AC 2011-988: RENEWABLE ENERGY REVIVES ELECTRONICS & COMPUTER ENGINEERING TECHNOLOGY

Joyce M.E. van de Vegte, M.A.Sc., Electronics & Computer Engineering Technology, Camosun College, Victoria, Canada
Alan P. Duncan, Electronics & Computer Engineering Technology, Camosun College, Victoria, Canada

Renewable energy revives electronics & computer engineering technology

Background

Concerns about greenhouse gases and dwindling fuel supplies have given rise to aggressive energy efficiency policies and renewable energy initiatives worldwide. New industry in this sector demands technicians, technologists and engineers with training in alternative energies. Between now and 2017, Canadian labour force requirements are expected to more than double in wind, solar photovoltaic and bioenergy, and triple in solar thermal industries.[1] Globally, a 11% compound annual growth rate in renewable energy demand is predicted to persist for the next decade, with an attendant US$2.2 trillion investment in renewable energy power generation.[2] Already the global market value of green energy is nearly US$5.2 trillion.[3]

Colleges and universities across North America are hastening to develop programs that will serve these new workers and industries. The programs address a wide spectrum of skills. Some train installers of systems; others give expertise in choosing suitable technologies for a given location and application; and still others prepare designers of renewable energy systems.

At Camosun College in Victoria, British Columbia, programming changes were made to respond to the new demand for graduates with training in alternative energies. The intent has been to give students the capacity to serve as renewable energy system design consultants. Such a person, according BC's Green Economy 2010 report "Securing the Workforce of Tomorrow," "assesses industry trends and related implications, monitors product developments and preferences, examines emerging technologies and advises clients on practical solutions."[3] Graduates might be called upon to compare a solar photovoltaic to a wind system for a given location, for example, or to select appropriate system components, such as inverters or batteries, for a remote installation. They can perform simple calculations to estimate the amount of available energy in a hydroelectric or solar resource. They are acquainted with all major alternative energy technologies.

Renewable energy components have been embedded within a structure, the Electronics & Computer Engineering Technology program, that includes analog and digital circuits, programming, wireless communications, digital signal processing, system control, and embedded systems, to ensure that traditional electronics and computer engineering technology proficiency is maintained. As with many other professional areas, "the lines between environmental jobs and occupations in more traditional sectors are becoming increasingly blurred."[3] In the next decades, graduates will be expected to master an increasingly large skill set.

In fact the changes made to the Electronics & Computer Engineering Technology program have produced several desirable outcomes: (1) giving graduate technologists the skills they require to serve as renewable energy system design consultants; (2) responding to the needs of local employers; (3) heightening program interest among prospective female students; and (4) preparing graduates to be conversant in renewable energy matters and to engage meaningfully in public energy debate. The changes have coincided with increasing student enrolment, but it is too early to tell whether this is due to a perception of greater program relevancy, a reaction to economic downturn, or simply coincidence.

This paper will present the changes made to the Electronics & Computer Engineering Technology program at Camosun College, and survey the consequences of adding renewable energy components.

What changes were made?

Two years ago, significant changes were made to Camosun College's Electronics & Computer Engineering Technology program to give the program a renewable energy focus. A first year survey course, Elex 121 Renewable Energy Systems, was developed, and several existing courses were modified to incorporate new renewable energy content.

Renewable Energy Systems is a twelve-week survey of: solar photovoltaic energy, wind energy, solar thermal energy, bioenergy, hydroelectricity, tidal energy, wave energy, geothermal energy, nuclear energy, energy storage (including hydrogen fuel cells), integration, and conservation. A technical approach that permits rudimentary system designs and comparisons is taken, and lectures are supported by weekly labs. Table 1 lists the major concepts covered by technology, Table 2 lists the learning outcomes for the course, and Table 3 shows the course lab exercises.

The intent is to prepare students to become intelligent assessors of renewable energy technologies with the ability to develop appropriate solutions for practical energy problems. Students perform research and prepare a group presentation on selected energy topics. At the completion of the course, students have a working understanding of major renewable energy technologies, including some of their less visible features, such as life cycle costs, waste disposal (especially of toxic or heavy metals), and grid integration, and are able to engage intelligently in public debate about the pros and cons of proposed alternative energy solutions.

