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Ir Dr Andrew K C CHAN

JP

Message from Delegation Advisor
The President of HKIE

I chose "Sustainability" as the theme of the 2009/10 session and presented in my Presidential Address last September my call for engineers to take the lead in building a sustainable future for Hong Kong, resilient to the effects of climate change and resource depletion. The leadership of the Institution's Divisions and Committees signed the protocol "Engineering a Sustainable Hong Kong" to show their support and since then the 'avalanche' of high quality activities surrounding the theme has been nothing short of spectacular in my opinion. We have achieved much but at the same time we need to learn from other parties and successful examples outside Hong Kong.

I have been particularly impressed by the Young Members Committee's (YMC) efforts in putting together the March delegation to Denmark – the country which has so much to offer with their experience in responding to climate change. I have had the good fortune of sharing with the delegation in my office during their preparation for the trip and was literally overwhelmed by the enthusiasm and their thoroughness in their background research.

Our society's action to combat climate change is the responsibility of this generation and of the next. And so it is exciting to see the initiatives being taken by the young engineers, focusing no longer in "why" but in "how". I am sure the young delegation has learned a great deal from the process and the trip, and this Delegation Debriefing Report is not the end of their trip but rather signifies the beginning of a journey by many more young engineers.

My special tribute to Ir Crystal Ho for her leadership and heartiest congratulations to everyone in the team for their success!

Ir Otto L T POON

BBS OBE

Message from Delegation Advisor
The Past President of HKIE

After two centuries of resource and fossil driven economic growth, it is recognized that such an economic model is unsustainable. Among world's many environmental problems, none is more threatening and urgent than climate change.

Scientific communities agree that green house gas in the atmosphere, primarily CO2 from burning of fossil fuels, must be contained to no more than 550ppm from today's 390ppm and the increase in average global temperature to less than 2 degree Centigrade in the coming few decades.

It is therefore truly heartening to note that the Young Members Committee of the Hong Kong Institution of Engineers had chosen climate change as it theme for this year's overseas technical visit. It is also very wise to select Copenhagen as its destination because Denmark stands out among the community of nations for having continuous economic growth with corresponding reduction in energy consumption.

I am honoured and privileged to be invited to join the Delegation which provided me with the chance to learn more about the latest technologies in energy conservation, renewable energy and policies to achieve a low carbon economy.

While I am writing, I must congratulate Ir Crystal and her team for a mission outstandingly accomplished. I greatly enjoyed the company.

Let us hope what we have learnt could be put to good use in Hong Kong and in the Mainland.

Ir Edmund K H LEUNG
SBS OBE JP
Message from Delegation Advisor
The Past President of HKIE

Indeed it is my privilege and honour to have been invited by the Young Members Committee (YMC) to be one of their Delegation Advisors.

For many years I have ardently supported YMC to make overseas technical visits. Delegates will gain a lot, not only in learning about the projects they see, but more importantly, in their exposure to overseas environment and the need to work as a team.

Without exception, I would look at the Denmark delegation this year as another success. This year, YMC has been a little bit ambitious in trying out a country that is far away from Hong Kong, and in many ways, most different. For this reason, their exposure and the experience they gain, will become even more valuable.

I look forward to seeing the report published, and I am sure the delegates would summarize the similarities and differences of Denmark and Hong Kong, and learn from these characteristics. It is the ability to learn from different scenarios that enriches the competence and analytical power of our delegates.

When they present this report, hopefully they will set excellent examples of learning and sharing knowledge. This process will also attract new young members to embark on overseas missions to experience for themselves the impact of overseas exposure.

I take this opportunity to congratulate Ir Crystal Ho and her team members for their success in organizing this Denmark mission, and accomplished their mission in flying colours, despite the various challenges they have come across. I am sure the experience they have gained will be most useful to them for the many years of their professional careers.

As Past Presidents, we should continue to encourage and lend support to YMC. It is the most valuable investment we can make.

Ir K K CHOY
Message from Delegation Advisor
The Vice President of HKIE

I always enjoy gathering with young members because I feel as young as they are every time in our meetings, dinners, happy hours or karaoke. Therefore, I often rearrange my schedule so as to join the YMC functions. This year I am very grateful to be one of their advisors for the YMC Overseas Delegation 2010 to Denmark.

Climate Change is a hot topic nowadays. While the Copenhagen summit has not arrived at any solid agreement in solving the problems, we, professional engineers, have the obligation to combat the climate change issues and should be prepared to help alleviating the global warming phenomenon. It is a good opportunity for our young engineers to visit Denmark, a country famous for climate solutions and environmental protection. There should be plenty of valuable experience to be gained by our delegates in this visit.

I would have high expectation on the delegates for their contribution towards a greener environment in Hong Kong in the coming decades as they will be the backbone of our future society.

I congratulate the YMC overseas delegation, under the leadership of Ir Crystal Ho, for the successful organization and the valuable achievements in the Denmark visit.

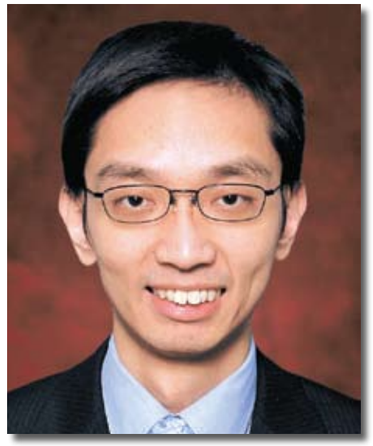
Ir Gary C W KO
Message from Delegation Advisor
The CPDC Chairman of HKIE

To enable members to keep abreast of the latest developments in engineering and establish worldwide link and recognition are two major roles of the Continuing Professional Development Committee (CPDC). I am pleased to note that the Young Members Committee (YMC) is always a self-initiated keen promoter of them. Among the long list of activities organised by the YMC, Overseas Delegation is probably the most comprehensive if not the most memorable one. Determination of themes of study, selection of delegates, solicit of funding, liaison with never met overseas organisations are the few challenges not normally faced by any engineers including the age-privileged senior members.

Climate Change reminds us the role of engineers in the quest to improve living standards of mankind. To strike a balance between development and minimisation of impact to the environment is delicate but yet achievable. All leading activities in relation to and the actual Overseas Delegation provide an opportunity for the delegates to understand more about the scientific, technical and socio-economic issues of Climate Change in a global and regional perspective, and, to witness the mitigation and adaptation measures adopted in a pioneer country. While Denmark may be the Mecca of Climate Change, the sites and organisations visited are not closely located and readily accessed for the convenience of the pilgrimage. The joys and pains gained from the planning, preparation and execution of the Visit will add invaluable experience to the organising members. I trust that this will contribute to the sustainable development of all delegates and the YMC.

I am delighted to learn that the YMC will share this Delegation with all HKIE members through presentations and publications. It is a value for money support exerted by the CPDC and I look forward to sealing the future association between the YMC and CPDC.

Lastly, I would congratulate the YMC especially Ir Crystal Ho and her team to have organised this successful Denmark Visit!



Mr. Leo H Y CHAN
Message from YMC Chairman

I write to congratulate the success of the YMC Denmark Delegation 2010!

Organizing overseas delegation to widen the exposure of young engineers in important engineering topics is a YMC tradition. Carrying on the footsteps of our predecessors, we organized a delegation to Denmark this session with the theme “Climate Change”. Indeed, with extreme weathers occurring more frequently than ever, YMC feels obligated to let our young engineers, who will be engineering leaders of tomorrow, know that for the benefit of our next generation, starting from today, we should pay extra attention on the impact of our work to the environment. This theme also echoes the theme “Sustainability” championed this session by President Ir Dr Andrew Chan. Furthermore, Denmark, being the host country of COP15, is a world leader in terms of its green policies, green technology and green engineering practice. Thus, it was chosen as the destination of this delegation.

This delegation also owes its success to the strong backing of the Continuing Professional Development Committee and the generous support of the sponsoring companies. I would like to take this opportunity to acknowledge them.

Furthermore, I must thank our six Advisors, who are all senior members in the engineering industry, to take time out from their busy schedules to give us their valuable advices. With the publication of this report, I can say responsibly that young engineers have learned and emerged more mature because of your support of this delegation.

Last but not least, my sincere gratitude goes to the sixteen young engineers taking part in this delegation. From liaison for overseas logistics to finding sponsors, from organizing local seminars and visits to writing this delegation report, these sixteen young engineers have done it all by themselves.

Therefore, I invite you to study this report in detail to see for yourself the important messages that our young engineers would like to convey after attending this delegation.

Ir Crystal W C HO
Message from Delegation Manager

Engineer's mission is to improve living standards of mankind. While we enjoy very much the new technologies invented and developed by the engineers, it is no doubt that we are still suffering from the adverse impacts induced by Climate Change such as global warming. What an engineer, particularly for a young engineer, could contribute more to build our sustainable future, and in turn to save our planet?

With the theme "Climate Change", the YMC Overseas Delegation 2010 to Denmark was organized to serve as an inspiration for young engineers to think proactively our role in Climate Change and in the mean time, to equip our future leaders with new experience and global exposure to environmentally practical projects in Denmark. It was also to respond to our President that we, the young engineers are willing to take the challenge and the lead in building the sustainable future.

This Delegation could not be made possible without the generous financial assistance provided by the Continuing Professional Development Committee and sponsored companies. On behalf of the Delegation team, I would like to express our sincere thanks to all of them.

I would also like to express our greatest gratitude towards all receiving organizations for giving us an insight into the green polices, technologies and practices being or will be implemented in Denmark. Special thanks are given to EnergyTour for coordinating for us with the receiving organizations which seldom accept visit request.

