhanced performance at system level (e.g. cities) and processes (e.g. industry). On the other hand, Cedefop (2010) highlights the need to revise and upgrade the skills of existing workers. As an example, for the strategic European "Build Up Skills" Initiative (European Commission, 2011-2015), it aims to stimulate continuing and further education/training in the building sector to increase the number qualified workers across Europe for high performance or zero-energy buildings. According to Cedefop (February, 2012), green skills building

will require a revamp of existing curricula, qualification standards and training programmes, as well as retraining of educators. In 2014-2015, green jobs training and capacity building activities have significantly expanded and diversified (ILO, 2016c). However, according to Cedefop (2010), it is imperative to anticipate skills needs and based on a survey conducted by World Economic Forum (Jan 2016), majority of the surveyed countries (i.e. 22 out of 27) have established platforms to anticipate skills needs. OECD (May, 2015) emphasises the need to map skills supply to demand through skills needs assessment (ILO, 2015) as well as instil appropriate green economy mindset in workers (beyond the issue of skills) that could shape a sustainable future. Based on a survey conducted by World Economic Forum (Jan 2016), a majority of the surveyed countries (i.e. 21 out of 27) reveals that skills mismatches are major obstacles to a green economy. The latest UN Environment Management Group Nexus Dialogue is held to discuss the "*Greening with Jobs*" transition to environmental sustainability (UNEMG, Oct 2018). It aims to provide the following: (i) a common understanding of a just transition; (ii) establish a global platform for knowledge and practices sharing, foster support of public and private stakeholders' support; (iii) and explore potential financial support and mechanisms ILO, Oct 2018; UNEMG, Oct 2018). The outcome of the discussion is 10 key messages (UNEMG & ILO, Oct 2018) that are relevant to the 2030 Agenda for Sustainable Development (UN, nda) and Paris Agreement on Climate Change (UNFCC, nd) to guide policy support, future research, partnerships and advocacy (ILO, Oct 2018). The crux of the messages addresses the following: (i) profound impact on economy and society; (ii) promotion of job equality; (iii) resilience and adaptability to imminent changes; (iv) technologies and market as drivers of change; (v) responsibility of government for appropriate policies and governance systems; (vi) promotion of democratic systems for participation and dialogue; (vii) involvement of youth as actors of change; (viii) innovative funding mechanisms; (ix) establishment of a knowledge sharing platform; (x) governmental implementation reporting (UNEMG & ILO, Oct 2018).

