EBC

Energy in Buildings and Communities Programme

International Energy Agency

Evaluation of Embodied Energy and CO_2 equivalent for Building Construction (Annex 57)

Guidance to Support Educators

2016

iea Energy Technology Network

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Edited by

Petr Hajek, Julie Zelezna,

Czech Technical University in Prague

iea Energy Technology Network

Published by Institute for Building Environment and Energy Conservation, Zenkyoren building, Kojimachikan, 3-5-1, Kojimachi Chiyoda-ku, Tokyo 102-0083 Japan

ISBN (978-4-909107-04-6)

Participating countries in EBC: Australia, Austria, Belgium, Canada, P.R. China, Czech Republic, Denmark, France, Germany, Ireland, Italy, Japan, Republic of Korea, the Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom and the United States of America.

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EBC Bookshop
C/o AECOM Ltd
Colmore Plaza
Colmore Circus Queensway
Birmingham B4 6AT
United Kingdom
www.iea-ebc.org
essu@iea-ebc.org

Preface

The International Energy Agency

The International Energy Agency (IEA) was established in 1974 within the framework of the Organisation for Economic Co-operation and Development (OECD) to implement an international energy programme. A basic aim of the IEA is to foster international co-operation among the 29 IEA participating countries and to increase energy security through energy research, development and demonstration in the fields of technologies for energy efficiency and renewable energy sources.

The IEA Energy in Buildings and Communities Programme

The IEA co-ordinates international energy research and development (R&D) activities through a comprehensive portfolio of Technology Collaboration Programmes. The mission of the Energy in Buildings and Communities (EBC) Programme is to develop and facilitate the integration of technologies and processes for energy efficiency and conservation into healthy, low emission, and sustainable buildings and communities, through innovation and research. (Until March 2013, the IEA-EBC Programme was known as the Energy in Buildings and Community Systems Programme, ECBCS.)

The research and development strategies of the IEA-EBC Programme are derived from research drivers, national programmes within IEA countries, and the IEA Future Buildings Forum Think Tank Workshops. The research and development (R&D) strategies of IEA-EBC aim to exploit technological opportunities to save energy in the buildings sector, and to remove technical obstacles to market penetration of new energy efficient technologies. The R&D strategies apply to residential, commercial, office buildings and community systems, and will impact the building industry in five focus areas for R&D activities:

- Integrated planning and building design
- Building energy systems
- Building envelope
- Community scale methods
- Real building energy use

The Executive Committee

Overall control of the IEA-EBC Programme is maintained by an Executive Committee, which not only monitors existing projects, but also identifies new strategic areas in which collaborative efforts may be beneficial. As the Programme is based on a contract with the IEA, the projects are legally established as Annexes to the IEA-EBC Implementing Agreement. At the present time, the following projects have been initiated by the IEA-EBC Executive Committee, with completed projects identified by (*):

Annex 1:	Load Energy Determination of Buildings (*)
Annex 2:	Ekistics and Advanced Community Energy Systems (*)
Annex 3:	Energy Conservation in Residential Buildings (*)
Annex 4:	Glasgow Commercial Building Monitoring (*)
Annex 5:	Air Infiltration and Ventilation Centre
Annex 6:	Energy Systems and Design of Communities (*)
Annex 7:	Local Government Energy Planning (*)
Annex 8:	Inhabitants Behaviour with Regard to Ventilation (*)
Annex 9:	Minimum Ventilation Rates (*)
Annex 10:	Building HVAC System Simulation (*)
Annex 11:	Energy Auditing (*)
Annex 12:	Windows and Fenestration (*)
Annex 13:	Energy Management in Hospitals (*)
Annex 14:	Condensation and Energy (*)
Annex 15:	Energy Efficiency in Schools (*)
Annex 16:	BEMS 1- User Interfaces and System Integration (*)
Annex 17:	BEMS 2- Evaluation and Emulation Techniques (*)
Annex 18:	Demand Controlled Ventilation Systems (*)
Annex 19:	Low Slope Roof Systems (*)
Annex 20:	Air Flow Patterns within Buildings (*)
Annex 21:	Thermal Modelling (*)
Annex 22:	Energy Efficient Communities (*)
Annex 23:	Multi Zone Air Flow Modelling (COMIS) (*)
Annex 24:	Heat, Air and Moisture Transfer in Envelopes (*)
Annex 25:	Real time HVAC Simulation (*)
Annex 26:	Energy Efficient Ventilation of Large Enclosures (*)