It is our great honor to have received supports and advices by the President, Past Presidents, Vice President and many senior members of the Institution. All these supports are greatly appreciated. I would also like to express our particular thanks to Ir Otto Poon who joined us in the first three days of visit squeezing from his very tight schedule, for providing us with advices over the visits through.

Lastly, I must express my million thanks to all delegates, the two deputy managers Ir Mandy Leung and Mr. Ryan Chak especially, for their hard works and great efforts to make the Denmark Delegation a memorable and successful one. It is my honor to have in team with all of you.

What is Climate Change?

When your phone rings, how will you usually answer the call? That probably might vary according to who the caller is – What if the caller's name appeared to be "Climate Change"? Do you have any idea of who she is? Will you pick up the call? If so, how will you answer her call?

Fig. 2.1 Hurricane Katrina approaching the Gulf Coast in 2005

Who is Climate Change?

Climate Change has been defined by different parties under different terms. One of the definition is by the Intergovernmental Panel on Climate Change (IPCC), whom refers Climate Change to any change in climate over time, whether due to natural variability or as a result of human activity [2.1]. Such changes cover a wide range of aspects, from global warming to sea level rising, and from heavy precipitation to frequent tropical cyclones (Fig. 2.1). In fact, Climate Change has already been calling us since centuries ago, but our attentions were only drawn towards her in the recent decades when she started making more frequent and aggressive calls. The recent rapid global warming hastened the melting of glaciers, which not only destroyed the habitat of polar bears (Fig. 2.2) but also further led to the rising of sea water level and caused severe flooding around coastal areas in the world.

Climate Change Impacts

Because of the natural disasters initiated by Climate Change, thousands of lives and millions of habitats have already been destroyed. Take our city Hong Kong as an example, according to the Hong Kong Observatory, a number of weather records were broken in Hong Kong in 2008. Firstly, it had been a year with the longest cold spell in 40 years, which lasted for 24 days from late January to mid-February. Several rainfall records were also broken. The deluges in June 2008 brought 1346.1mm of rain, making it the wettest month since record began in 1884. Temperature-wise, October 2008 with a mean of 26.5 degrees Celsius was the warmest October ever [2.4]. All these are telling us one thing – We are facing progressively worsening weather extremes.

Besides, an analysis conducted by the Hong Kong Polytechnic University pointed out that the mortality would increase in extremely cold and extremely hot days, particularly among the elderly. Moreover, an increase in temperature during summer would facilitate mosquito breeding. The analysis indicated that a 3 degree Celsius rise in mean temperature would increase the epidemic potential of Malaria by 18.7% [2.5].

It is envisaged that the worse is yet to come - unless we have promptly answered the call from Climate Change. So what shall be the next step by our generation to ensure a sustainable future of the world? And is there anything in particular that we as engineers can contribute to?

Fig. 2.2 Helpless polar bears clinging on the melted iceberg

Role of Engineers in Climate Change

Many people believe that the hastened climate change in the past decades, particularly on global warming, is majorly caused by human activities. This is where engineers fit in as the key people in tackling the current climate change challenge:

- Insight to the future – making bold assumptions and accurate predictions of the future world scenario;
- Efficient problem solving – making right decisions at the right time in the right place;
- Creativity and innovation – introducing new ideas and advanced technologies for minimizing the negative impact of human activities.

As the vision of nowadays engineers no longer just focusing on a deliverable design and construction, but also extended towards a sustainable development for the sake of our future generations, there is no doubt that engineers will boldly take up the responsibility in answering the call from Climate Change for the benefit of the human nation and world village.

Fig. 2.3 Ir Otto Poon and sixteen young engineers going to Denmark for solutions to Climate Change

Fig. 2.4 Delegates at DONGEnergy Avedøre Power Station

Purpose of Delegation

The Young Members Committee (YMC) of the Hong Kong Institution of Engineers (HKIE) has been organizing various overseas and mainland delegations since 1991 aiming at widening the vision and horizon of young engineers. These delegations also enhanced the relationship between HKIE and the Overseas / Mainland Institutions and promoted both Hong Kong and engineering profession.

In 2008, the YMC Overseas Delegation to Australia on Sustainable Development greatly aroused young members' interest and enhanced their knowledge on sustainable development. In 2009, the YMC Overseas Delegation to Dubai on Engineering Miracles provided our young engineers with an opportunity to visit the world famous engineering wonders, in the meantime, to arouse their innovative thinking.

This year, in response to Climate Change, YMC has set her as the theme for the YMC Overseas Delegation 2010 and Denmark had been selected as the target country. (More information about Denmark is presented in Section 3.1 of this Report). The YMC Overseas Delegation 2010 to Denmark has the following objectives:

- To acquire new experience and global exposure to environmentally practical projects in Denmark, with particular focus on investigating the state policies towards environment and economics
- To learn from Denmark of her pioneering incentives to tackle climate change and to appreciate its efforts
- To inspire young engineers to think proactively about how engineers can contribute to providing solutions to climate change
- To encourage young engineers to extend their network and increase the horizon
- To arouse the attention of HKIE members to the importance of climate change. This will be achieved through the delegation visits and pre-/post-trip local seminars and visits series
- To promote the professional image of HKIE and Hong Kong engineers

To achieve these, the YMC Overseas Delegation 2010 to Denmark comprised the following key elements:

- Organizing an 8-day delegation to Denmark from 21 to 28 March 2010. Programme included meetings with engineering professional bodies and visits to green technology and renewable energy demonstration site
- Organizing a series of local seminars and visits related to climate change
- Publishing a report and organizing a presentation sharing the findings from the delegation and drawing an analogy with the Hong Kong practices. The report will be distributed to the visiting organizations and companies overseas and major engineering organizations and companies in Hong Kong

Areas of Our Study

Although engineers play an important role in tackling climate change, our sustainable future could not be achieved without participation of all individuals. A set of previsional policy which helps driving the solutions to climate change is of particular importance. To comprehensively find out the solutions to climate change, the Delegation was divided into three areas of study. They were:

- Danish green policies
- Engineering technologies
- Engineering in practice

Composition of Delegates

Similar to previous YMC overseas delegations, overwhelming responses had been received during the recruitment of delegates and it was not an easy task for the YMC advisors to pick 16 delegates out of a group of over 40 elite young engineers. The 16 selected delegates came from a wide range of engineering disciplines, including building services, civil, electrical, electronics, environmental, geotechnical, information technology and mechanical. They also represented different sectors of the engineering profession, including government departments, public sectors and consultants.

Fig. 2.5 Delegates at the Low Energy Building

Fig. 2.6 Group Photo at Technical University of Denmark (Riso National Laboratory for Sustainable Energy)

The Report

This report documents the findings and the events that were held locally and in Denmark. It also provides an insight into Hong Kong's response to Climate Change after visiting Denmark, the country with pioneering incentives and acts to tackle climate change.

References:

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[2.3] http://www.metro.co.uk/news/815719-polar-bears-cling-to-iceberg-as-climate-change-ruins-their-day

[2.4] http://www.hko.gov.hk/climate_change/climate_change_e.htm

[2.5] http://www.epd.gov.hk/epd/english/environmentinhk/air/studyrpts/files/Climate_Change_Report_final.pdf

3.1 Why Denmark?

Denmark is the pioneer towards tackling climate change. Through persistent and active energy policy focusing on enhanced energy efficiency, Denmark has been able to sustain the high economic growth while at the same time reduce fossil fuel dependency and protecting the environment.

In terms of production, including CO2 emissions which are regarded as one of the greenhouse gases, Denmark is one of the most efficient users of energy. Despite relatively low energy consumption, Denmark is among the best in the European Union at continuously reducing its energy dependency and CO2 emissions. From 1990 to 2007, economic activity in Denmark increased by more than 45%, while CO2 emissions were reduced by more than 13% [3.1].

The composition of energy consumption in Denmark has changed significantly as a consequence of energy policy measures to promote the use of renewable energy. Renewable energy in Denmark makes up more than 19% of final energy consumption [3.1]. That is why, even with almost no hydropower resources and the lack of a long tradition of utilizing biomass, Denmark has still managed to be among the leading countries in renewable energy.

Fig. 3.1 The offshore wind farm of Denmark

Moreover, Denmark has carried out a number of initiatives to increase the efficiency of end-user consumption, that is, consumption by consumers and enterprises. Such initiatives include the establishment of high energy standards for buildings and energy labeling schemes for electrical appliances, public campaigns to promote energy savings in households, energy saving agreements with industry, and the implementation of taxes on energy consumption. Environmental and energy taxes in Denmark are the contributing factors in making the price of consuming energy better reflecting the environmental costs of production, use and disposal.

The persistent political and commercial focus on energy efficiency, along with the introduction of new technologies, have demonstrated the effort by Danish enterprises throughout the past years in developing and gaining valuable experiences from new technology solutions, which have been further converted into increased exports. Today, Denmark is a leading player in wind turbine production which has covered about one-third of the global wind turbine market.

With the theme "Climate Change", Denmark is undoubtedly the best country for the YMC Overseas Delegation 2010.

Background of Denmark

Denmark is located in Northern Europe between the North Sea and the Baltic. Denmark also includes the Faroe Islands and Greenland in the North Atlantic. The bulk of Denmark is the peninsula Jutland, which juts up from the European continent and has a border with Germany. The rest of the country consists of 406 islands, 78 of which are habitable. Denmark has a total coast line of 7,314km, corresponding to a sixth of the globe's circumference. The average wind force across the year is 7.6m/s, which helps explain why Denmark is the world's largest exporter of wind turbines.