3. PERCCOM MASTERS PROGRAMME

The PERCCOM Masters programme is jointly developed by five European Universities located in France, Sweden, Finland, UK, and Germany. Its primary goal is to create a new international ICT programme that prioritises green IT skills and competences building with a view of a holistic approach to integrated digital infrastructures and services design. Other than inculcating environmental awareness, the programme aims to promote multicultural diversity and equip the students with multi-cultural competences. Through this programme, students will have first-hand experience, and better appreciate local cultures, way of life, legislations, and corporate cultures in at least three European countries in the course of their study. Some of the planned activities (other than the academic courses) for every cohort of students are language courses and cultural visits (e.g. castle, museums, sports events, culinary events, etc…). Additionally, each cohort of students is selected not only based on academic merits but also their countries of origin. This means that the PERCCOM programme provides a rich and invigorating environment for students from different countries (with multicultural diversity) to collaborate on projects (e.g. student contests, code camp, etc…). Traditionally, each PERCCOM cohort comprises approximately 18 students hailing from at least 12 different countries across the globe. To reiterate embedded Green IT skills in the programme aims to address both environmental and societal impacts of ICT. Specific courses delivered in PERCCOM include new knowledge and skills development related to sustainable development. Issues explicitly considered are: energy, environmental impact (e.g. pollution), natural resources, ethics, cost benefits analysis, etc… Green Concepts such as *Lifecycle Accounting and Environmental Management* (e.g. ISO 14000 series, (ISO, nd)), *Circular Economy* (Ellen MacArthur Foundation, 2017), *Biomimicry* (Benyus, 1997) (Drouant, 2014) are reviewed, critically analysed, and applied to practical examples. In addition, PERCCOM students undergo training that involves the analysis of trade-offs between performances and sustainability of ICT systems. Such training will equip them with eco-friendly technical know-how, and ground them in corporate environmental responsibility so that they will know how to design, develop, and implement efficient yet sustainable IT solutions to deal with environmental and social impacts. Students will acquire knowledge skills and knowledge on ICT as an enabler for a sustainable future (including cleaner environment) (aligned to GESI 2008, 2012) and as solutions to address 21st century challenges (GESI, 2015) in the following domains: energy, building, food, mobility and logistics, work and business, and manufacturing. They will also learn how to analyse trade-offs between negative and positive sustainability impacts of ICT. For example, when they develop controllers for reducing the environemental impact of a system, the ICT-enabled controllers themselves will have direct emissions Additionally, due to students' diverse countries of origins, they will be able to provide first-hand account of climate change effects on their respective parts in the world. Organisation of the academic semesters is as follows: (i) Semester 1 - students start the programme at University of Lorraine (courses delivered relate to network, green ICT, automatic control for environment-related applications, holistic design, and French culture); (ii) Semester 2 - students move to Lappeenranta University of Technology (courses are: software engineering, sustainability, and Finish culture. Semester 2 ends with 2 weeks in St Petersburg with lectures on control and management of smart cities and coding; (iii) Semester 3 - Lulea University of Technology hosts Semester 3 and provides courses on Wireless mobile networks, Internet of Things for controlling environment systems, Green datacentres and Swedish culture; Semester 4 - dedicated to masters theses proposed by academia or companies in PERCCOM consortium. All the thesis topics are either on Green ICT or on Greening by ICT. PERCCOM Masters has the Erasmus Mundus brand name and is funded by Erasmus +. Majority of students receives scholarship covering both tuition fees and life costs.

4. PERCCOM MASTERS GREEN JOBS AND GREEN SKILLS

The analysis of green skills and green jobs are based on the following: an investigation on PERCCOM master theses and

internships undertaken by students during their final semester; survey conducted on seventy PERCCOM Alumni (i.e. Cohorts 1 to 4) to investigate whether their current vocation is in IT sector, a green job, or research.

4.1. Masters Thesis Feedback

Master thesis topics provide the first opportunity for students to validate their Green ICT skills. During the 5 years of PERCCOM programme, a total of 88 research topics have been proposed by 13 Universities in 10 different countries. The interesting observations are as follows:

- Green ICT is an international and global issue;
- Green ICT a diverse range of topics with special focus on one of the following pillars of sustainable development: **Profit pillar**, **Pollution pillar**, and **People pillar**. For example, in Germany, the topics are more technical and focuses more on the **Profit pillar** than the **People pillar** in Finland. This observation is relevant because Green ICT caters for students' preferred orientation (i.e. Profit, Pollution, or People focus) when choosing their future careers.
- Proposed research topics aim to address local climate change related challenges. Several examples are systems for controlling and management of: river flooding (University of Chittagong, Bangladesh); smart city waste (ITMO, St Petersburg); outdoor pollution (Universities in Melbourne, Australia). Other examples are: home automation systems to reduce carbon footprint (Lappeenranta University of Technology and Harz University of Applied Sciences)
- Numerous Industrial-University collaborative research topics have been proposed, particularly in France and Sweden. Some examples are: 5G wireless networks (Ericsson, Sweden); SDN and NFV (InfoVista, France); Energy efficient networks and software (Orange, France). It clearly shows that Green ICT is not only an academic but business concern.

Thus far, a total of 88 master thesis results have been published in 48 papers in conferences, journals and book chapters while 19 theses are in progress (final PERCCOM cohort).

