Volume 21, Number 2, 2019

Global Journal of Engineering Education

Solar energy educational programme for sustainable development in Egypt

Rami Ghannam†, Marion Kussmann‡, Andreas Wolf*, Ahmed S.G. Khalil & Muhammad A. Imran†**

University of Glasgow, Glasgow, Scotland, United Kingdom†
German Arab Chamber of Industry and Commerce, Giza, Egypt‡
Vela Solaris AG, Zurich, Switzerland*
Fayoum University, Fayoum, Egypt**

ABSTRACT: Exploiting the Sun's energy can help in the sustainable development of nations with transitional economies, such as Egypt. Fortunately, Egypt is located in the world's solar belt and enjoys excellent solar availability. However, there are few dedicated postgraduate training programmes for Egyptians in the field of solar energy. The authors have carried out a systematic needs analysis in Egypt by surveying a range of Egyptian solar energy companies and undergraduate students, who were the main target groups of the educational programme. According to statistical analysis from the surveys, 76% of students were motivated to study solar energy for environmental and economic reasons. The surveys also revealed that the most important skill needed by companies was concerned with the design of solar energy systems, which is a process that requires a mixture of intuitive, analytical and technical skills. Consequently, they have developed customised software tools to enrich the theoretical and practical teaching of the programme, which was certified and approved for delivery at three different Egyptian universities. The authors also present the programme that was co-created by a consortium of European and Egyptian partners, its structure and its main achievements, such that it can be used as a pilot model for solar energy education in other developing countries.

Keywords: Education for sustainable development, solar energy, simulation software

INTRODUCTION

The Egyptian energy sector is among the industries that has experienced many challenges following the revolution on 25 January 2011 [1], especially since the country heavily depends on fossil fuels to meet its energy needs [2]. Indeed, Egypt's economic development hinges on the energy sector, which represents 13.1% of overall gross domestic product (GDP) [3]. In recent years, domestic supplies have fallen short of demand due to the ongoing increase in consumption, stagnation in production and a very generous subsidy policy that heavily contributed to increasing consumption [4]. In fact, Egyptian energy consumption has risen by more than 200% during the past 35 years [5]. Unsurprisingly, this has led to an increased strain on Egypt's financial and environmental resources [4][6].

In an effort to help Egypt achieve its sustainable development goals, a consortium of European and Egyptian partners developed a project that aimed to add economic value and create local jobs. This article describes the needs of the target groups that will benefit from this programme. The authors also describe the pedagogical approach used in designing the curriculum, which was based on statistical data analysis from 57 companies and 718 students.

Currently, there are few practical training opportunities for Egyptians in the field of solar energy systems design. According to the literature review, only Ain Shams University provides a dedicated postgraduate training programme in solar energy. Other Egyptian universities, such as Cairo University, the British University in Egypt and TU Berlin Gouna Campus offer generic renewable energy education with limited hands-on practical training in solar energy.

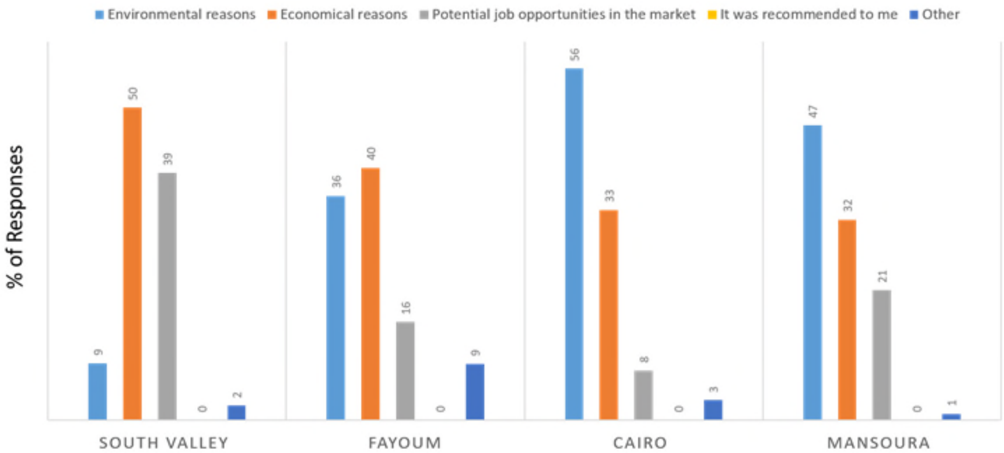
According to the review carried out by the authors, current curricula tend towards academic research than everyday solar energy system design and installation practice. Thus, the solar energy systems design using advanced learning aids (SOLEDA) project was initiated, which was co-funded by the EU Tempus programme. The project's aim was to train graduate students in designing and installing decentralised solar energy systems, and to prepare these graduates for the job market.