Denmark has a population of abut 5.5 million (2010). Excluding the Faroe Islands and Greenland, the area of Denmark is 43,098km2

which gives a population density of about 128ppl/km2. The gross domestic product per capita was 57,260 DKK (about HK$ 85,900) in 2008, which places Denmark the top fifth of the EU countries [3.2].

3.2 Observations and Learnings

In order to have a thorough understanding of Danish effort in climate solutions, this Delegation had been divided into three areas of study including Danish green policies, engineering technologies and engineering in practice. The itinerary of the Delegation was prepared accordingly to cohere with these areas. Fourteen visits were made to the engineering professional bodies as well as green technology and renewable energy demonstration sites. This section summarizes the observations and learnings from the Denmark Delegation and the itinerary of the Delegation is presented in the following table:

Monday Mar 22	AM	Danish Energy Agency
	PM	Green LightHouse (University of Copenhagen)
	PM	COWI A/S
Tuesday Mar 23	AM	Amagerforbrænding Waste Incineration Plant
	PM	Danish Society of Engineers
Wednesday Mar 24	AM	DONGEnergy Avedøre Power Station
	PM	Confederation of Danish Industries
	PM	Technical University of Denmark (Department of Environmental Engineering)
Thursday Mar 25	AM	Solar City Copenhagen
	AM	Low Energy Buildings in Municipality of Copenhagen
	PM	Technical University of Denmark (Risø National Laboratory for Sustainable Energy)
Friday Mar 26	AM	District Cooling Development Project - "Kongens Nytorv"
	AM	Green Roofs in Copenhagen
	PM	CleanCharge Solutions

Note:

- Danish Green Policies
- Engineering Technologies
- Engineering in Practice
- Engineering Knowledge Exchange

Fig. 3.2 Discussion with Mr. Anders Hasselager and Mr. Jan Bünger

3.2.1 Danish Green Policies

From Energy Crisis to Green Policies

Denmark is a renowned pioneer in energy and climate industries. Tracking back the origins, what made it successful was the well-defined national vision since the energy crisis in 1970s. It was time when there were general beliefs that the most widely-used fossil fuel, oil, would run out shortly. This aroused the awareness of the Danish Government over the reliance of imported fossil fuels, and, on top of it, the energy efficiency and possible pollution. Since then, the Danish Government took steps to develop Climate and Energy Policies, which targeted to convert Denmark into a fossil free society. These measures were later refined to align with the call of climate change.

In this Delegation, three policy-related parties were visited. They were the Danish Energy Agency, the Danish Society of Engineers and the Confederation of Danish Industries. These visits helped delegates to better understand how climate-related measures in Denmark were taken all the way through the Government, the Engineering societies and the Industries.

Danish Energy Agency

The Danish Energy Agency was established in 1976. It is under the Ministry of Climate and Energy as its executive arm to look after the whole chain of tasks linked to the production, transportation and utilization of energy, together with their impact on the climate. Its major task is to ensure the legal and

Fig. 3.3 Presentation by delegates

political framework for reliable, affordable and clean supply of energy in Denmark.

During the visit, Mr. Anders Hasselager, Senior Policy Advisor, and Mr. Jan Bünger, Programme Manager of Energy Technology Development and Demonstration Programme (EUDP) shared with the delegates on three topics: "Energy Policies in Denmark", "Development and Promotion of Green Energy Technologies" and "Bioenergy in Denmark". In this informative sharing, highlights of the Danish energy policies and the latest developments in energy technologies were discussed.

It was known that the energy policies in Denmark are visionary in both the national and international horizon. In terms of national measures, the Danish Government led its way through proper energy planning, prudent exploration and development of oil and gas, promotion of energy saving measures, and also investment in research and development programs. On the international scope, the Danish Government, together with other Nordic countries, formed a comprehensive Nordic energy system which made the best use of natural resources through energy trading activities. With wind energy in Denmark, hydropower in Norway and nuclear power in Sweden, more effective use of renewable energy could be achieved through proper composing of various electricity production and consumption profiles of each country. On top of these, Denmark also positioned itself as the center of excellence in exporting climate and energy solutions, which promoted the utilization of greener energy and more efficient technologies, mainly through its successful example in delinking economic growth with increase in energy intensity.

Highlights of Danish green policy are presented as follows:

Promotion of New Initiatives – Tax and Price Control

Green policies should not be merely pressing task in terms of environmental and health protection. It is important to have measurable benefits coming along with the policies. However, in reality, it is a common phenomenon that even though citizens can realize the importance of combating against climate change, they do not intend to shift their ways of living to a climate-friendly one. For the case of Denmark, the same was encountered.

To roll out new initiatives in tackling climate change, Denmark being a capitalist country, used to alter the selling price or material cost to change the market trend and customer's behavior, mainly by imposing taxes or price control on specific products. For example, the Sulphur tax, Carbon Dioxide tax and Energy tax imposed on fossil fuels. On the other hand, in order to further encourage the use of sustainable energy source, the Danish government imposes certain tax reduction respectively. This brings in comparative advantages to the originally much expensive sustainable source of biomass fuels, and the not-shown wind energy, which helps to promote the use of sustainable energy.

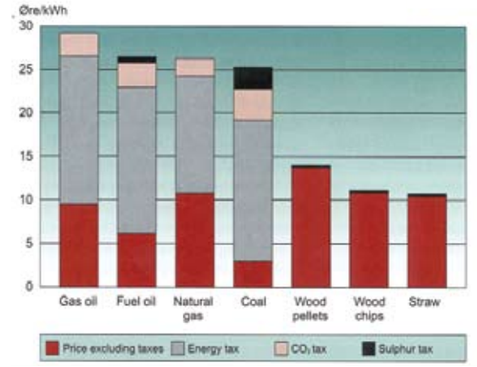

Fig. 3.4 Danish taxes on different type of energy source

Another effect of these taxes is to put forth innovation of existing power plants to either reduce pollutants or enhance energy efficiency of fuel used.

As mentioned, taxes are also imposed to the material cost to change the customer's behavior. One of the examples was the recycling of glass and plastic bottles. Details of the recycling mechanisms are presented in Section 3.2 "Participation by Citizens".

Bridging the Valley of Death – Research and Development Programmes and Subsidy Schemes

When it comes to the new initiatives in tackling climate change, advanced technology is usually under the spotlight. There are general beliefs that technological researches and developments are not adequate to overturn our current situation. Nevertheless, the truth is that most advanced technologies have been proven practical; instead, it is the business model that required further justification. Usually, processes bringing researches from scratches to the market involved high cost and high risk, and is thus known as the "Valley of Death".

In Denmark, there is an Energy Technology Development and Demonstration Programme (EUDP) which provides supports to the private sectors and shares their risks in bridging the "Valley of Death". The main idea of the programme is to form a public-private partnership to prepare for full-scale demonstration of prioritized researches or technologies. This approach of "showing-how" instead of just "knowing-how", helps to demonstrate the readiness of a project for the market. It also arouses business interests and promotes the latest feasible technologies. In the meantime, the collaboration of private and public sectors could lower the economic risk, mainly by business consideration from the private sector and the funds provided by the public sector. From 2007 to 2009, 1 billion DKK (about HK$1.5 billion) had been awarded for 150 projects through EUDP. This amount will be doubled in 2010. Under the EUDP, successful projects which are adopted by the market include wind power, fuel cells, hydrogen and liquid bio-fuels. Currently, new initiatives of low & zero energy buildings and intelligent energy systems are being rolled out.

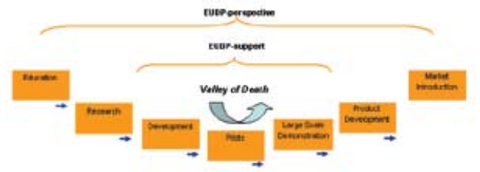

Fig. 3.5 Bridging the "Valley of Death"

Fig. 3.6 A decentralized CHP of Denmark

Centralizing Systems to Enhance Efficiency – Combined Heat and Power Production

Scandinavian countries are famous for their high energy efficiency. One clue of it is the application of Combined Heat and Power Production (CHP).

Due to prolonged cold weather, demand of heating installations in Denmark is very high. Before utilization of CHP and district heating system, over 30% of electricity generated was used for heating. Linking together the production of heat and electricity, CHP was introduced to cater for the huge demand in heating. CHP means the simultaneous production of heat and electricity in a single plant, which involves modification of power plant to make use of waste heat for district heating. This can reduce fuel wastage and greatly enhance energy efficiency to about 85 – 90%, comparing to only around 50% for either heat or power production.

In Denmark, to better utilize CHP and district heating network, hierarchy of CHP system has been built up. This hierarchy introduced decentralized CHP Plants on top of the original centralized CHP plants throughout the country, which together form an efficient network of fuel and energy transportation. Currently, as much as 1.5 million domestic heating installations are connected to the district heating system.

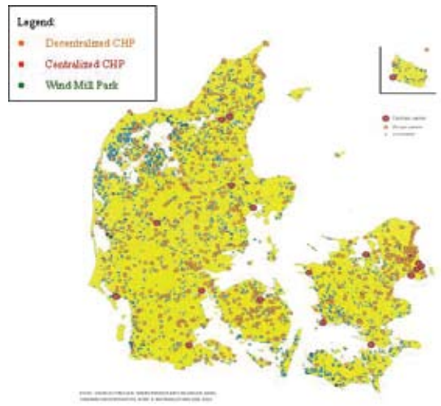

Fig. 3.7 The concept of CHP hierarchy in Denmark

Utilization of Natural Resources – Wind Energy

Each country has its own natural resources and the self perpetuating resources usually hint solutions for sustainable energy. In Denmark, the solution is wind.