4.2. Post PERCCOM Vocation Survey Feedback

The second analysis is focused on the vocation of PERCCOM Alumni. A survey is conducted on seventy PERCCOM Alumni (i.e. Cohorts 1 to 4) to investigate whether their current vocation is in the IT sector, a green job or research. This is followed by investigating on their application of green skills in their current jobs. Figure 2 reveals that: 40% of the alumni are in academia (i.e. Academic, Research, or pursuing a PhD degree; 44% are in the IT sector (i.e. software development or engineering, IT service, IT systems, network engineering, IT consultancy, IT security, IT management, data engineering); 16% in the non-IT sector (e.g. business and data analysis, management, customer care, other, etc...). Findings are as follows:

- A majority of PERCCOM alumni continues to doctoral level. There are two possible explanations: the selection procedure for PERCCOM students is rigorous and thus, the PERCCOM Masters programme serves as a stepping stone to a doctoral programme; the proposed PERCCOM Green ICT masters research topics are high level (note: evidence is in the number of published work), cutting edge, relevant and applied (note: some are industry-led).
- All the students easily find an ICT job due to the shortage of ICT competences in the labour market. An observed evidence is 84% of PERCCOM Alumni (Figure 3) remain in Europe after completing their PERCCOM Masters (note: 85% of all PERCCOM cohorts are from non-European countries). These figures raise an ethical issue regarding brain drain since under developed and developing countries will need more experts for their sustainable development initiatives.

Figure 3 shows another imbalanced results where more than 50% of PERCCOM Alumni found jobs in Northern Europe (Sweden, Finland, Denmark, and Netherlands). This observation is interesting to assess which European countries would profit from EMJMD (Erasmus+) programme. The possible explanations are:

- Two semesters are organised in Sweden and Finland. This demonstrates their capacity to attract PERCCOM graduates.
- English is a common language spoken in these countries. Thus, this facilitates the integration of PERCCOM Alumni into their societies because they are mainly Anglophone.
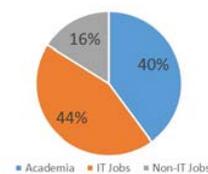- The salary in these countries is higher than the rest of other European countries.

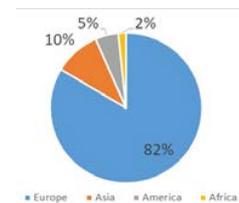Figure. 2. A Distribution of PERCCOM Alumni Vocation (n=70)

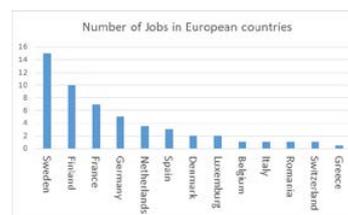Figure. 3. A Distribution of PERCCOM Alumni Vocation by continents (n=62)

Figure. 4. Number of jobs found by PERCCOM Alumni by European Country
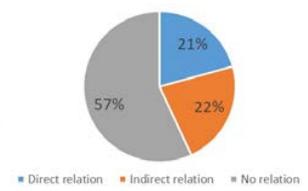

Figure 5. Distribution of PERCCOM Alumni in Green Jobs (n=58).

Finally, to date, Ericsson has employed 13% of PERCCOM Alumni. This shows that ICT skills of PERCCOM Alumni are highly relevant to their company needs.

Figure 5 shows the results of the question "*Is your job related to Sustainability?*" A total of 21% of PERCCOM Alumni agree that their ICT jobs have a direct impact on sustainability. This figure seems to be reasonable considering the fact that sustainability is a new trend in ICT. However, 75% of these positive responses include PERCCOM Alumni who are currently pursuing PhD programmes and have confirmed that Green ICT is a popular research topic. Additionally, the infusion of Green ICT in companies is at its infant stage and research topics are more oriented towards Greening by ICT rather than Greening of ICT. This is supported by the fact that a majority of Green jobs leans more towards developing smart applications rather than developing solutions for mitigating environmental impact of ICT itself. Another comment is some PhD topics are industrial-led (e.g. Orange) and this evidences their new concern for the Green ICT challenge. In the same figure (i.e. Figure 5), a total of 79% (i.e. 57%+22%) of responses reveal that their jobs are not relative to sustainability. This is not a surprise viewing the acute shortage of ICT skills in Europe. PERCCOM Alumni are employed primarily based on their ICT rather