In this article, the authors describe an approach to designing the curriculum and highlights the programme's main modules. The methodology described herein could be used as a pilot model for solar energy education in Egypt and beyond. The SOLEDA project's detailed work-package descriptions, deliverables and aims are described in a previous publication [7].

First, to understand why Egyptian students might be interested in studying solar energy, the consortium of partners shown in Figure 1a designed paper-based surveys that were distributed to 1,000 undergraduate students in the universities of South Valley, Mansoura, Cairo and Fayoum. In total, 718 students took part in our surveys (71.8% response rate) and approximately 56% of the participants were females. According to their feedback, 76% of students were interested in studying solar energy for both economic and environmental reasons, as shown in Figure 1b. Interestingly, student responses largely depended on geographic location. For example, students in Fayoum University and South Valley University were keen on studying solar energy for economic reasons. This could be attributed to the higher occurrences of poverty and the poorer living conditions in these cities [8]. In contrast, students in Cairo and Mansoura were in favour of studying solar energy for environmental reasons, which could be attributed to the higher levels of pollution existing in those regions [9]. The results in Figure 1c show that 56% of students in Cairo and 47% of students in Mansoura were interested in studying solar energy for environmental reasons, whereas 50% of students in South Valley and 40% of students in Fayoum wanted to study solar energy for economic reasons.

a)

b)



c)

Figure 1: a) SOLEDA consortium; b) student motivation behind studying solar energy; and c) distribution of student responses according to their geographic location.

An on-line questionnaire was also distributed via the German Arab Chamber of Industry and Commerce's (GACIC) database of companies to understand the training gaps in the market. The services of these companies were clustered around solar water heating, solar water pumping and backup PV power plants. Out of the 206 solar energy companies that are registered with Egypt's National Renewable Energy Authority (NREA), a total of 57 Egyptian companies took part in the surveys and the results are shown in Figure 2. According to the surveys, most Egyptian companies working in the field are small and medium sized, as shown in Figure 2a. In fact, 62% of our responding companies employed less than 50 people, whereas market leaders typically employ between 50-100 people.

Despite the rather limited number of companies in the field, the market outlook of most companies is positive, as shown in Figure 2b. The majority of the companies see a growth potential in their sector of between 10 to 20% (71% of all respondents). 25% expect a growth rate of 20-40% and three companies are expecting a growth rate of over 50%. Furthermore, most companies in the Egyptian market are local system integrators and suppliers. These suppliers provide spare parts, systems design, various consulting services and system installation. They mostly offer after-sales services for operation and maintenance. Most of the market leaders are agents of foreign solar energy and PV products.

As for company structure and size, 63% employ between 1-50 people in the training division (c.f. Figure 2c) and 65% employ less than 50 people in the installation division, as shown in Figure 3d. However, 53% of companies have no manufacturing division (Figure 2d), 25% have no installation division and 30% of companies have no after sales division (Figure 2e). These high figures could be attributed to the lack of human resources available in these areas. Only 40 companies employ less than 20 people in the after sales division, whereas 25 companies employ 1 - 5 people in the same division. All these numbers indicate that specialist training programmes are desperately needed in these areas.

Furthermore, to ensure that graduates have the necessary attributes required by the Egyptian industrial sector, the authors again surveyed the companies to enquire about the skills needed by the job market. The results of this survey are shown in Figure 2g. Respondents were asked to choose five skills and attributes from a list of 10 items. According to their responses, almost all of the items were important. However, the most popular skill was concerned with the design of solar energy systems. Companies clearly needed graduates who were well informed about the latest solar energy trends and equipment. They also needed staff members who were competent in performing the necessary calculations in order to design effective solar energy systems. The next most important skill was concerned with understanding the *basic theory of operation* of these systems. According to their feedback, other important graduate attributes included *project management* and *maintenance* of solar energy systems.