There are a total of 5,200 wind turbines in Denmark, with a total of 3,300MW installed capacity. At normal wind conditions, the turbines generate 24% of the electricity demand, while it is usual that more than expected energy would be generated. Since it is not easy to store electricity, the excess wind power will be sold to the nearby European countries where the wind power girds are connected to. These lead to the current challenges in Denmark to have a constant supply of wind energy for better energy planning, and also to feed wind energy into the general power grid instead of selling them to other countries when they are in excess.

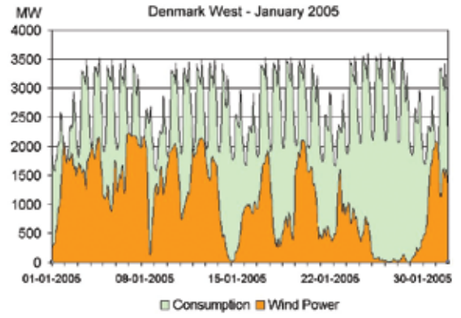

Fig. 3.8 Consumption of Energy and Wind Power (2005) of Denmark

Danish energy policies play an important role in promoting the utilization of wind energy. On top of the tax and price control measures mentioned before, a fast-tracked projects cycle has been allowed. Fig. 3.9 shows an example of 400MW wind farm near Anholt. In this Design and Build contract, a close-working partnering relationship was achieved between the private and public sectors. The main advantage was that the administrative procedures were in parallel with the project, which speeded up the whole programme, e.g. construction permit was issued before design engineering stage which allowed construction to be in parallel with the design process. Through this practice, Denmark could respond to the needs of wind farm in a rather quick way.

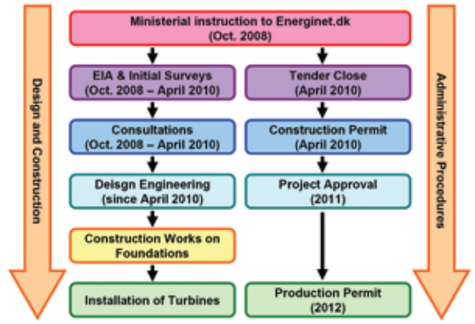

Fig. 3.9 An example of 400MW wind farm near Anholt

Fig. 3.10 Straws for energy production.

Encouraging Development of Renewable Energy – Biomass "The Sleeping Giant"

Following wind energy, Denmark in response to the EU 20-in-20 target, put forth the extensive utilization of bioenegry as the next sustainable source of energy. Bioenergy is the energy produced from biomass like wheat straws, wood pallets or waste, which are usually agricultural by-products. With regard to the high potential of bioenergy, it has been named "The Sleeping Giant".

The first step of adopting biomass in CHP plant is completed. What come next would be further researched but it could not proceed without developments of different kind of biomass and the utilization of it. In the near future, energy planting might be a new terminology for the globe.

Fig. 3.11 Wood pallets for energy production.

Encouraging Energy Saving for Building

Being one of the major energy consumers in Denmark, around 30% – 40% of total energy are consumed by heating, ventilation and lighting of buildings. As such, a series of regulation has been set up by the Danish Government to enhance building energy efficiency.

Fig. 3.12 Souvenir presentation to Mr. Anders Hasselager and Mr. Jan Bünger

One highlight is the introduction of low energy classes to the Danish Building Regulation in 2005. In this policy, two low energy classes for buildings were introduced to further tighten the requirements for building energy use. These two low energy classes, served as a clear target for progressive development of low energy buildings in Demark, corresponded to 50% and 75% of the previous minimum requirements set for total building energy consumption.

The steps forward would be further tightened in Building Regulations. The target is 25% - 30% further reduction in 2010 and a shift of minimum requirements to the current lowest energy class in 2015.

Fig. 3.13 Group photo at balcony of Danish Energy Agency

Danish Society of Engineers

The Danish Society of Engineers (IDA) is a professional body and trade union for technical and scientific professionals. IDA has around 77,500 members who are from all engineering disciplines and other professional background in science, and represents the interests of employees, managers and the self-employed within the fields of pay and employment, the labour market, industrial policy, skills, careers and training, the working environment, technology and research.

Fig. 3.14 Presentation by Mr. Bjarke Fonnesbech

In response to climate change, IDA took an initiative to produce energy plan for Denmark and worked with other worldwide engineering associations to produce the regional climate plan which provided suggestions to the Danish Government and European Union on the climate and energy policy.

In the visit, Mr. Bjarke Fonnesbech, the Policy Director of IDA, introduced one of the distinguish projects, the Future Climate – Engineering Solutions. It is a consolidation of national action plans for the reduction of greenhouse gas emissions developed by project partners, which consist of 13 engineering associations around the world. Participating associations develop their own national climate action plans which give a technical evaluation of the national possibilities for reducing climate gas emissions to a level matching Intergovernmental Panel on Climate Change (IPCC)'s the best case scenario, i.e. a less than 2˚C rise in global temperature. Mr. Fonnesbech then further elaborated the IDA Climate Plan 2050, in

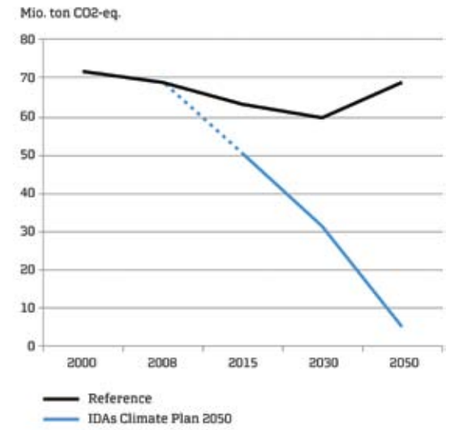

Fig. 3.15 Denmark's greenhouse gas emissions – The Danish Energy Agency's reference and The IDA Climate Plan 2050 [3.4]

which ambitious goals are suggested:

- To reduce greenhouse gas emissions by 90% by 2050.
- To maintain Denmark's energy self-sufficiency.
- To develop Denmark's commercial position in the climate and energy field.
- To develop the Danish economy and affluence.

The IDA Climate Plan 2050 described the opportunities and challenges by reducing greenhouse gas emission, targets and arguments for them, and the concrete measures that are essential to realize the plan in six of the major sectors: energy systems and energy production, agriculture, trade and industry, construction, transport and climate adaptation. The Climate Plan showed that it is technologically and economically possible to reduce greenhouse gases by 90% through

Fig. 3.16 Group photo at IDA with Mr. Bjarke Fonnesbech and Ms. Lisbeth Andersen.

implementation of the recommendations suggested in the plan.

Fig. 3.17 Presentation by Mr. Jen Holst-Nielsen at DI office

Confederation of Danish Industries

The Confederation of Danish Industry (DI) is a premier lobbying organization for Danish business on national and international issues, funded entirely by 11,000 companies in the manufacturing, trade, and service sectors. There are 8 multi-trade communities in DI, namely

- Danish Service Industries Federation
- Danish ICT and Electronics Federation
- Danish Building Materials Federation
- Danish Energy Industries Federation
- Danish Food and Drink Federation
- Danish Transport Federation
- Federation of Danish Knowledge Advisors
- Danish Commercial Industries Federation

Aiming to provide the best possible working conditions for the Danish industry, DI is a strong common voice for industry with a strong role in society as well as a strong international strategy. DI handles matters within labor force, tax, climate and integration. Categories of DI's activities are as follows:

- Policy advocacy - at local, national, and international level
- Membership services - information, advisory services, and consulting
- Network relations - between members and with society at large

DI advocates public-private partnership to ensure service quality, competitive and sustainable public service markets. DI also advises the Danish Government on the practicality of climate policy in the industries.

Working with climate at national and international level, DI works on issues related to European climate policy and issues in the international climate negotiations in the United Nations Framework Convention on Climate Change (UNFCCC) through their European business organization BUSINESSEUROPE. Moreover, DI has set up an internal Climate Policy Plan for the DI members to engage with at local, national, and international level. The DI Climate Policy Plan focuses on five themes. They are:

- Global climate agreement is essential
- Global price on CO2 to secure a level playing field
- Market based systems
- Low carbon technologies must be deployed intelligently, and
- Research and development of new technologies

In the meeting, Mr. Jen Holst-Nielsen, the Senior Adviser, introduced the role of DI as well as contributions by the Danish industries sector in relation to climate solutions. To strike a balance between prosperity and sustainability, the confederation advocates minimizing "Emissions per GDP" by developing, commercializing and disseminating energy efficient and renewable energy technology among its member companies, which echoes the national policy of delinking its economic growth from energy intensity. They called this collaborative effort cross the industry "Thinking Bright Green".

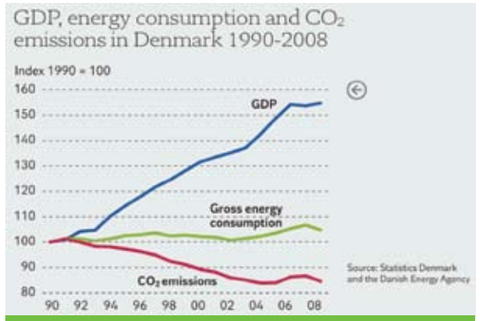

Fig. 3.18 GDP, energy consumption and CO2 emissions in Denmark 1990 – 2008.

Over the last two decades, Denmark has taken a great leap towards a Bright Green Nation with GDP growth, CO2 reductions and stable energy consumption.

Fig. 3.19 Ir Crystal Ho, Delegation manager presenting souvenir to Mr. Jens Holst-Nielsen.

EnergyTours and EnergyMap

EnergyTours and Energy Map are the primary projects under the Climate Consortium Demark which is a public-private partnership between the Danish Government and five major Danish business organizations set up in June 2008 to prepare for Denmark's hosting of the UN Climate Conference, COP 15.