than Green ICT competences and skills. A total of 57% of PERCCOM Alumni claim that their jobs are not directly linked to sustainability. This figure is rather alarming despite the fact that all PERCCOM Alumni are made aware that ICT has de facto an impact on the environment. Even though their jobs have no direct link to sustainability, their company activities would certainly have carbon footprints. This seems to imply that PERCCOM Alumni have not been proactive in the application of their Green ICT competences and skills. However, about 21% of the alumni indicate that their job-related activities include computation optimization and software deployment for energy consumption reduction. On the other hand, 22% of PERCCOM Alumni perceives an indirect relation between their job and Green ICT. This implies that though Green ICT is not the main indicator driving their professional activity, the relation between ICT and sustainability has been duly considered.

5. CRITICAL DISCUSSIONS

PERCCOM Masters is an innovative and international programme in Green ICT. Based on the findings discussed in Section 4, we draw 5 main lessons for developing green education in ICT and in other domains:

Lesson 1: "*Green jobs are not __solely__ based on Green Skills*" All PERCCOM Alumni easily find jobs either in companies or academia because they have a solid ICT training which corresponds to necessary ICT skills. A company prioritises traditional ICT competences to expertise in sustainability. This implies that new training in sustainability ought to be traditional training with embedded sustainability to meet green economy market.

Lesson 2: "*Greening education is not __at the expense of__ developing experts for a specific domain*". Adding new sustainable competences in ICT Masters programmes is feasible because it is not counterproductive with traditional ICT training. This is supported by the survey results that show PERCCOM Alumni easily find ICT jobs. However, sustainability ought to be a metric that needs to be considered for assessing ICT solutions. Additionally, it is recommended that it be reinforced as an ICT best practice. It should be included as a code of conduct of energy efficiency for ICT solutions (just as in data centres) that will prescribe general rules to ICT engineers for measurement, assessment, and optimisation of a solution. This idea is illustrated in Rondeau et. al. (2017), where an optimised Quality of Service and costs in a network architecture depicts trade-offs for sustainability and performances. Greening mainly means developing goods practices of engineering. It could be beneficial to conduct a comparative analysis for approaches adopted by students with and without green training in the designs, implementation, and rationale of their engineering solutions.

Lesson 3: "*Holistic approaches are __fundamental pre-requisites__ for green jobs*". A holistic approach is essential when an Engineer needs to design an artefact or a system. This will help the Engineer understand the interaction between the artefact (or system) with its environment. Thus, green engineers would have to consider environmental constraints (and impacts) in their designed solutions. As an example, in order to convert software code champions to Green ICT specialists, they have to be mindful of energy (and

resource) consumed during software updates, bug fixing, versioning, testing etc… Thus, systems engineering content should always be integrated in Green education. Systems engineering approach provides an overview of the entire life cycle of developed solutions in including their end of life (recycling) phase. Finally, holistic approaches are suitable for analysing the trade-offs between performances of developed solutions and their impact on environment. Typically, in IFAC TC 8.3 on "Modelling and Control of Environmental System", contributions mainly focus on the design of controllers for the benefits of the environment without considering the negative environmental impact of the controllers (e.g. energy consumption and carbon footprint, air pollution, visual pollution, recycling,…).

Lesson 4: "*Developing green education is for __saving the planet__ and not (necessary) for economy*". The justification for a new Green education programme is to create a new green economy with new green jobs. This would address means to mitigate pollution, preserve natural resources, etc… The Green ICT PERCCOM Masters is not devoted to the development of new jobs. However, it entails the evolution of new green skills that consider new inputs (e.g. Quality in Sustainability) produced by the environment. Additionally, it would be impractical for a company to deliver Green and Brown ICT services in parallel. If this were to occur than, both traditional and Green ICT are seen as separate silos. To reiterate, this is the case depicted in Figure 5 where 57% of PERCCOM Alumni view their jobs as having "no direct Green ICT relation". However, Green ICT approaches ought to underlie all existing ICT services and this should be reinforced for the next generation of students. As a matter of fact, PERCCOM ought to have infused Green concepts in their enterprise even if their job is not clearly labelled as Green.