Thus, the consortium tailored the training programme towards the narrower scope of decentralised solar energy solutions. Instead of specialising in either solar thermal or photovoltaic systems, the surveys revealed that companies required graduates who were familiar with planning, sizing, installing and maintaining solar energy systems. Furthermore, the survey showed that companies required more engineering graduates who were competent in communicating their designs to potential clients. To tackle this issue, the consortium's approach was two-fold: 1) to design a specialist module on technical sales and marketing; and 2) to develop an Arabic solar energy software tool. Such a tool would be a valuable resource for teaching the principles of hybrid solar energy systems and enable engineers to professionally communicate their designs to potential clients.

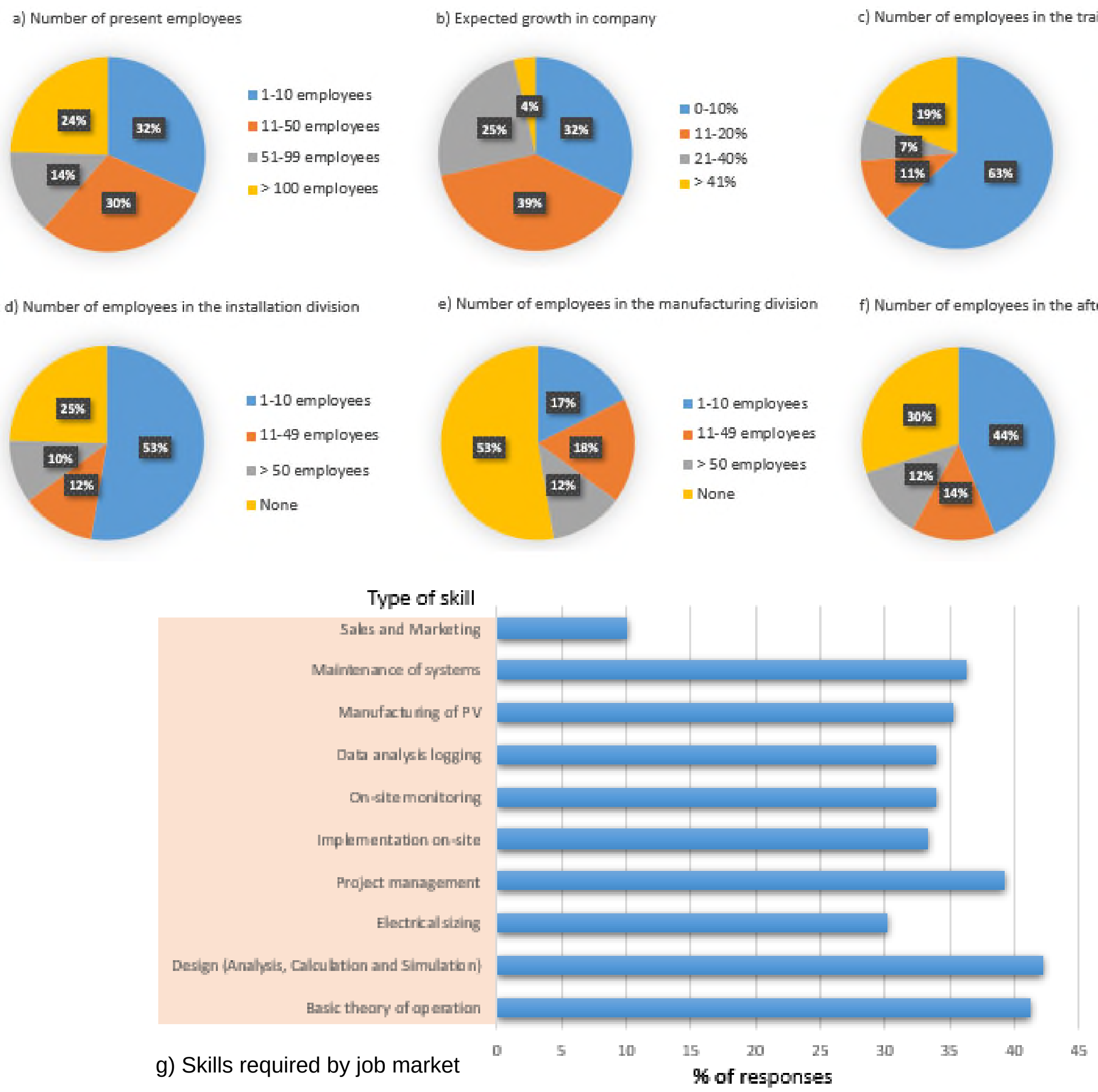
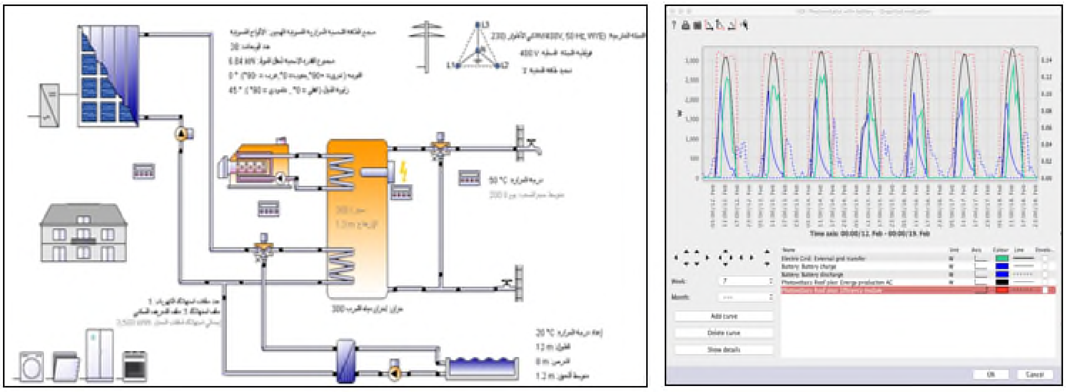