The purpose of Climate Consortium Denmark is to increase awareness of Danish climate solutions and technologies offered by the Danish businesses, industries and universities and to spread this message internationally. The long-term objective of Climate Consortium Denmark is to assist in increasing Danish clean technology exports in order to attract investment, labour, scientists and foreign students to Denmark.

EnergyMap is a web based guide showcasing

Fig. 3.20 Souvenir presentation to Ms. Anette Braender of EnergyTours

Danish clean technology suppliers and solutions. It presents climate and energy technologies from inception as research and development projects, through demonstration to mature solutions and implemented cases that contribute to mitigating climate change.

While EnergyMap provides information about the latest energy and climate technologies, projects, solutions, cases and events, which aims at facilitating international collaboration through export, joint research and development and investment opportunities [3.6], EnergyTours helps to plan trips for companies, scientists, investors, professional and politicians to points of interest presented at EnergyMap [3.7].

Fig. 3.21 Energy Map

EnergyTours represents the players in the Danish energy and climate solution sectors. They help organizing meetings with decision makers and leaders in different climate solutions and technologies of requested areas of interest.

With the help of EnergyTours, delegates had the opportunity to meet with those leaders and to share with them both the contributions by and challenges in Hong Kong. Delegates deeply respected the determination and dedication by the Danish Government in promoting her vision and competencies in climate solutions and support to the climate businesses.

Summary of Danish Green Policies

Denmark has committed an ambitious and binding target for reducing its greenhouse

gas emission by 20% relative to 2005 by the year 2020. Practical and effective policy has been set up and implemented by the Danish Government for meeting the targets. The Danish energy policy has three focus points: security of supply, climate impact and cost effectiveness. Danish Government has a vision to make her society independent of fossil fuels. Some of the highlights of Danish climate policies include:

- Imposing high energy tax and CO2 tax on fossil fuel while having very low tax on renewable fuel such as wood pallets and straw.
- Promoting and setting up combined heat and power (CHP) plant which reduces fuel consumption by up to 30% and increases net efficiency of fuel from 40% to maximum 90%.
- Increasing the share of wind energy in electricity production by being the facilitator and interconnector of the tendering process of wind farm projects.
- Increasing the share of other renewable energy (e.g. biofuel) and natural gas in electricity production.
- Supporting the set up of pilot plants and full-scale demonstration plants for research and development projects to help them breaking through the gap between research and market.
- Setting up further building regulations to ensure achievement of building energy efficiency during the construction of new buildings and renovation of existing buildings.

Not only government sector such as Danish Energy Agency is putting a lot of effort in developing climate-related policy, the non-government organizations are also playing a significant role in both supporting and assisting the formulation of these policies. Danish Society of Engineers (IDA) as a professional organization, took the initiative to research and analyze the potential for climate technology in Denmark and has made a lot of technical and practical suggestions for different sectors on Danish climate policy in its Climate Plan 2050.

On the other hand, the Confederation of Danish Industries (DI) which represents most of the major business in Denmark, encourage its member companies to involve in the climate-related businesses. The DI also acts as a bridge for the member companies to showcase the climate-friendly technology developed and commercialized by them to the international market by the project Bright Green for attracting global business opportunities. This indirectly encourages the energy technology business in Denmark by making it more economically feasible and profitable.

Due to the tight schedule of the delegation, delegates were not able to visit all policy-related organizations of different policy aspect. Nevertheless, it is learnt that Denmark has put great effort in implementing different policies in relation to combating against climate change such as transportation planning for better cycling track network and increasing recycling of plastic waste. Observations on these two topics are presented in Section 3.4 of this report as “Participation by Danish Citizens”.

3.2.2 Engineering Technologies

Advancement of technologies often helps the world to flip towards a new page of life, and that is why Denmark has put a lot of effort in encouraging innovative and sophisticated engineering technologies to tackling climate change. The findings by the Delegation on the latest inspiring technologies by Denmark in response to climate change are presented in this section.

Fig. 3.22 Delegate learning the operation of an EV charger

CleanCharge Solutions A/S

Transport electrification could be an important step for renewable energy development in countries that heavily rely on wind, owning to its potential to store and overturn the barriers of non-guaranteed and non-controllable wind supply. Car batteries can be recharged when there is spare wind energy power available during non-peak hours and in turn, the stored energy could then be delivered into the power network during peak hours. Thus the electric car fleet with batteries could ideally serve as a distributed storing system, similar to reversible station but in large scale that involve thousands or millions of vehicles. This bi-directional wind supply and electric vehicle charging integration creates the conditions that help overturn many of the power network management difficulty from wind generation. In addition, Denmark is also an ideal place for Electric Vehicles (EV), featured by its fuel prices and short driving distances, the use of EV makes a viable alternative to conventional petrol vehicle, bringing the benefit of reduced roadside emissions and increasing the overall efficiency of transport.

Fig. 3.23 A key to open the EV charger

Denmark currently draws 20% of its domestic electricity consumption from wind sources [3.8], and is an exporter of electricity sourced from wind. Wind energy on its own could in principle provide all electricity needed for the vehicular fleet. In near future, it has the potential to see development of reversible electric network, i.e. energy flow from network to vehicle during off-peak hours (Fig. 3.24) and from vehicle to network during peak hours (Fig. 3.25), using car batteries to store electricity produced by strong wind at night and during low demand hours and sell it to the network at favourable price during peak hours. This reversible electric network would drive the demand for a comprehensive EV charging infrastructure, which was well explained by CleanCharge, a Danish developer of EV charging station.

Fig. 3.24 Energy flow during off-peak charging hours

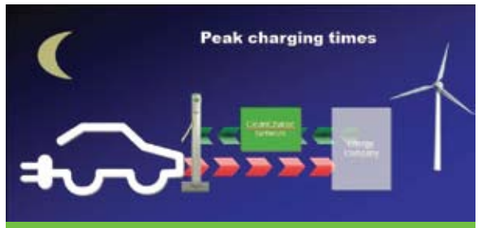

Fig. 3.25 Energy flow during peak charging hours

CleanCharge is the roll-out partner of Elektromotive [3.9] which joined hand to carry out the installation, and to lead the ongoing promotion of the Elektrobay recharging technology to legislators and businesses in Denmark. In the visit to CleanCharge, Mr. Nils Dullum, CEO of CleanCharge explained the development of charging facilities would

Fig. 3.26 Sharing discussion with Mr. Nils Dullum

bring 4 main objectives:

- Improving operational performance of power network, by smoothening out the peaks and valleys in demand to improve of efficiency of power gird
- Improving productivity and efficiency – by continual development of charging technology
- Reducing source consumption – by overturning the limitation by wind generation, thus reducing reliance on fossil fuel
- Reducing pollution and CO2 emission – Electrification is cleanest way of transportation

There will be need for further driving realization of this reversible network where price signal to customer plays an important role in it. In addition to education, build-in technology of charging station which captures customer behaviour profile with add-in price incentive could be the next phase of development. Further enhancement in charging technology to shorten or allow more flexible charging time could be another direction of advancement.

Fig. 3.27 Group photo at CleanCharge Solutions A/S office

District Cooling Development Project - "Kongens Nytorv"

Kongens Nytory is a district heated area in inner Copenhagen and is also the first area being upgraded for district cooling system (DCS) under planning by Københavns Energi (KE) (Copenhagen Energy Ltd.). In the visit to "Konges Nytory project", Mr. Jan Don Hogh, the Senior Project Manager, introduced why district cooling is being taken place in Copenhagen. It includes:

- Big scale central units are more efficient
- Cooling demand increase constantly (40%-50% of cooling demand for computer server cooling)
- Less tolerance for noise
- Advantages over traditional electricity-driven air condition system, e.g. energy saving and reduction in CO2 emission

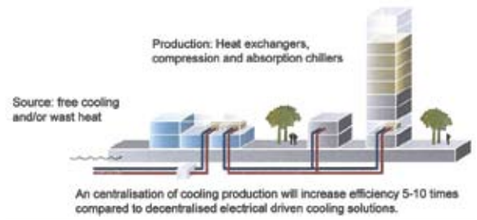

Fig. 3.28 The concept of the centralized DCS

Because of the advantage to the environment, people in Copenhagen are very keen for DCS. According to Mr. Hogh, eight potential areas in Copenhagen had been identified for district cooling with a total demand of minimum 150MW. By using this "free cooling–sea water" concept, comparing with the conventional solutions, it would help saving energy consumption of 60GW per year (-80%) and reducing CO2 emission by 25,000 tons per year (-65%).

The cooling system included production and distribution of district cooling based on an integrated production of cooling from existing cooling water generated from

Fig. 3.29 Mr. Hogh introducing the potential areas in Copenhagen requiring district cooling system

electricity production or low-temperature water retrieved from the sea or ground water. Depending on the seawater temperature, the cooling system would be operated in either free cooling, chiller cooling mode or a combined operation. The annual cooling demand of the design district cooling system was estimated to be 21,600MW with a design life time of 25 years. Cooling water was designed to reach customer sub-station at 6˚C and the return temperature from customer sub-station would be in the range of 13 – 16˚C.