Lesson 5: "*Developing green education is __developing new way of thinking__ in engineering*". Basically, engineering is mainly focuses on hard and not soft skills. Engineering pathways considers skills in mathematics, physics, chemistry, etc… Typical designed engineering solutions are mostly tunnel-visioned without considering the environmental, social nor ethical aspects of the solutions. For example, some ICT engineers code software without taking into consideration of data privacy and governance issues. Green education is an excellent way to widen students' perspectives (i.e. consider a solution and its relationship to an ecosystem or environment). Cultural elements included in the PERCCOM curriculum would help produce new generations of engineers that are more open, adaptive, and who appreciate multi-diversity. Such soft curricular content seems to have made the programme more attractive to female students viewing the fact that all PERCCOM cohorts consist of approximately 35% female students.

As a summary, the discussion for this paper could be organised according to the following points:

Discussion 1: As previously discussed, PERCCOM aims to **exploit the use of ICT** for sustainable development to meet UN and EU 2030 Agenda for Sustainable Development (UN, nda). It adopts a holistic approach to seamless integration of: digital infrastructures and services design; theories and practice; technical curriculum design with underpinning

environmental considerations (i.e. Greening of ICT and Greening by ICT) As an example is the incorporation of the following content in the delivery of PERCCOM programme (e.g. MSc. Systems Engineering): ICT Systems, Corporate Social Responsibility; Circular Economy and Biomimicry for ICT; General Environmental Standards, etc… As there are numerous academic programmes on sustainable development, it is recommended that we pause and critically reflect on their specific competences building and also review whether their associated sustainable development methodologies are holistic and seamless.

Discussion 2: <u>**Education with embedded sustainability**</u> ought to target concrete and specific practical as well as applied skills and competences. Several examples are as follows: Material Science/Engineering Experts ought to be recycling experts; Electrotechnical Expert should be renewable energy experts; ICT experts should be an expert in one or more of the following areas - e-waste, green radio emission, energy management, etc… In this paper, we shall define two phrases for *Green Jobs*: *Greening with Jobs* (i.e. creation of new jobs for green economy that requires new skills and competences) and *Greening of Jobs* (repurpose of existing decent jobs for sustainable development that requires evolution of existing skills and competences). We shall take Smart Buildings as an example which have to be compliant to EU Directives on energy performance of buildings (European Parliament and of the Council, May 2010) and energy efficiency (European Parliament and of the Council, Nov 2012). They aim to improve energy efficiency, reduce operation costs, increase safety, productivity, and occupants' quality of life (see GESI 2008, 2012, 2015). Smart Buildings encompass the following components: (i) intelligent building management; (ii) data analysis tools; (iii) communication protocol design; (iv) control and automation systems (involving Internet of Things, IoT); (v) energy harvest and recycling. This means the Smart Building sector could entail the following *Greening with Jobs* (for component (v)) and *Greening of Jobs* (for components (i), (ii), (iii), and (iv)). Evidently, the latter category of jobs take precedence and this forms a concrete basis for advocating green structural change (ILO, ndd), which involves redefinition of existing jobs or retraining as stipulated in ILO (ndc).

Discussion 3: <u>**A dichotomy of green and brown jobs in the ICT sector cannot be advocated**</u> (note their respective impact on energy efficiency has been discussed in Garrett-Peltier, 2017). If such a distinction exists, then the challenge raised is the rationale behind organising ICT departments into Green ICT Departments and Non-Green (or brown) ICT departments. Such a dichotomous partitioned structure is undeniably impractical because green ICT is one of the bedrocks of sustainable development. It is recommended that all workers in the ICT sector be grounded and equipped with sustainability skills and competences. This would see a seamless intertwine of ICT and sustainability. Effective management of a global environment policy calls for a holistic approach to a synchronised interplay of diverse activities in different sectors (see Discussion 1). Another question raised is "Is an excellent ICT engineering without green skills or competences detrimental to the planet?" In Rondeau et. al. (2017), the traditional role of a good ICT

engineer is to propose optimised solutions with reduced ICT resources, easy maintenance, reduced costs while delivering high quality of services to clients (or users). However, optimisation is one of biomimicry principles that respects an eco-matured system (Benuys, 1997). Thus, optimisation is viewed as a nature inspired strategy towards sustainable solutions. In Rondeau et. al. (2017), an optimised Quality of Service and costs in a network architecture well depicts trade-offs for sustainability. However, some ICT engineers might find it cumbersome having to observe environmental constraints in the course of their work and consequently, resist the adoption of green ICT practices. In order to address this, to reiterate, it is imperative to intertwine ICT and sustainability so that sustainability is seamlessly embedded in operations, business models, and strategies.