Annex 27:	Evaluation and Demonstration of Domestic Ventilation Systems (*)
Annex 28:	Low Energy Cooling Systems (*)
Annex 29:	Daylight in Buildings (*)
Annex 30:	Bringing Simulation to Application (*)
Annex 31:	Energy-Related Environmental Impact of Buildings (*)
Annex 32:	Integral Building Envelope Performance Assessment (*)
Annex 33:	Advanced Local Energy Planning (*)
Annex 34:	Computer-Aided Evaluation of HVAC System Performance (*)
Annex 35:	Design of Energy Efficient Hybrid Ventilation (HYBVENT) (*)
Annex 36:	Retrofitting of Educational Buildings (*)
Annex 37:	Low Exergy Systems for Heating and Cooling of Buildings (LowEx) (*)
Annex 38:	Solar Sustainable Housing (*)
Annex 39:	High Performance Insulation Systems (*)
Annex 40:	Building Commissioning to Improve Energy Performance (*)
Annex 41:	Whole Building Heat, Air and Moisture Response (MOIST-ENG) (*)
Annex 42:	The Simulation of Building-Integrated Fuel Cell and Other Cogeneration Systems (FC+COGEN-SIM) (*)
Annex 43:	Testing and Validation of Building Energy Simulation Tools (*)
Annex 44:	Integrating Environmentally Responsive Elements in Buildings (*)
Annex 45:	Energy Efficient Electric Lighting for Buildings (*)
Annex 46:	Holistic Assessment Tool-kit on Energy Efficient Retrofit Measures for Government Buildings (EnERGo) (*)
Annex 47:	Cost-Effective Commissioning for Existing and Low Energy Buildings (*)
Annex 48:	Heat Pumping and Reversible Air Conditioning (*)
Annex 49:	Low Exergy Systems for High Performance Buildings and Communities (*)
Annex 50:	Prefabricated Systems for Low Energy Renovation of Residential Buildings (*)
Annex 51:	Energy Efficient Communities (*)
Annex 52:	Towards Net Zero Energy Solar Buildings (*)
Annex 53:	Total Energy Use in Buildings: Analysis & Evaluation Methods (*)
Annex 54:	Integration of Micro-Generation & Related Energy Technologies in Buildings (*)
Annex 55:	Reliability of Energy Efficient Building Retrofitting - Probability Assessment of Performance & Cost (RAP-RETRO) (*)
Annex 56:	Cost Effective Energy & CO2 Emissions Optimization in Building Renovation
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Annex 69:	Strategy and Practice of Adaptive Thermal Comfort in Low Energy Buildings
Annex 70:	Energy Epidemiology: Analysis of Real Building Energy Use at Scale

Working Group - Energy Efficiency in Educational Buildings (*)
Working Group - Indicators of Energy Efficiency in Cold Climate Buildings (*)
Working Group - Annex 36 Extension: The Energy Concept Adviser (*)

Contents

Scope of the guideline

These guidelines are targets especially to educators, teachers at different levels of education (primary schools, secondary schools, universities etc.) and to all other specialists involved in this dissemination area. The main aim is to bring the basic information about an importance of consideration of embodied impacts (embodied CO_2 emission and embodied energy) and to provide ideas and basic principles for education at different levels and different types of education process.

This guideline is based on the work and results of IEA EBC ANNEX 57 “Evaluation of Embodied Energy & Embodied GHG Emissions for Building Construction”.

This publication is a part of a series of publication guidelines targeted to specific groups of actors working in education system.

1. BACKGROUND

1.1 Education for Sustainable Development - ESD

Education for Sustainable Development (ESD) is an important keystone in the process of promoting and dissemination the knowledge in the field of Sustainable Development (SD). UN Agenda 21 [1] was the first international document identified that the education as an essential tool for achieving sustainable development and highlighted areas of action for education. The aim of ESD is to engage people in negotiating a sustainable future, making decisions and acting on them. Efforts towards sustainability in any field should be based on communication, learning, and sharing knowledge in order to engage all stakeholders of the process – all people as individuals or as members of communities or organizations.