Fig. 3.30 Mr. Hogh introducing the operation of the cooling system

KE paid much attention on the energy efficiency of the district cooling system. In this district cooling system, the use of primary energy source was a key issue and had been measured by the Primary Resource Factors (PRF) when comparing with different cooling options. The PRF for a specific cooling system is defined as the ratio between net fossil energy consumption and cooling energy delivered to the building. As shown in Fig. 3.31, the design PRF value for the Kongens Nytory was at 0.3, which was a lower value than the conventional decentralized compressor units (PRF = 1.0). Comparing with the conventional cooling systems, district cooling allows the use of less primary energy and at the same extent,

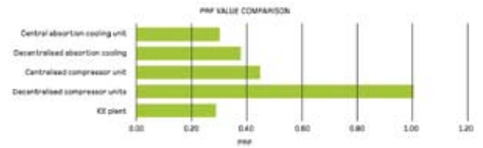

Fig. 3.31 PRF values for different cooling systems [3.11]

Fig. 3.32 Delegates in the district cooling system plant

less CO2 emissions. The lower PRF value for district cooling system in a KE plant, the lower the CO2 emission is anticipated. The relation between PRF and CO2 emission of cooling different systems are shown in Fig. 3.33.

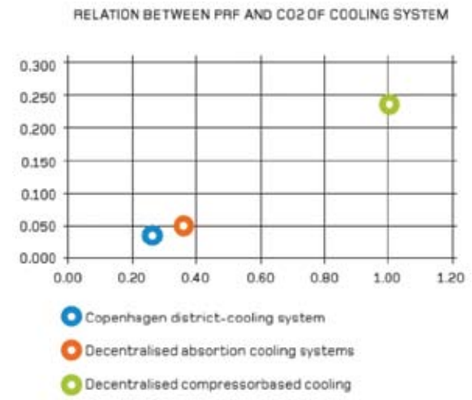

Fig. 3.33 CO2 emission versus PRF [3.11]

Fig. 3.34 Group photo at Kongens Nytory district cooling system project

Mr. Hogh stated that in the planning and design of a DCS, a lot of issues needed to be

considerated and addressed, which included the pipe laying works, traffic diversion and environmental impacts. However, in the long run, customers should be ready to accept this collective system as the major cooling supply in Copenhagen.

Technical University of Denmark (Department of Environmental Engineering)

The Department of Environmental Engineering (DTU Environment) is one of the largest departments of Technical University of Denmark (DTU) aiming at developing technical and sustainable solutions to minimize the impact of society on the environment through research and teaching in water supply, wastewater, solid waste, hydrology, geology, ecotoxicology, environmental chemistry and microbiology at an international level.

In the visit, Dr. Stefan Trapp, Associate Professor of DTU Environment and an expert on risk assessment of chemicals, environmental modeling and environmental biotechnology, gave an introduction on the DTU Environment and the DTU. After the introduction, presentations on bio-energy activities and climate change adaptation were given to demonstrate DTU Environment's research achievements on technical solutions against climate change.

In the second part of the visit, Prof. Thomas H Christensen, Professor of DTU Environment and Dr. Thomas Astrup, Associate Professor of DTU Environment, shared with the delegates the waste management and researches conducted by the Waste Research Group.

Waste management activities generate emissions of greenhouse gases including carbon dioxide (CO2), methane (CH4) and nitrous oxide (N2O). However, waste management also reduces climate change impacts indirectly by recovering materials and by producing energy that could have been produced from fossil fuels. In view of it, the Waste Research Group, led by Prof. Thomas H Christensen, has been putting utmost effort in mapping current greenhouse gas emissions and savings from waste management.

The Waste Research Group in collaboration with Life Cycle Assessment (LCA) Research Group developed the EASEWASTE (Environmental Assessment of Solid Waste Systems and Technologies) LCA-model which models resource use and recovery as well as environmental emissions associated with waste management in a life-cycle context. It contains default data for waste composition and source segregation efficiencies as well as for most technical processes: collection, transports, thermal treatment, composting, anaerobic digestion, landfilling, recycling processes, use-on-land, material utilization and energy utilization. It calculates mass flows, resource uses and recoveries, and provides all emissions to air, soil, surface water and groundwater. Fig. 3.35 shows the concept of the EASEWASTE model.

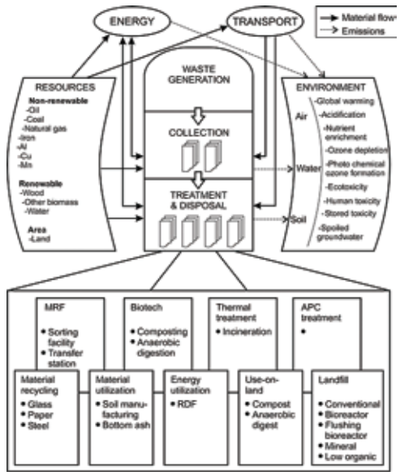

Fig. 3.35 [3.12] The concept of EASEWASTE model

In 2008, the International Solid Waste Association (ISWA) Publication Award was given to Professor Christensen and the research group for the outstanding publication "Experience with the use of LCA-modelling (EASEWASTE) in waste management" and related papers published in Waste Management & Research.

Research studies on biomass and waste

Fig. 3.36 Souvenirs presentation to Dr. Astrup (3rd from the left), Dr. Trapp (3rd from the right) and Prof. Christensen (2nd from the left)

Fig. 3.37 Group photo at DTU Department of Environmental Engineering

management by DTU Environment contribute to the development of the new form of waste management system, leading the industry to relieve the problem of energy supply and greenhouse gas emission.

3.2.3 Engineering in Practice

Being the pioneer in response to the call from climate change, there have been numerous inspiring and practical engineering climate solutions in Denmark. This Delegation visited some of these establishments. Findings are presented in this section.

Avedøre Combined Power Station and Wind Turbines

The Avedøre Combined Power Station (Avedøre) is one of DONG Energy's central power plants in Denmark which consists of two units: Avedøre 1 and Avedøre 2. The former is primarily a coal-fired plant built in 1990 with additional capability of an oil-fueled boiler. The later is a multi-fuel-fired plant built in 2001 which consists of both steam and biomass boiler for propelling the steam-turbine plant. Natural gas, oil, wood pellets and straw are all fuel being fired in Avedøre 2. Avedøre 1 and 2 together supplied electricity for 1.3 million homes in Northern Europe and district heating for 200,000 homes in Greater Copenhagen.

Fig. 3.38 General view of Avedøre Combined Power Station

Fig. 3.39 Guided tour by Mr. Hansen

As learned from Mr. Jacob Bruun Hansen, Communication Officer of DONG Energy, the Avedøre symbolized DONG Energy's vision in transforming to a low carbon-emission future through shifting the energy generation with CO2 production into other means with less or no CO2 production (see Fig. 3.40). It is envisaged that 85% electricity production without CO2 emission can be achieved in Avedøre by 2040.

The emphasis of Avedøre 2 on low carbon-content fuel and bio-fuel has laid the milestone for the low carbon power generation vision.

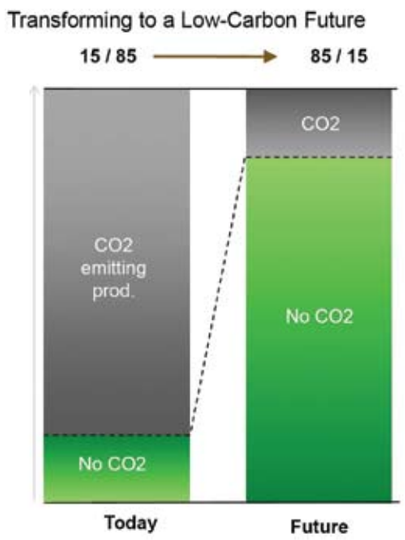

Fig. 3.40 [3.13] Vision towards low carbon power generation by Avedøre

Natural gas and oil are co-fired with wood pellets in the steam boiler while straw bales (Fig. 3.41) are fired in the biomass boiler and the boilers jointly propelled the steam turbine for power generation. Questions had been raised on the sustainability of biomass supply. Mr. Hansen explained that

Fig. 3.41 Straw bales for firing

the diversified supply of wood pellets from Portugal and Canada and straw from farmers in Zealand and the southern islands ensured a continuous supply of biomass fuel for Avedøre 2. Moreover, through a proper planning of the tree planting scheme, wood pellets supply can be controlled and forestation can be maintained.

The Avedøre also illustrated the success of Denmark in significantly increasing the energy efficiency of the plant through combination of the power plants with district heating system. Conventional power generation bears low efficiency due to the massive heat energy loss through the condensers, while heat energy is invaluable to Denmark with regard to the cold climate. By using the residual heat produced during electricity generation to heat up the water for the district heating system, over 90% of the fuel energy can be utilized in comparing with an efficiency of less than 50% for conventional electricity generation (see Fig. 3.42). This ranks Avedøre among the most efficient combined power stations in the world.

Energy efficiency

Electricity generation:	Avedøre 1:	Avedøre 2:
Electricity	45%	49%
Loss in flue gas (primarily)	10%	8%
Loss in condenser	45%	43%
Electricity and full district heating generation:	**Avedøre 1:**	**Avedøre 2:**
Electricity	40%	42%
Loss in flue gas (primarily)	10%	8%
District heating	50%	50%

Fig. 3.42 [3.13] Energy efficiency comparison between Avedøre 1 and Avedøre 2`

Apart from the combined power generation concept, Avedøre has also pioneered the renewable energy in Denmark by giving birth to the largest wind turbines in Denmark. The two 3.6MW wind turbines, each with a hub height of 93m above sea level and blade diameter of 120m, was a joint pilot project between DONG Energy and Siemens to test and optimize new wind turbine concepts. The project development commenced in 2007 and was completed in 2009. The wind turbines were installed very near to the shore to allow easy access by engineering staff to carry out research works on the wind turbines before they are implemented on an actual large-scale offshore wind farm project.

These wind turbines also illustrated the sophisticated power generation network within Avedøre which combines natural gas and biomass firing together with renewable

Fig. 3.43 Group photo in front of the largest wind turbines in Denmark

energy to provide a sustainable low carbon energy supply for Denmark. It is clear that achieving high energy efficiency through combined heat/power generation and eliminating of high carbon emission through reliance on more biomass-firing and renewable energy in power plants are the directions envisaged by Denmark for the upcoming decades.