Figure 2: Collected responses from 57 Egyptian companies regarding their structure and the skills required by the solar energy market.

THE POLYSUN SOFTWARE TOOL

Solar energy systems design is a complex process that requires detailed information about the location in which the system will be installed, in addition to a set of skills that the system designer must possess. In fact, given the complexity and costs of today's solar energy systems means that students need to be well versed in computer-aided design (CAD) tools. Students must learn to develop their designs, simulate them and understand how their systems will perform before implementing these systems in the real world. Despite the high interest in integrating computer aids into courses, there are a number of challenges in implementing these changes. First, teaching CAD tools takes time, which leaves little room for faculty members to cover all the course's intended learning outcomes (ILOs). Consequently, the consortium was keen on customising a well-established technology CAD programme known as Polysun for simulating a variety of solar energy systems [10]. In doing so, the authors aimed to expose students to modern industry software tools that can improve their employability, since they will be trained in methods that are appropriate for the environments in which they will work. Such software tools have previously demonstrated many benefits in higher education teaching [11][12].

Polysun is a Swiss software product that allows designers of solar thermal, solar photovoltaic and solar air conditioning systems to recommend, configure and predict the performance of a solar energy system in ways that meet customers' satisfaction. In addition, it provides designers with a wealth of technical specifications for the latest solar energy systems. For example, students were able to compare the results of their simulations with experimental set-ups. They were able to observe how a change in tilt angle, position and radiation strongly influenced the performance of their solar energy system. One of the case studies that were examined during the course involved designing a PV system for a family with three children in Aswan, which consumes 3,000 kWh of electricity per year. Students were told to assume that the family is connected to the grid, but they wish to install a PV system and a battery bank to give them greater independence from the grid's volatile price fluctuations. Students were required to design a system that enabled the family to rely exclusively on their PV system (including batteries) in at least nine months of the year. Students were informed to consider that the family's south-oriented house roof measures 8 × 5 m and has a pitch of 10 degrees. The modules' tilt angle must follow the roof pitch, but the number and type of modules, as well as the inverter can be defined freely, as long as they fit on the roof. Figure 3 illustrates the graphical evaluation of the simulation results using Polysun.



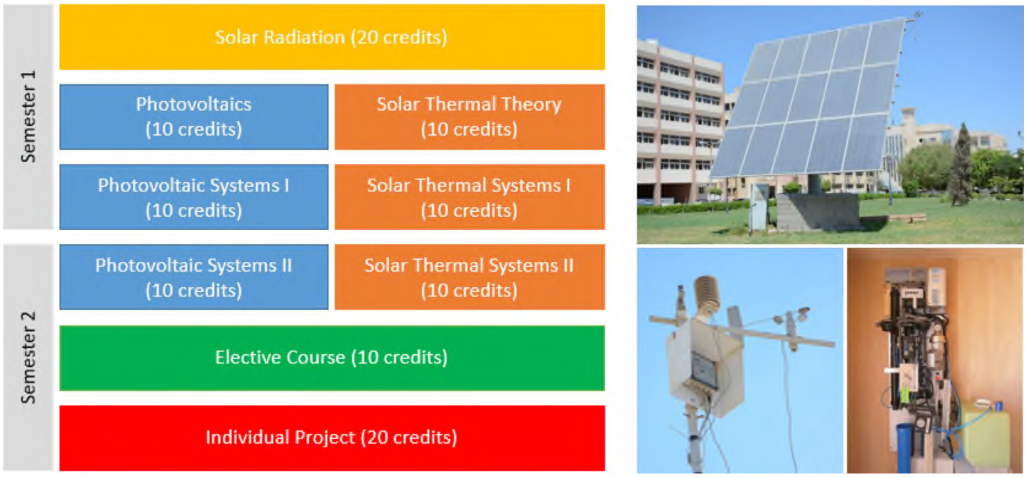
a) b)