The United Nations General Assembly declared 2005-2014 the UN Decade of Education for Sustainable Development (DESD). UNESCO (leader of this action) has developed an International Implementation Scheme for the Decade. The goal was to provide an opportunity for refining and promoting the vision and principles of sustainable development – through all forms of education, public awareness and training; and to give an enhanced profile to the important role of education and learning in sustainable development. Education for sustainability is the practice of learning how to achieve global and local sustainable communities through following objectives:

- Facilitate networking linkages, exchange and interaction among stakeholders in ESD,
- Foster increased quality of teaching and learning in ESD.
- Help countries make progress towards and attain the Millennium Development Goals through ESD efforts;
- Provide countries with new opportunities to incorporate ESD into education reform efforts.

1.2 Embodied Impacts in Building Construction

One of the most critical environmental aspects within sustainable development issues is gradually increasing amount of CO_2 emissions resulted from different human activities. Significant portion of this amount is associated with energy use during operation of buildings – *operation energy* and for production of products used for building construction or maintenance – *embodied energy*. The proportional significance of embodied impacts (embodied CO_2 and embodied energy) is increasing with ongoing process of reduction of operation energy in buildings during entire life cycle of buildings. The dissemination of these trends, methods of evaluation and examples of reduction of embodied impacts of buildings in the form appropriate to different levels of students (at primary, secondary or university level) or other interested people is highly important for the future ***change of thinking and living pattern*** of whole society. This necessary change of motivation, thinking and living pattern of people is the principal keystone in the process of sustainable development.

2. HOW TO MOTIVATE FOR ENERGY AND CARBON EFFECTIVE LIFE?

It is highly important to motivate people of all ages to change their living pattern in order to reduce environmental impact from high-energy consumption and high production of CO_2 emissions. This can be done through education; which starting from young ages and provided at different education levels: kindergartens, primary schools, secondary schools or universities.

Older people are rather conservative in introducing new living patterns and new customs. In opposite young generation is more open to learn and understand new knowledge and to start introducing it in everyday life. It is easier to motivate young generation for using new practice especially if they see better quality of their life in the future. Consequently, there is a chance to motivate and influence older generation - parents and grandparents through children to change also their pattern of life by examples and ideas brought by children from their schools.

3. PRINCIPLES OF EDUCATION FOR ENERGY AND CARBON EFFICIENCY

The following skills are essential to ESD according to Tilbury and Wortman [2]:

- *Envisioning* – being able to imagine a better future. The premise is that if we know where we want to go, we will be better able to work out how to get there.
- *Critical thinking and reflection* – learning to question our current belief systems and to recognize the assumptions underlying our knowledge, perspective and opinions. Critical thinking skills help people learn to examine economic, environmental, social and cultural structures in the context of sustainable development.
- *Systemic thinking* – acknowledging complexities and looking for links and synergies when trying to find solutions to problems.
- *Building partnerships* – promoting dialogue and negotiation, learning to work together.
- *Participation in decision-making* – empowering people.

4. EDUCATION ON DIFFERENT EDUCATIONAL LEVELS

The following text describes the education approaches, principles and examples not only concerning embodied carbon and embodied energy, but also general environmental education, as in most cases it can be easily adapted to EC and EE issues. The reason is that not many cases from the practice (examples) were found for some levels of EC and EE education (e.g. pre-school, seconda23ry school levels).

4.1 Education in Schools

"Schools have the highest potential to become an ideals of good practice for their communities and to inspire **positive sustainable behavior**, not just through their teaching but through also their management and their engagement with local communities.

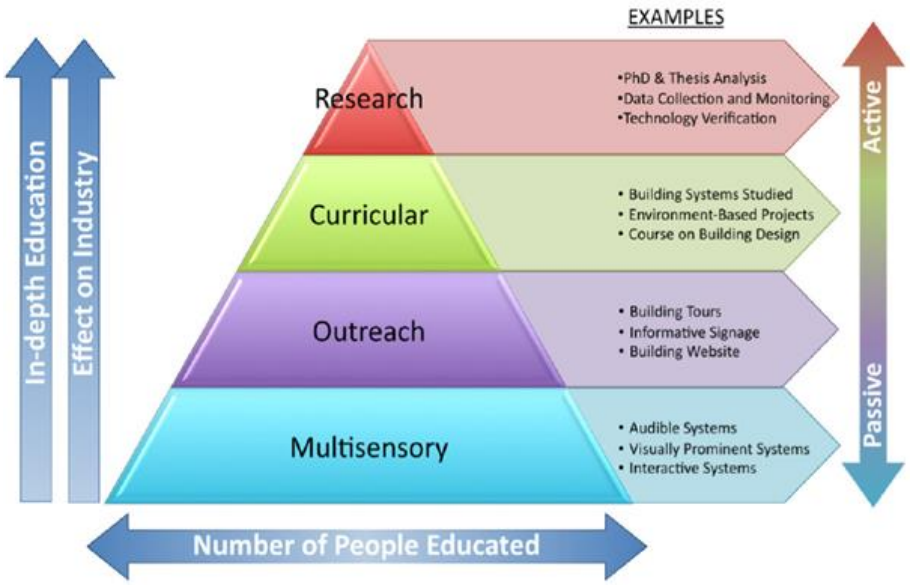
Schools can act as hubs for learning and change towards sustainability in their communities such as the focal point of community-based energy systems or as demonstration centers for recycling. Being seen to lead by example among the wider community is a mean of building confidence in sustainable development, showcasing what can be achieved." [3]