Renewable energy content has also been injected into: circuit analysis, semiconductor devices, system control, and power electronics courses. Details of the changes are outlined below:

Elex 142 Circuit Analysis introduces students to network theorems and electric circuit fundamentals and is a great place to introduce the characteristics of solar photovoltaic panels. The latter can be used as examples for maximum power transfer theorem. The learning outcomes that were added to this course are:

- Describe and analyze the characteristics of solar photovoltaic (PV) panels
- Analyze simple battery charging circuits

Elex 143 Electronic Devices 1 introduces students to discrete semiconductor devices. It covers essential topics from basic semiconductor theory through to the application of diodes, transistors and thyristors. The emphasis of this course is on the classic application of these devices. In addition the PV panel is examined from a semiconductor perspective. The learning outcomes that were added to this course are:

- Describe the semiconductor construction of a PV cell
- Describe the device IV characteristics of a semiconductor PV cell
- Demonstrate the assembly of a solar panel using solar cells

Elex 241 Fundamentals of Control covers: open and closed loop systems, time and frequency domains, transient and steady state response, control of discrete and continuous processes, PID controller design, Bode plots, stability, gain and phase margins, fuzzy control, and adaptive control. Control theory is explained by using examples from renewable energy systems, such as optimal power extraction for solar PV panels and optimal power conversion for wind turbine control systems. The learning outcomes that were added to this course are:

- Describe the control methods used in solar power controllers for tracking maximum power
- Describe methods of controlling wind turbine output power
- Describe effects of turbine parameters on turbine power output

Elex 242 Power Electronics introduces power electronic devices such as triacs, thyristors, GTOs, etc. Applications of these devices include power supplies, DC and AC drive systems, inverters for grid-tied systems, power control, and microprocessor-controlled equipment. Without the topics in this course, many renewable energy systems cannot be fully understood. The learning outcomes that were added to this course are:

- Describe power conversion techniques (DC-DC conversion using choppers and DC-AC conversion using inverters)
- Describe the role of conversion in connecting large wind turbines to the grid

Elex 244 Electronic Devices 3 links many devices to renewable energy applications, for example, the application of switching regulators to maximum power point tracking.

Graduates from Camosun College's two and a half year program receive a diploma in Electronics & Computer Engineering Technology – Renewable Energy.

Why make changes?

The explosive growth in the renewable energy sector is a constant theme in the media. Renewable energy production technologies, which have experienced "double-digit annual growth rates for more than a decade," contributed 23% of global energy generation in 2008, compared with 5% in 2003.[4] In many parts of the world, renewable energy growth is linked to favourable government policies or greenhouse gas targets.[5] [6]

British Columbia's Green Economy reports[3] suggest that "BC's economy could face shortages of more than 60,000 skilled green workers by 2020." Recognizing a "pressing need to address anticipated shortages," a key recommendation of the Canada–U.S. Clean Energy Dialogue Forum, Building the Power Workforce of Tomorrow, was to "increase training and apprenticeship programs with colleges."[7]

Table 1 Major renewable energy concepts, by technology

Renewable Technology	Major Concepts
Solar Photovoltaic Energy	• PV cell and model • types of cells • IV characteristics • maximum power point and buck-boost converter • insolation and effects of time and date • capacity factor • PV modules in series and parallel • design of PV array using insolation data • life cycle costs • solar PV applications
Wind Energy	• HAWT and VAWT turbines • basic aerodynamics • power in wind • power captured by turbine • effects of wind speed of air density and height • wind speed frequency distribution and average wind speed • average power captured by turbine • Weibull distribution • friction coefficients • cut-in, rated and shut-down speeds • tip-speed ratio • capacity factor • control techniques (including pitch control, stall and furl) • wind turbine applications
Solar Thermal Energy	• passive vs active collection • parabolic trough and dish • capacity factor • efficiency • Carnot cycle • Stirling engine • ideal gas law • air source heat pumps in heating and cooling modes • coefficient of performance • solar thermal applications