Figure 3: a) customised Polysun tool for simulating a hybrid solar energy system. The tool has been translated to the Arabic language during the project's funding period; b) graphical evaluation of simulation results using Polysun.

RESULTS AND DISCUSSION

The decentralised systems taught during the programme relied on using photovoltaic panels for street lighting, residential, water pumping and water purification applications. Similarly, the programme taught students how to design solar thermal systems for domestic and commercial hot water applications. Teaching during the laboratory sessions was learner centred, where the instructor acted as a facilitator and assessor, while the students were engaged in their design projects. These laboratory exercises required students to verify their experimental results with simulation and intuitive sizing methods. Examples were carefully chosen to reflect local and market needs to ensure that the training is relevant. Finally, summative assessment consisted of one examination and four laboratory sessions, which weighed 40% of the module's final grade.

Students in the first semester were taught solar radiation, solar thermal theory, the basics of photovoltaics, basic photovoltaic systems and basic solar thermal systems, as shown in the programme structure in Figure 4a. Furthermore, students were given the opportunity to assemble a weather station, a 2-axis tracker and a solar driven reverse osmosis (RO) desalination system, as shown in Figure 4b. In the second semester, students examined advanced solar thermal systems, such as the planning and layout of high concentration solar towers. Four elective courses were offered in the second semester, which were: Solar Desalination, Project Management, Technical Sales and Marketing, as well as Hybrid Energy Systems. Finally, students had to submit an individual thesis on a solar energy research topic of their choice.



a) b)

Figure 4: Structure of the SOLEDA diploma; a) components of the SOLEDA diploma; b) some of the equipment, which include a weather station, PV tracking system and a solar desalination unit.

It is worthy to note that the three partnering Egyptian universities have received approval from Egypt's Ministry of Higher Education to launch the diploma through their Faculty of Science. Each of the partnering Egyptian universities has a dedicated solar energy laboratory that is accessible to all staff and students that are interested in the field. To ensure maximum sustainability of the programme, selected staff members from the three partnering Egyptian universities were trained in using the software, setting up the practical exercises and in delivering the lecture material. During the EU funding period, the programme was delivered twice and 24 students enrolled into the diploma and successfully completed their assessments. More than 70 applications were received in each round. Admission requirements did not discriminate against age nor gender. In fact, during the first round 40% of the enrolled candidates were female.

CONCLUSIONS

In this article, the authors described their approach to designing a graduate curriculum for solar energy systems, which was strongly tailored towards the needs of the Egyptian solar energy industry. Thanks to the generous funding from the EU, this curriculum has been implemented successfully in three public Egyptian universities. The programme consisted of 110 credit hours of contact training with the students. The unique features of the programme include: 1) courses that covered the fields of solar thermal and photovoltaic energy; 2) hands on training in hybrid solar energy systems that met the needs of the local market; and 3) development of an Arabic software tool that was designed in close partnership with staff and students. Interviews with the students showed that the diploma achieved the overall satisfaction of the students.

ACKNOWLEDGEMENTS

The SOLEDA consortium gratefully acknowledges the financial support of the European Union, European Commission TEMPUS (Education, Audiovisual and Culture Executive Agency, EACEA) (TEMPUS IV): Project Number 530296-TEMPUS-1-2012-1-ES-TEMPUS-JPHES.