According to [3], the carbon savings coming from behavioral change are calculated to 10%. It also shows the actual trends and their impact on schools procurement emissions, see Table 1.

Trend	Impact on carbon emissions
Increased awareness / take up of sustainable procurement frameworks	Decrease
Health and wellbeing agenda for school food procurement	Decrease
Opportunities to embed sustainability in OPEN e-procurement system	Decrease
Capital projects increasing demand for construction materials	Increase
Lack of information about low carbon options	Increase
Real or perceived cost differential of sustainable products	Increase
Lack of alternative products	Increase
Increased procurement of energy intensive products (eg, ICT and electronic equipment)	Increase

Some of the trends and influences impacting on schools procurement emissions. [3]

Regarding different teaching strategies, the following chart shows qualitative findings representing the beliefs of many of the professionals, according to [4].



Preliminary qualitative analysis of the benefits of different teaching strategies [4]

4.1.1 Roles of the School

When the school should influence the carbon emissions and energy use through its pupils, staff, building etc., it has to implement the reduction plans and issues in the following areas [3]:

- School objectives and development plans

  Direct engagement of the school into the plans leading to carbon and energy reduction is necessary – the school serves as the best example for pupils, parents, staff, community and other stakeholders. The school must commit to taking action to minimize the carbon impact.

- Curriculum

  The need of implementation of carbon and energy issues into curriculum is clearly needed to raise awareness and change behavior of pupils. Schools should see them as a learning opportunity. They can be used in the following manner:

  - Theoretical lessons
    - as individual subjects or
    - as a part of other subjects (environmental topics for writing, reading, listening, drawing etc.)
  - Practical lessons
    - direct engagement of pupils in carbon and energy reduction activities
  - Complex debates of pupils

  Most common strategies include [4]:

  - Environment based projects;
  - Studying of the building's systems;
  - Studying of the building's site;
  - Student maintenance of facilities;
  - Course on building design.

- School staff awareness

Every person working in the school should be educated about the carbon and energy reduction issue, including school leaders, teachers, site staff (technicians etc.), which improves their influence on pupils as well as on operation efficiency of the school.

4.1.2 Education Approaches

Several practical approaches on how to reduce the environmental impacts can be found:

a) Sustainable design

"Sustainability should be a visible part of the educational environment. For instance, this can be achieved through the following:

- integration of living roofs;
- planting within the building;
- low-embodied energy and sustainable timber construction, and the
- use of renewable energy technologies." [5]

Also new school buildings should serve as an example, and the schools should push for zero carbon new buildings.

b) Reduction of impacts from operation

Schools should encourage:

- reducing emissions from energy use in school buildings;
- reducing emissions from school procurement and waste;
- reducing emissions from school travel and transport. [3]

c) School procurement

Procurement of goods and services represents a large proportion of schools' carbon footprint. The impact can be lowered by the help of a "Strategic framework" [3], including

- strategic commitment;
- supply chain engagement;
- specifications of goods and services (available tools that allow to procure low carbon goods and services);
- product choice and labelling (e.g. source local food);
- accreditation of suppliers;
- product market development; etc.

d) Pupils involvement = behavioral change

Pupils and staff are involved in monitoring energy and waste around the school and regularly visit other schools, colleges and community groups to present their environmental work and encourage others to follow their example. [3]

This approach includes:

- practical projects around the school;
- monitoring and reporting (energy, waste);
- setting targets for energy reduction.

The school should serve as a teaching tool [6].