Table 1 continued Major renewable energy concepts, by technology

Renewable Technology	Major Concepts
Bioenergy	• biomass sources • energy density comparisons • combustion • production and uses of biodiesel • production and uses of ethanol • use of waste products • combined cycle gas plants
Hydroelectricity	• comparative advantages and large- and small-scale hydro • potential and kinetic energy of water • head • turbine types • installations in British Columbia
Tidal Energy	• tidal cycles • spring and neap tides • potential energy of water in a tidal lagoon • ebb, flood and two-way operation of tidal barrages • tidal stream systems • tidal turbines in Bay of Fundy and Race Rocks
Wave Energy	• types of wave energy converters • energy in waves • effects of period, height. wavelength and water depth • Wells' turbine • examples of fixed, floating and tethered devices
Geothermal Energy	• heat flow and enthalpy • thermal gradients in the earth and thermal conductivity • Darcy's law • flash • hot dry rock technology • ground source heat pumps
Nuclear Energy	• nuclear fission concepts • sustainability • radioactivity and disposal concerns

Table 1 continued   Major renewable energy concepts, by technology

Renewable Technology	Major Concepts	
Energy Storage	• compressed air storage • thermal energy storage • pumped hydro storage	
	batteries	• lead acid batteries • NiMH batteries • NiCd batteries • lithium ion batteries • lithium polymer batteries • lithium iron phosphate batteries • sodium sulphur batteries • ultracapacitors and supercapacitors • flow batteries • energy densities • battery discharge curves • internal resistance • C-rates • battery charge curves • electric vehicles
	hydrogen fuel cells	• properties of gaseous and liquid hydrogen • energy density by mass or volume • production of hydrogen • hydrogen safety • hydrogen transport and storage • metal hydrides • electrolysis and fuel cell reactions • polarization curves • mass rates for H_2, O_2 and H_2O • efficiency and cell voltage • types of fuel cells (principally PEM) • fuel cell applications

Table 1 continued Major renewable energy concepts, by technology

Renewable Technology	Major Concepts
Integration and the Grid	• combining multiple energy sources and technologies • intermittency of supply • distance from grid • management of energy parameters (frequency and phase) • net metering • “smart grid” • intelligent energy management systems
Conservation	• passive solar thermal measures • CFL and LED light sources • energy efficient appliances • energy efficient practices

Table 2 Learning outcomes for Elex 121 Renewable Energy Systems

- Describe characteristics of renewable energy (RE) resources
- Explain the principles of operation of RE systems
- Explain the benefits of RE systems vs conventional power generation
- Analyze the operation of RE systems
- Perform economic analysis of RE systems using commercial software package
- Calculate the energy inputs, outputs and efficiency of RE systems
- Explain differences between AC and DC power generation/distribution systems
- Explain operation of RE system components (generators, inverters, chargers, controls)
- Perform rating calculations for RE components and cabling
- Specify RE system based on stated energy supply requirements
- Describe characteristics of energy storage systems
- Specify battery charging systems
- Explain the operation of grid-tie RE systems
- Analyze and give examples of RE case studies
- Demonstrate competence in RE system design/operation in lab

Table 3 Laboratory Exercises for Elex 121 Renewable Energy Systems

- Lab 1 Generation of DC and AC Voltage and Inverters
  Students see demonstrations of cranked and inverter AC generation. They use a 555 timer, two power transistors, and a transformer to light a neon bulb from a DC supply.
- Lab 2 Photovoltaic Solar Energy: IV Characteristic and Dynamic Resistance
  Students plot the IV characteristic for a 600 mW solar PV panel and study its behaviour under various lighting and load conditions.
- Lab 3 Photovoltaic Solar Energy: Panel Efficiency
  Students use a 600 mW solar PV panel to study the effects of light spectrum, tilt and temperature on panel efficiency.
- Lab 4 Hydrogen Fuel Cell: Electrolysis of Water
  Students electrolyze water using a PEM fuel cell to produce hydrogen and oxygen, and measure gas generation rates.
- Lab 5 Hydrogen Fuel Cell: Performance
  Students operate a PEM fuel cell car and calculate its fuel efficiency and car mileage.
- Lab 6 Wind Energy: Generated Voltage and Power
  Students construct a small geared wind turbine from a kit and measure its output power for various wind speeds and blade configurations. They verify the wind power law.
- Lab 7 Wind Energy: Tip Speed Ratio, Blade Pitch and Gearing
  Students study the effects of wind speed on tip speed ratio, and the effect of blade pitch on output power. They use gearing to study the relationship between output power and torque.
- Lab 8 Solar thermal: Heat Pumps and Stirling Engines
  Students see a demonstration of a heat pump, and use temperature measurements to calculation coefficient of performance (COP). They see a demonstration of a Stirling engine.
- Lab 9 Battery Discharge Characteristics
  Students perform 1C and 2C discharges of lead acid, NiMH and Li-ion batteries under room temperature and cold conditions, and calculation energy densities by mass an volume.
- Lab 10 Field Trip
  2009 Race Rocks Tidal Turbine
  2010 T'Souke Nation Solar PV Project and Jordan River Hydroelectric Dam