Discussion 4: According to ILO (2018), <u>**climate change mitigation**</u> could slightly reduce the proportion of woman in total employment due to typically male-dominated green economic sectors (e.g. renewables, manufacturing, construction, etc…). However, the PERCCOM programme seems to have an approximately equal proportion of female and male. Thus, it is recommended that green economy training programmes be made attractive to both female and male in order to address gender inequality in newly emerging green economic sectors. ILO (ndd) emphasises the importance of roles played by women as agents of change and thus, it is recommended that the agenda on sustainable development policy include inclusion, gender equality, and non-discrimination.

Discussion 5: Undeniably, <u>**the demand for high-tech skills**</u> is increasing high due to the advent of ICT and smart technologies that pervades all sectors (see GESI 2012, 2015). It is estimated that the number of IT practitioners in the EU labour market will grow from 8 millions in 2015 to 8.7 millions in 2020 (eLeadership, 2015). This is for non-green IT job shortages and could thus have impact on the high proportion of PERCCOM Alumni in non-green jobs/research (depicted in Figure 3) and not being able to apply their acquired green skills in their current vocation. This highlights the important role organisations have to play in promoting *Greening with Jobs* (see Discussion 2) and developing a platform for the implementation of green ICT strategies, and policies for a greener economy. ILO (2016c) has emphasised the need to guide organisations in promoting environmental sustainable economies and enterprises. Additionally, it will be vital to rethink the definition of *Green Jobs* as *Greening of Jobs* and *Greening with Jobs* (see Discussion 2) where the latter could subsume ICT as an enabler for a green economy. OECD (May 2015) maintains that the skills required for the transition to a green economy are not uniquely 'green skills' but more of "professional/ technical, management, innovation, communication, and entrepreneurial skills. This implies the need for a convergence of diverse skills for an effective and fruitful transition. ILO (2018) recommends a legal framework for providing incentives for greening the economy while maintaining ensuring that decent work legal standards. However, we recommend an integrated green and decent work legal framework (as in *Greening of Jobs* and *Greening with Jobs* presented in Discussion 2). ILO (2018) has conducted a research on the challenges and drivers of a

green transition. Although some countries surveyed have successfully integrated skills development environmental policies, a majority of them has not established concrete linkages between sustainability plans and skills policies. Thus, this calls for an urgent need of policy coherence at the national level that needs to be cascaded down to the regional and organisational level. ILO (2012) has warned that the success of green economy hinges on the right policies and institutions capable of implementing them.

5. CONCLUSIONS

PERCCOM is the first Masters programme on Green education in digital sectors in the world. The positive feedback we receive after 5 years of existence reveals that the new generation of students are very keen to pursue such type of education programme. However, survey results expose the general lack of Green IT exploitation in companies that PERCCOM Alumni work in. The underlying reason could be that in Europe, there is an acute shortfall in qualified automatic control system and ICT engineers. Thus, Green ICT expertise has not been given any pre-eminence in the ICT industry. Today, some sectors such as Datacenters, consider energy efficiency a pressing challenge because they are directly impacted by energy costs for feeding and cooling servers. Even though automatic control has a huge potential for reducing enviromental impact of systems, they are major consumers of resources. For example, systems control requires tremendous amount of digital resources for: analysing big data (in servers); collecting information (via Internet of Things); making safe and secured distributed connections (via Blockchain), etc… In the foreseeable future, the performances of controllers would have to be analysed not only based on traditional metrics (e.g. stability, overshoot,..) but metrics associated with quality in sustainability. This new consideration should be included in automatic control curriculum.

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