REFERENCES

1. Abdou, P. and Zaazou, Z., The Egyptian revolution and post socio-economic impact. *Topics in Middle Eastern and African Economies*, 15, **1**, 92-115 (2013).
2. British Petroleum, *Statistical Review of World Energy* (2018), 8 May 2019, www.bp.com/content/dam/bpbusiness-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2018-full-report.pdf
3. International Renewable Energy Agency. Renewable Energy Outlook: Egypt. Abu Dhabi: IRENA (2018).
4. US Energy Information Agency. Egypt (2018), 8 May 2019, www.eia.gov/beta/international/analysis.php?iso=EGY
5. Wesseh, P. and Lin, B., Energy consumption, fuel substitution, technical change, and economic growth: Implications for CO2 mitigation in Egypt. *Energy Policy*, 117, 340-347 (2018).
6. Vidican, G., *Building Domestic Capabilities in Renewable Energy: A Case Study of Egypt.* Bonn: German Development Institute (2012).
7. Khayet, M., Ghannam, R. and Khalil, A., Solar Energy System Design using Advanced Learning Aids (SOLEDA): an EU Tempus Project. Valencia, Spain, 2283-2291 (2014).
8. Soliman, M., Pro-poor tourism in protected areas - opportunities and challenges: the case of Fayoum, Egypt. *Anatolia*, 26, **1**, 61-72 (2015).
9. Wheida, A., Nasser, A., El Nazer, M., Borbon, A., El Ata, G.A.A., Wahab, M.A. and Alfaro, S.C., Tackling the mortality from long-term exposure to outdoor air pollution in megacities: lessons from the Greater Cairo case study. *Environmental Research*, 160, 223-231 (2018).
10. VelaSolaris. Polysun (2019), 4 May 2019, www.velasolaris.com.

11. Flavin, M., Technology-enhanced learning and higher education. *Oxford Review of Economic Policy,* 32, 632-645 (2016).
12. Brown, R., Incorporating computer-aided design into an electrical engineering/computer science curriculum. *IEEE Trans. on Educ.*, 35, **3**, 182-189 (1992).

BIOGRAPHIES

Dr Rami Ghannam is a Lecturer (Assistant Professor) in Electronic and Nanoscale Engineering. He graduated with top first-class honours from King's College in 2001 and was awarded the Siemens Prize. He then obtained his DIC and MSc degrees from Imperial College London, followed by his PhD from the University of Cambridge in 2007. He has held previous industrial positions at Nortel Networks, IBM Research GmbH, Shaker Consultancy Group and Starkon S.A.E. He is the co-director of the *Microelectronics Lab*, a member of the Communications, Sensors and Imaging group. His research work encompasses the fields of electronic devices, materials science and nanotechnology. He holds five patents in the area of photovoltaic systems.

Ms Marion Kussmann is Head of EU Projects at the German Arab Chamber of Industry and Commerce. She has over 20 years of experience in managing various funded projects. Ms Kussmann has a proven track record of start-up support services for young entrepreneurs, the organisation of major match-making fora, management training, networking and is a lobbying specialist for the German Chamber.

Dr Andreas Wolf is the International Sales Manager of the Swiss company Vela Solaris AG, which develops and markets Polysun, the leading dynamic simulation software for renewable energy systems (solar thermal, photovoltaics, geothermal). He has more than 20 years of experience in teaching and international know-how transfer in different languages, cultures and countries. He has been collaborating in international projects in Egypt (SOLEDA 2012-2016) and China (Renewable Energy Training and Certificate 2015-2017).

Dr Ahmed Saad Gomaa Khalil is an Associate Professor in Fayoum University and leads the Environmental and Smart Technology Group. Dr Khalil received his PhD in physics and materials science in 2008 from Max Planck Institute in Germany. He received his BSc and MSc in Physics from Cairo University in 1999 and 2003, respectively. Dr Khalil was a postdoctoral associate (2008-2010) at the University of Duisburg-Essen, Germany, and a visiting scientist at IBM Research labs in Zurich, Switzerland (2010-2011) and the University of California Berkley, USA (2013). His research interests expand into different areas including water desalination, printed electronics and solar energy.

Professor Muhammad Ali Imran is the Vice Dean Glasgow College UESTC and Professor of Communication Systems in the School of Engineering at the University of Glasgow. He was awarded his MSc (Distinction) and PhD degrees from Imperial College London, UK, in 2002 and 2007, respectively. He has over 18 years of combined academic and industry experience, working primarily in the research areas of cellular communication systems. He has been awarded 15 patents, has authored/co-authored over 300 journal and conference publications, and has been principal/co-principal investigator on over £6 million in sponsored research grants and contracts. He has supervised 30+ successful PhD graduates. He is a senior member of IEEE and a Senior Fellow of Higher Education Academy (SFHEA), UK.