Industry feedback

The Electronics & Computer Engineering Technology – Renewable Energy program has an industry program advisory panel that meets every quarter. The members of the panel are selected from a broad group of local companies representing both government and the private sector. We held a focus group session that was independently facilitated on 28 April 2009. The questions posed were:

What present and future trends in relation to renewable energy do you think might influence what employers will need in the coming years? Five years from now, where do you see your company in relation to renewable energy?

It was clear that our local employers saw a need for a program that incorporated renewable energy systems. Some of their responses are included here:

- Many companies are using elements of renewable energy right now so this is certainly emerging.
- Added to this is the possibility of changes to public policy that might enhance this even more.
- Clearly, though, this area is enjoying a level of growth and creative responses are required from our organizations.
- Renewable energy options fit in with our increasing need to provide added value for our current clients. They want to see us do more in this area and offer solutions that are green and cost effective.
- Customers also require an increased level of energy efficiency in our products and services and are reluctant to pay for what they see as waste. We need to justify changes here.
- Future technologists in this area are going to need to know what the alternate energy options are and provide clients with a range of options. This also supports a company's ability to be increasingly competitive as the marketplace changes.
- There are currently not many technologists out there with this range of knowledge and abilities, especially in the areas of solar and wind power.
- Energy harvesting will also be required – how do we collect it, along with how and where do we store it are some of the fundamental issues we are discussing.
- Camosun College offers an applied/experiential approach that is essential to the skills base. The application component in relation to renewable energy is critical.
- There has to be an emphasis on the basics with a strong foundational component to content.
- Students have to undertake field trips to businesses to see firsthand what is going on.

How much did the changes cost and how long did they take to implement?

The program changes were implemented relatively quickly. A number of faculty used their allocated development time to develop labs and curriculum for these program changes. At our institution, we get one quarter of release time every two years so no additional funding was required. About six months of curriculum development time were required to implement the program changes, with an estimated cost of approximately $50,000. Specialized lab equipment and supplies for the renewable energy course (detailed in Table 4) cost $11,100. Thus, the total cost for the program revision was about $61,100 of which only $11,100 had to be funded.

Table 4 Lab supplies

Item	Cost per unit $	Number of units	Total cost $
solar panel	5	15	75
light source	20	15	300
light meter	40	15	600
wind turbine kit	65	15	975
anemometer	114	15	1,710
floor fan	25	15	375
tachometer	80	15	1,200
fuel cell car kit	172	15	2,580
beakers	20	15	300
containers	10	15	150
universal battery charger	175	3	525
NiMH batteries	12	30	360
lead acid batteries	15	30	450
lithium ion batteries	10	30	300
rheostat case	11	15	165
knobs	7	15	105
sense resistor	2	15	30
rheostat 50 W	60	15	900
		Total	11,100

What effects did changes have?

It would appear that the changes made to our program coincided with a large change in our enrolment data. Whether this change is a direct result of these program changes is hard to determine, though it is the case that many students entering our program are excited by the fact that they will learning about renewable energy systems.

Using 2007 as a reference (see Figure 1), we saw a 43% increase in applicants in 2008, a 56% increase in 2009 and a 63% increase in 2010. This increase in applicants resulted in an overall increase in students attending the program. At this time we also raised the number of students in a lab group from 15 to 22 resulting in increased capacity with no increase in costs. While this (imposed) change has not been without consequences, it has enabled us to increase our capacity without the additional burden of increased staff costs. The continued growth of interest in our program has led to our program having a significant waitlist for the first time in many years, as shown in Figure 2.