Amagerforbrænding Waste Incineration Plant

Amagerforbrænding Waste Incineration Plant is located in the centre of Copenhagen. It is a green waste treatment and energy company working to utilize the values in waste. Following Danish waste strategy of reducing, recycling, incineration and deposit, the company operates both waste recycling stations as well as waste incineration plant. The waste recycling stations allow wastes to be sorted to different categories for further treatment. In Copenhagen, 56% of wastes are recycled, 39% are incinerated, 3% are sent to landfill while the remaining is specially treated like electronic waste is sent back to supplier for reuse.

In the visit, Ms. Julie Bauer Larsen, Communications Officer of Amagerforbrænding, introduced that the Plant has been operating for 40 years since 1970. It has a capacity of incinerating waste of 1,500ton/day. While this incineration plant contributes a lot to waste treatment, it also plays an important role in converting waste into energy. Heat produced from burning waste is used to generate steam. At the very beginning, steam was solely supplied to the district heating system. Starting from 1991, some of the steam has been supplied to generate electricity instead. By now, 20% of heat produced is used for generating electricity and 80% of heat produced is used for district heating, capable of supporting 140,000 household. This waste-to-energy is climate friendly because it replaces energy that would otherwise have been generated from burning fossil fuel. It is 80% CO2 neutral as most of the waste consists of organic materials. It is also eco-friendly because flue gas from incineration is cleaned before discharge.

Waste is transported to the plant by trucks. It is then dumped into a silo and then lifted to the furnaces by grabs. Waste is incinerated in 4 furnaces at around 950ºC for 2 hours using propane gas burner and biomass as starting fuel. Heat generated boils the water along tube at the furnace wall. 20% of steam is passed to drive 2 generators (8MW and 20MW respectively) for electricity while the remaining is used to heat up water and distributed to the district heating system. Flue gas is treated before discharge. Limestone resulted from the reaction with flue gas is collected and sent to Norway for deposit, while slag resulted from burning is cleaned and reused in construction work.

Fig. 3.44 Group photo in front of Amagerforbraending Waste Incineration Plant

Apart from daily incineration, Amagerforbrænding has also worked with The University of Copenhagen, Technical University of Denmark, Haldor Topsoe (A

3. Findings in Denmark

catalyst and technology company) and DONG Energy, on a research and development project called REnescience (Renewable, Science and Renaissance of the energy system). The objective of the REnescience

Fig. 3.45 Waste dumped into silo by truck

Fig. 3.46 Ms. Larsen introducing the plant

Fig 3.47 Delegate taking a look of the firing in furnace

project is to upgrade household waste for optimum utilization of its content of energy and minerals. As part of the project, a pilot plant with capacity of 800kg/h has been built in Amagerforbrænding incineration plant and commissioned since December 2009. This plant involves pre-sorting of waste prior to incineration through enzyme liquefaction followed by physical separation.

Waste is pre-heated in a rotating chamber at 100ºC. It is then transferred to enzyme reactor for treatment at around 30ºC to 80ºC. After that, the waste is subjected to physical separation. While the liquid fraction is subjected to further treatment to bio-fuel, the solid fraction including metal and glass will be recycled and plastics will be sent to incineration. While this project helps to "distill out" the useful substance from the waste, it also helps to well sort the waste before sending to incineration since substances like metal and glass always impede the incineration process and may even damage the furnaces.

Ms. Larsen told the delegates that as Amagerforbrænding is located at the centre of the city, in order to minimize impacts to neighboring stakeholders, Amagerforbrænding has been working closely with the community. Moreover, sustainable future needs assistance from every people and therefore Amagerforbrænding has taken

Fig. 3.48 Waste transferred to the rotating chamber

Fig. 3.49 Different fractions in waste being separated out

Figs. 3.50a & b Solid & liquid fraction from waste

an important role in educating the Danish citizen on waste management including waste reduction, reuse, recovery and sorting as well as the conversion of waste-to-energy. An education centre has also been set up in the Plant to receive visitors from local communities and overseas.

Green Lighthouse (University of Copenhagen)

Green Lighthouse is Denmark's first public carbon neutral house. It is inaugurated on the 20th October 2009. The Gross Floor

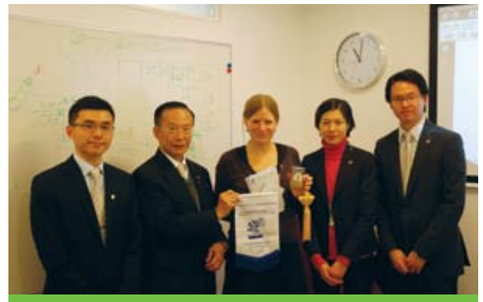

Fig. 3.51 Souvenir presentation to Ms. Larsen

Area (GFA) in this building is about 950m2 [3.14]. This building is also named as "Green Cheese" as it is a round-shape building which is white in middle but green outside.

Green Lighthouse is a new carbon-neutral house which is located at the North Campus of University of Copenhagen and is now being used for student services functions, study administration and meeting facilities. It is an excellent example of the standard for future buildings which demonstrates functionality and meanwhile environmental friendly.

Fig. 3.52 External view of Green Lighthouse

How Green Lighthouse Reduces Energy Consumption

For the energy consumption, this building is classified as low-energy Class 1 building according to Danish building regulations (BR 08). When compare with present building standards, this building's energy consumption is reduced by around 75% [3.15]. The estimated energy consumption is within 50kWh/m2/year.

The green cladding is made of lightweight and optimal thermally-insulated façade walls. This kind of material is stronger and more resistible to different weather condition when compared with other construction materials for façade walls such as concrete and glass.

Green Lighthouse is controlled by a building management system (BMS) called Window Master. It is the "brain" of the house which collects and measures the weather data like light intensity, wind speed as well as wind

Fig. 3.53 Delegates listening to the introduction of the external green cladding

direction from the rooftop. It also provides indoor climate control by opening or closing of windows for optimum indoor temperature and humidity. The ventilation system for the whole building is mainly natural ventilation.

Fig. 3.54 Introduction of "Window Master" for indoor climate control

Green Lighthouse has a total of 18m2 area of window which can maximize natural ventilation through the building. The thermo glass windows can minimize the heat loss and at the same time, ensure that the sun heats up the house during winter time. The frame and sash of the window are made of a revolutionary new material - Helo-Fibre that consists of PUR (polyurethane) strengthened with thin glass threads [3.16].

Renewable Energy Adopted in Green Lighthouse

In the Green Lighthouse, approximately 50% of the house's energy is covered by renewable energy.

With an aim to fully utilize the roof, 30.8m2 solar collectors have been installed to provide 4.25kwh/m2/year. The solar panels produce surplus heat during summer, and the excess heat is stored in the warehouse underground for use during winter and periods with less sun light penetration. The electricity created would be aimed at powering pumps, lighting as well as heating pumps.

For the use of sunlight in the House, it has been guaranteed that the daylight factor will be at least 3% in all working stations and minimum 2% in hall ways except night time or very dark day. This means that daylight is evident in all rooms under normal condition [3.15]. Furthermore, square windows are installed on the ceiling of top floor for maximizing the sunlight entry. However, to cater for those extreme weather conditions, artificial light will still be lightened under monitoring by the "brain". LED lamps at 4W installed on the ceiling can provide high power conversion efficient with long lifetime.

Fig. 3.55 Solar panels on the roof

Fig. 3.56 LED lamps and roof square windows

During summer, the energy from sunlight will pass thru the solar panel and excess building heat is stored underground with drill holes accommodating vertical plastic pipes.

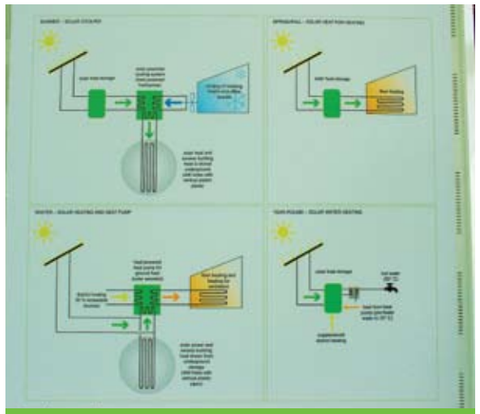

Fig. 3.57 Operation diagram for energy supply of Green Lighthouse

In winter, the stored energy is drawn from underground storage by heat pump. At the same time, 35% of heat is provided by district heating for floor heating and heating inside the building.

Other Special Features

With the new building fund, an art piece (Fig. 3.58) has been installed on the ceiling which is made of Aluminum. It can reflect the sunlight from the roof and illuminates all part of the building for lighting.

Fig. 3.58 Art piece on the top floor for reflecting the sunlight from the roof

The floor is made of rubber instead of wood. Application of rubber floor can greatly reduce the echo effect inside the building. However, it bears the disadvantage of being difficult to clean.

To utilize the use of daylight, Green Lighthouse has installed a "natural light" on the ceiling of staircase to the roof. The "natural light" captures the light directly from the sun and the daylight is diverted to the staircase through an aluminum pipe with reflective glass lining placed inside.

Low Energy Buildings in Municipality of Copenhagen by Copenhagen Properties

Since 2006, the Municipality of Copenhagen has required that the municipality's new constructions and rate-supported buildings live up to the Danish low-energy Class 2 building requirements. This means that energy consumption of these buildings should be 25% lower than comparable standard constructions. Copenhagen City's Climate Plan sets the stage for a further tightening in 2010, reducing the energy consumption in new constructions by another 25%, corresponding to low-energy Class 1 building requirements [3.17].