Firstly, several installations should be made, e.g.:

- implementation of walking trails, outdoor exercise/play areas, classroom gardens;
- minimization artificial lighting, install high-efficient fixtures, and utilize natural day-lighting;
- efficient heating, ventilation and air conditioning (HVAC) systems;
- photovoltaic panels;

- water savings is a priority – installation of a cistern for rain and grey water harvesting; installation of low-flow fixtures installed;
- installation CO_2 monitoring system;

Secondly, the school can serve as a teaching tool. Teachers determine lessons they can develop for different aspects of the building and the students are actively part of those ideas, e.g.:

- experiments and projects on air cleanliness, the water systems, bacteria, the insulation, and the UV shaded windows.

e) Inter-school collaboration
f) Involvement of local authority professionals

4.2 Education on Pre-School Level

Main principles:

- Pattern at home – the highest importance is education at home by parents – children imitate their parents;
- Pattern at kindergarten – teachers should
    - lead the children to behave nicely to nature,
    - to understand the importance of it,
    - to understand saving water, saving electrical energy, sorting waste for recycling,
    - involve parents – education of parents through common activities with children.
- Development and application of special toys, puzzles and plays showing potentials of savings;
- Providing special children books explaining principles in the form appropriate to their age;

Example: Forest Kindergarten

(Association of Forest Kindergartens, Czech Republic, but exists worldwide)

Forest Kindergarten philosophy:

- Encourage children to have close relationship with nature, develop knowledge, understanding and skills related not only to nature, which also help children to create their attitude and judgment.
- Move children closer to the natural rhythms and cycles of nature.

- Encourage children to create an responsible attitude towards the environment.
- By being outdoors the physical development and wellbeing is supported. Also the immune system of children is strengthened.

Example: Eco- Kindergarten

(NGO Tereza, Czech Republic, but exists worldwide)

Eco- kindergarten philosophy:

- Emphasis on the development of respect to nature and on environmental sensitivity - frequent stay of children in the nature.

  Three levels of relationship to nature:
  - Adaptation to the environment – I can be in nature, I can move through it and not be afraid of it;
  - Aesthetic level – I perceive nature at an aesthetic level, I see her beauty, originality and uniqueness;
  - Ethic level – I understand that nature should be protected, I want to take care of it responsibly and I have skills that will allow me to do it.

- Involvement of parents and the community in the program.
  - Parents are in close connection with their children
  - Kindergarten is becoming the centre of the community and shows how it is possible to behave nicely to the environmental.

- Involvement of children
  - Through imitation of adults
  - Through democratic elements in education: a partnership approach to children, respectful communication, participation of children in decision-making, support for children to independently seek solutions, think critically, take over the missions and responsibilities.

4.3 Education in Primary and Secondary Schools

Main principles:

- Pattern at home - importance of education at home by parents – this requires the education of parents, ideally by their involvement into common projects;
    - Development and application of special teaching materials: books, booklets, quizzes, questionnaires, exercises, experiments, videos.
- Organization of special seminars, workshops and education sessions
    - for pupils as well as their teachers, focused on water saving, saving electrical energy, sorting waste for recycling etc. (e.g. Schools at University for Climate and Energy – SAUCE [7]; Embodied Carbon footprint of houses; Energy-saving projects; Sustainable school posters creation)
- Involvement of students into actions:
    - Organization of competitions (monitoring, calculations, quizzes, actions etc.)
        - in class among students (e.g. build a model of a house with the lowest EE, EC)
        - between student groups in one school (e.g. travel by bicycle)
        - between schools nationally or internationally (e.g. Carbon detectives [7], Eco-schools, U4energy [8], Zlín CO_2 League [9])
    - Through curriculum change
        - EE, EC issue in standard subjects like Mathematics or Literature
        - special subjects about EE, EC; experiments
        - practical action plans
    - School projects (action plans)
        - give students responsibility over some issue (e.g. monitoring energy, creating eco-codex (Eco-codex); be reporters of the school carbon footprint; Carbon detectives; Energy-saving project based on a system of financial incentives; How to combat climate change in an artistic way etc.)
        - create some real thing (e.g. Green Oasis – together build a garden house from low EE, EC materials; Powerado; Green schools)
        - programs for schools (e.g. Eco-schools [11] – seven step change process, Towards a Schools Carbon Management Plan [3])
- Education materials for pupils and teachers
    - booklets; CDs; posters
    - e.g. Powerado; Was ist gerecht?; Sustainability Innovation in United Kingdom Schools [12]; Eco-schools materials [11]; Carbon detectives materials [8]; U4energy [9]; Environmentally friendly buildings [13].
- Games
    - as a part of school curriculums (e.g. game by Eco-schools)

- online games for free time (e.g. Agent in the service of the Earth [14], Powerado [15])

- Showing good practice
  - Integration of sustainable solutions in the school building;
  - visit other schools or places where the change is visible.