Figure 1 Program applicants

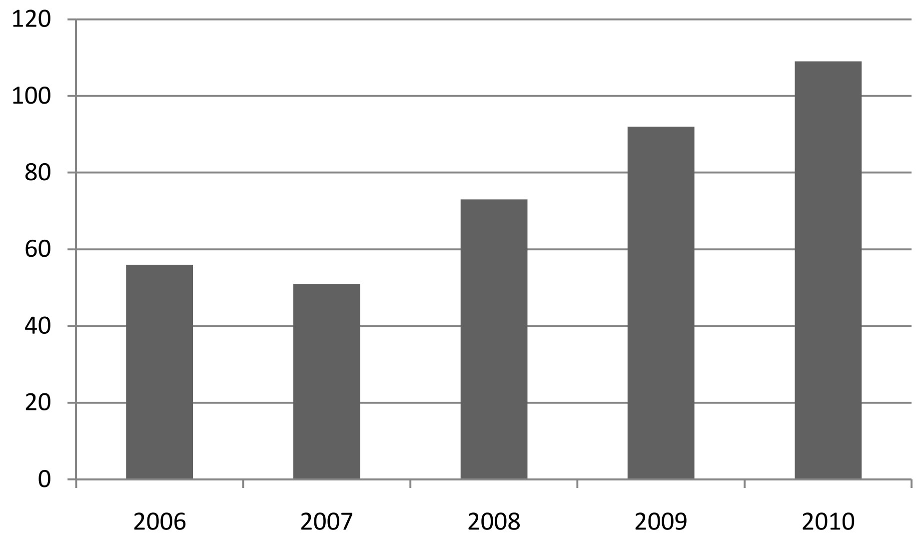
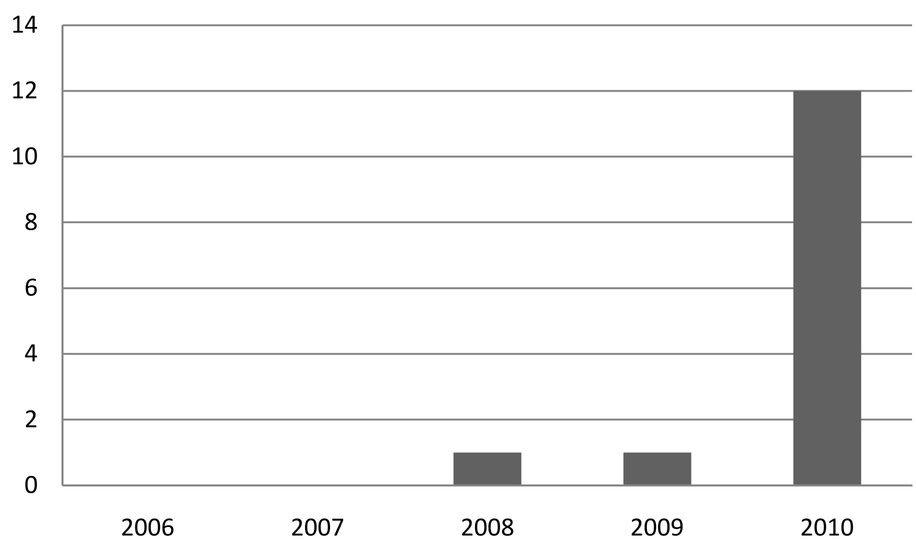
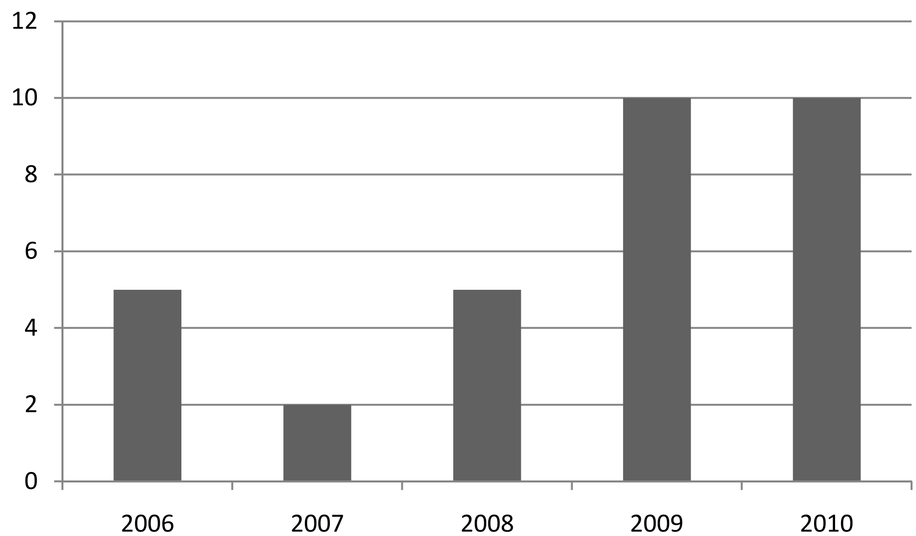


Figure 2 Waitlisted students



It has long been observed that in North America women are severely underrepresented in engineering and technology. Despite efforts made in recent decades, young women continue to choose these fields dramatically less often than young men,[8 9] even though many women engineers and technologists report high job success and satisfaction.[10] Girls are more likely to choose careers that they perceive help people and with which they feel a positive association, and they prefer to work in teams.[11] [12] For this reason, when girls visit the department, we showcase such renewable energy applications as the use of solar pumping for clean water supplies or solar lighting for rural hospitals in developing countries. Indeed, girls have expressed heightened interest in the electronics program at Camosun College perhaps because the renewable energy focus creates a link with caring responsibly for the planet. Since making our program changes, the number of female applicants to our program has increased significantly (see Figure 3). This is certainly an underrepresented group in all of our programs, and it is particularly refreshing to see this trend in the right direction.

Figure 3 Female applicants



School groups and prospective students that visit our department are keenly interested in past student projects that relate to renewable energy. Table 5 lists these projects. More information may be found at www.elex.camosun.bc.ca/programs/projects.htm.

The Future

The changes made to the Electronics & Computer Engineering Technology program at Camosun College have been well received by students. Several have indicated that they hope to make their careers in renewable energies. Certainly the changes have triggered renewed interest from local schools and media. The department hopes to develop and offer more advanced renewable energy programming in an online or evening format that would permit more intensive study of certain renewable energy technologies. The Electronics & Computer Engineering Technology – Renewable Energy program, with the addition of advanced studies elements, may eventually form the core of a renewable energy degree program.

Table 5 Student projects related to renewable energy

Electric vehicles	• 2004 Human Transport Vehicle The Human Transport Vehicle (HTV) is a two-wheeled "Segway"-type vehicle that balances a user vertically and propels them forward or backward with the ability to steer. It uses control feedback from both a gyroscope and an accelerometer to achieve balance. The HTV is mounted on wheelchair motors and powered by four sealed lead acid batteries. • 2006 Electric power assisted bicycle The electric-assisted bicycle is powered by the rider, ultracapacitors, and lithium-ion batteries, enabling the rider to travel greater distances or use less effort. A brushless DC motor, controlled by a MOSFET H-bridge driven by a dsPIC, is used to drive the wheels. Strain gauges on the rear axle provide a measure of torque. • 2007 Electric van A Ford Windstar shell is used for an electric vehicle conversion. DC power from a battery pack is converted to three phase AC power for driving an AC induction motor. IGBTs and their gate driver circuits, driven by DC/DC converters, perform the inverter function. Logic drive signals are supplied to the inverter in the form of a PWM-generated sine wave called Space Vector Modulation (SVM). The SVM software contains three PID control loops, controlling stator flux, stator torque, and rotor angular velocity. • 2010 Electric motorcycle A 48 VDC to 30 VAC, 7.5 kW inverter is designed to power a three phase AC induction motor, which provides the main drive system for a Honda CBR1000F Hurricane. The inverter is powered by four 12 V lead acid batteries and is capable of driving a motor at 0 – 120 Hz which is approximately 0 – 150 km/h. The control system for the inverter consists of an ARM Cortex-M3 microcontroller with an RTOS, a three phase driver chip, and twelve MOSFETs mounted on a custom aluminum heat sink, all powered by a custom switched mode power supply. Optical isolation protects the control system from the high power system. Two DC/DC converters are used in the isolated system to provide sufficient power to the microcontroller, the throttle, the current sensors, the temperature sensors, and several LEDs.