Example: Carbon Detectives

(http://www.carbondetectiveseurope.org)

European wide Carbon Detectives program. Mission of this program is to link schools and pupils across Europe to help slow down the impact of global climate change, and inspire and empower the young people to take practical action to save energy and carbon in school and to enthuse and support teachers to bring carbon saving to life in the classroom.

The Carbon Detectives program provides support and ideas for actions that a school can take to shrink its carbon footprint size. It also provides tools to allow monitoring progress and report of the school savings.

Example: Competitions – Build a House with the Lowest EC (Japan)

Example: Seven Steps to Become Eco-School

(http://www.eco-schools.org/menu/process/seven-steps)

1. "Eco-Schools Committee

   The Eco-Schools Committee is the driving force behind the Eco-Schools process. The committee directs the operations of a school's Eco-Schools program.

2. Environmental Review

   Work begins with a review or assessment of the environmental impact of the school. The results of the Environmental Review will inform the Action Plan; assisting the school to decide whether change is necessary, urgent, or not required at all. It will also help to set realistic targets and measure the success.

3. Action Plan

   The action plan is the core of the Eco-Schools work and should be developed using the results of the environmental review. This information is used to identify priority areas, create an action plan, setting achievable, realistic targets and deadlines to improve environmental performance on specific issues by listing a number of agreed environmental objectives, along with deadlines and clearly allocated responsibilities for each step. Where possible, it should also be linked to the curriculum, show any cost implications, and specify arrangements for monitoring and evaluation.

4. Monitoring and Evaluation

   To find out whether or not the school is successful in achieving the targets laid out in the Action Plan, you must monitor and measure the progress.

   As well as allowing judging the success of activities and planning any necessary changes, a continuous monitoring process will help to make sure that interest in the program is maintained throughout the school.

5. Curriculum Work

   Besides increasing the status of the program, linking Eco-Schools activities to the curriculum ensures that Eco-Schools is truly integrated within the school community.

   The general strategy suggested is that of infusing environmental education concepts into the already existing subjects and not that of presenting a new subject. In addition to increasing an awareness of the environment, the weaving of an environmental education dimension in a particular subject enriches the subject concerned and thus makes it more relevant and interesting.

6. Informing and Involving

   One key aim of the Eco-Schools program is to raise general awareness of your environmental activities - throughout the school and the wider community - and to make sure that as many people as possible get a chance to take part.

   Actions should not just be confined to the school: for example, pupils should take home ideas to put into practice.

7. Eco-Code

   The Eco-Code is a mission statement. It should demonstrate in a clear and imaginative way, the school's commitment to improving its environmental performance. It should be memorable and familiar to everyone in the school.

Seven steps to become an Eco-school (http://www.eco-schools.org/menu/process/seven-step)

The Eco-Code should list the main objectives of the given Action Plan, covering real actions that pupils and staff intend to carry out. It is crucial that pupils play a key role in the development of the eco-Code, as this will give them a greater sense of responsibility towards the values the Eco-Code represents." (http://www.eco-schools.org/menu/process/seven-steps)

4.4 Academic Education

According to academic education survey, and the university programs, if available, are focused on integrated building design and holistic point of view, including the carbon footprint issue. The specific information about some universities program is listed in the Universities survey form.

However, not many action plans and programs were found. One very interesting example is shown below. It focuses on lowering the carbon footprint of the University campus.

Example: Five key action steps critical for reducing your campus carbon footprint

(http://appa.org/files/PDFs/FINAL09APPASustainabilityGuide.pdf)

1. **From a stakeholder group**. Identify key roles and responsibilities.
2. **Complete a greenhouse gas emissions inventory**. Develop baseline measures through facilities and energy audits.
3. **Develop a strategic climate action plan**. Outline mission, goals, and timeframes; brainstorm all possible options; and create a roadmap to carbon neutrality.
4. **Identify resource investments**. Allocate financial, intellectual, and personnel resources to reduce emissions.
5. **Implement a tactical plan**. Identify and carry out specific projects and initiatives, and monitor, report, and validate progress

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