Table 5 continued Student projects related to renewable energy

Solar PV projects	• 2007 Automated solar panel sun tracker charger system with MPPT A GPS receiver, digital compass, and real time clock is used to calculate the exact position of the sun in the sky at all times. This data is used to control two motors to pan and tilt a solar PV panel, obtaining 30 – 35% more power compared to a stationary panel. Collected power is used to regulate the charging of a 12 V battery by means of maximum power point tracking (MPPT). • 2008 Wind turbine and solar panel MPPT data acquisition system The project includes an MPPT to efficiently use energy from a solar PV panel and wind turbine. Information collected by a monitoring system from different energy sources is transmitted to a touch screen user interface using SPI and CAN bus protocols. The system also incorporates an embedded web server.
Conservation projects	• 2009 Greenhouse climate control This greenhouse climate control system uses a PIC microcontroller. Sensors providing input to the PIC measure air temperature inside and outside the greenhouse, air and soil moisture levels, ambient light, and water supply level. Actuators include a fan, a water pump connected to a soaker hose, and a PWM-controlled LED grow light panel. • 2009 BC Games "green torch" The prototype for the LED pods and lighting controls used in the BC Games "green torch" was a student project. Each pod consists of four banks of seven LEDs of different colours controlled using modules compatible with the DMX protocol, which can dim and address up to 512 banks of LEDs. A total of 303 high power LEDs are controlled to simulate natural flame, requiring only a fraction of the energy used by the original BC Games torch, which was fuelled by natural gas. www.camosun.ca/ccr/news/2009/nov/bcgames-torch.html • 2010 Home control system A wireless system unifies the control of household electronics, including televisions, stereos, video players, computers, lights, and heaters into one small and portable module. The user controls the system remotely through the Internet using a Smartphone, with an application designed for the Android operating system. The home control system features a wide range of wireless connectivity including infrared, Bluetooth, X-10, and Wi-Fi, controlled by a 32-bit mbed ARM microcontroller.

References

[1] Delphi Group, "Situational Analysis of the Canadian Renewable Energy Sector with a Focus on Human Resource Issues," Final Report, Prepared for Human Resources and Social Development Canada, 30 January 2007.
http://selkirk.ca/media/departmentsandschools/renewableresources/renewableenergy/Human_Resource_Analysis.pdf

[2] Robert Clover, "Sizing the climate economy," Alternative Energy Research, HSBC Global Research, London, September 2010.
http://www.research.hsbc.com/midas/Res/RDV?ao=20&key=wU4BbdyRmz&n=276049.PDF

[3] Globe Foundation, "BC's Green Economy – Securing the Workforce of Tomorrow," September 2010. http://bcgreeneconomy.globeadvisors.ca/media/4855/globe_green_economy_report_ii_final.pdf

[4] Janet L. Sawin and William R. Moomaw, "Renewable Revolution: Low-Carbon Energy by 2030," Worldwatch Report, Worldwatch Insitute, 2009.
http://www.worldwatch.org/files/pdf/Renewable%20Revolution.pdf

[5] Jennifer Kho, "Renewables Hit the Big Time," Renewable Energy World, May 25, 2010.
http://www.renewableenergyworld.com/rea/news/article/2010/05/renewables-hit-the-big-time

[6] Elisabeth Malkin, "Businesses Seek Clarity on Climate Goals," The New York Times, November 8, 2010.
http://green.blogs.nytimes.com/2010/10/06/businesses-seek-clarity-on-climate-goals/

[7] Electricity Sector Council, "Report recommends ways to boost the electricity sector workforce in Canada and the United States ," Ottawa, June 16, 2010.
http://www.brightfutures.ca/en/projects/Canada-US%20Forum/pdf/10Jun6-ESC_Building-the-Power-PressRelease.pdf

[8] Jennifer Myers, "Why more women aren't becoming engineers," The Globe and Mail, Tuesday, Nov. 09, 2010.
http://www.theglobeandmail.com/report-on-business/managing/on-the-job/why-more-women-arent-becoming-engineers/article1792386/singlepage/#articlecontent

[9] Chris Garofolo, "Panel reviews lack of women in science, engineering fields," Brattleboro Reformer, Saturday, November 13, 2010.
http://www.reformer.com/localnews/ci_16600951

[10] Patricia Shafer and Barbara Trautlein, "Women in Technology – 2007 report," Women in Technology International, WITI SAVVY (2007): p. 19-23.
http://www.witi.com/center/webinar/WomenInTechnology07Report.pdf

[11] Jacquelynne Eccles, " Social Influences on Girls Interest in Math and Science," WEPAN webinar, Fall Series 2008, October 9, 2008.
http://www.wepan.org/displaycommon.cfm?an=1&subarticlenbr=333#

[12] Kaninika Bhatnagar and Mary L. Brake, "Gender Differences in Technology Perceptions of High School Students and Their Intent to Choose Technology College Majors," Journal of Engineering Technology, Fall 2010.