In this visit, Mr. Niels-Arne Jensen, Chief Consultant of Copenhagen Properties, a municipality-owned property company holding Denmark's largest real estate portfolios, led the delegates to visit two sites featured with Copenhagen's new directives of achieving low energy consumption and carbon emission: renovation of old buildings and innovation in future design.

Fig. 3.59 The "natural light".

Figs. 3.60a & b Aluminum pipe with reflective glass inside

The first site was Osram Culture Centre in Valhalsgade which was renovated from an old building. The Osram Culture Centre was formally a light bulb store house since 1953. It was taken over by the Municipality of Copenhagen in 1982 and turned into a cultural and community centre for sports and music activities. The Centre had undergone a major renovation in 2008. This renovation demonstrated two key objectives for energy renovation of existing buildings: to minimize renovation cost incurred and to preserve original building structure for cultural preservation.

Fig. 3.61 Mr. Jensen introducing the low energy concepts adopted in the Osram Culture Centret

The Centre has been provided with extra insulations at façade in order to reduce heat exchanges from building to the surroundings, which in turn reduce energy consumption for cooling in summer and heating in winter. The Centre also promotes effective daylight utilization through the installation of skylights (Fig. 3.62). The use of LED light bulb also helps in saving energy. The Centre is also equipped with an energy efficient heating and ventilation systems which are monitored by a computer model (Fig. 3.63). The Centre after renovation gives an annual reduction of 66% in heat and electricity and 29.5tCO2. Through innovative design and technology, low energy building renovation can be achieved by financially feasible solutions, which conveys a strong encouraging message to the people

Fig. 3.62 Daylight utilization through window installed on the roof

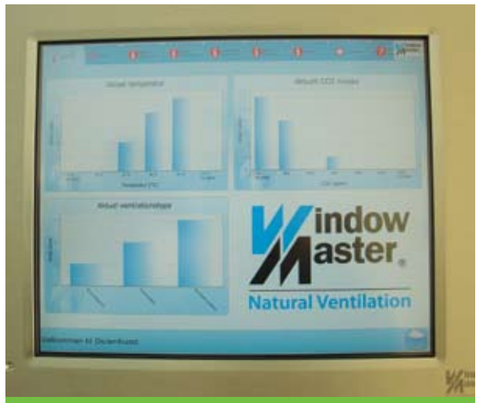

Fig. 3.63 Computer monitoring and regulating system for regulating the building's energy consumption

in Copenhagen to go green.

In the second part of the visit, Mr. Jensen led the delegates to the Universet which is a new building of low-energy Class 1 opened in November 2009. It is an after-school activities centre as well as facilities for the local community. As most of its structure is elevated in a way to preserves playground underneath the building, it has also been called "the flying after-school centre" by the community.

Similar to the Osram Culture Centre, the energy improvements for Universet include extra insulation and 3-layer energy windows, energy-efficient ventilation with heat recovery and daylight utilization and energy saving lighting. Moreover, the Universet has also adopted the district heating and solar panels installed on the roof to relief the energy consumption by renewable energy.

When compare with traditional building, the Universet gives an annual reduction of 47% in heat and electricity and 6.3tCO2.

Solar City Copenhagen

Solar City Copenhagen is an organization promoting solar panels and energy-optimized buildings. It was established in 2004 by Copenhagen City Authorities, The Danish Energy Authorities, Copenhagen Energy and a number of players in the Danish solar energy field [3.18].

In the visit, Ms. Karin Kappel, Architect of Solar City Copenhagen guided the delegates to five different sites which well demonstrated the practical application of solar panels on street furniture and building structures.

The first site was located at Eriksgade. When

Figs. 3.64a & b Extra insulation of facades

Fig. 3.65 Mr. Jensen introducing the energy improvement adopted in Universet

Fig. 3.66 Group photo in front of Universet

Fig. 3.67 Two sets of solar panel at Eriksgade

Ms. Kappel pointed out the location of the solar panels, delegates were surprised by it and highly praised the innovative idea made by the Danish architects. There were two sets of solar panel and each set was placed in the middle and on top of the street supported by a truss frame installed onto the top of two building structures. The electricity generated from the solar panels will be used for the street lighting at night.

Fig. 3.68 Close view of the solar panel

The second site was an old industrial building in Gasværksvej 16. It was a malt house from 1912 which delivered malt to the Carlsberg factory [3.19]. It is now an office building and the solar panels are mounted on the façades of the building and the staircase tower. Some solar panels on the wall are set inclined to maximize the absorption of the sunlight. The main advantage of mounting the solar panels on wall is being visible to Danish citizens and in turn promoting the solar city. In term of electricity generation, for the same area size of solar panel, although placing it on the building roof will generate

Fig. 3.69 Solar panels on the façades of building and the staircase tower

Fig. 3.70 Ms. Kappel introducing the solar panels on building

more electricity taking into account the longer exposure to higher light intensity, it is limited by the area of the roof. Alternatively, the building walls usually have a larger surface area that mounting solar panels on walls may contribute to larger electricity production.

The third site was Ørestaden which solar panels are installed on the main facade of the new headquarters of Copenhagen Energy. Solar panels are placed in front of strips of glass facade between the heavy concrete slabs. The polycrystalline solar cells are laminated on the upper side of the horizontal

Fig. 3.71 Adjustable solar panels on headquarters of Copenhagen Energy

Fig. 3.72 Group Photo in front of Crowne Plaza

slats of iron-free glass. Gills are maintained at an angle of 20 degree with galvanized steel brackets in front of the building's glass facade. The solar cells filter can soften the light of the underlying space. The cells also have a foreclosure effect against the direct sunlight. The solar cells are specially designed for such purposes. [3.19]

After Ørestaden, Ms. Kappel led the delegates to the newly opened Crowne Plaza Copenhagen Towers. The hotel is one of the world's greenest hotels. It is CO2 neutral and has applied different technologies to lower the energy consumption such as Denmark's first groundwater-based cooling and heating system. It also has the largest built-in solar panel on facades among all hotels in the northern Europe.

The final destination for the Solar City Copenhagen was an art piece by solar panels hanging on the wall of a local house in Valby. The artist Anita Jørgensen decorated the building with red neon tubes and solar cells, which has become a significant landmark for Valby seen daily by thousands of train passengers [3.20].

Fig. 3.73 Ms. Kappel introducing the art work by solar panel

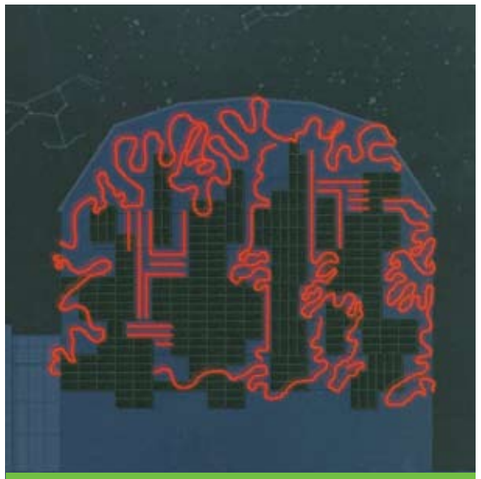

Fig. 3.74 The art work at night

Green Roofs in Copenhagen

Green space has increasingly been seen as an important part of helping cities to adapt to and mitigate for the effects of climate change. Copenhagen is the first city in the northern Europe to adopt a mandatory green roof policy for all new buildings with roof

Fig. 3.75 Green roof together with the newly constructed building

gradient of less than 30 degrees. A parallel policy of levying 'climate tax' on those who have no green initiatives might also be put forward [3.21].

Fig. 3.76 Layers of material to facilitate vegetation and water-sealing

The green roof policy is part of Copenhagen's ambitious climate plan aiming to make Copenhagen the world's first carbon neutral capital by 2025. The City of Copenhagen has set out requirements for green roofs. Buildings with green roofs should be able to meet at least two of the following effects:

- Absorb 50-80% of the precipitation that falls on the roof
- Provide a cooling and insulating effect of the building and reduce reflection
- Help make the city greener, reducing the urban heat island effect, counteracting the increased temperatures in the city
- Contribute to a visual and aesthetic architectural variation that has a positive effect on the quality of life
- Double the roof life of the roofing membrane by protecting it against UV rays

Fig. 3.77 Delegates learning the layers of material for green roof

Copenhagen presently has about 20,000 m2 (over 215,000 ft2) of flat roofs and at least 30 buildings have green roofs. It is envisioned as much as 5000 m2 of new development each year will be covered with vegetation [3.21].

In this visit, Ms. Dorthe Rømø of Municipality of Copenhagen guided the delegates to Det Kongelige Rigsarkiv which showcased the implementation of green roof in Copenhagen. She also introduced the benefits of green roofs and explained how the Municipality of Copenhagen worked to promote green roofs.

Fig. 3.78 Green roof introduction by Ms. Rømø

Green Roof Benefits

It has been learned from the visit that green roofs provide a long list of benefits for buildings and their surroundings, which are summarized as follows:

- Help to reduce the urban temperatures, so-called the Urban Heat Island Effect
- Significantly reduce the surface run off volumes and rates of rainfall leaving roofs which help to reduce stress on stormwater systems
- Enhance the biodiversity which provide important refuges for wildlife in urban areas
- Protect roof membranes from the sun's UV rays and the greatest temperature swings, such that roof membrane life is extended
- Help to reduce the need for air conditioning in summer and can provide a degree of insulation in winter. The combination of soil, plants and trapped layers of air within green roof systems can act as a sound insulation barrier
- Help to give a better air quality as airborne particles and pollutants can be filtered from the atmosphere by the substrates and vegetation on a green roof
- Provide an amenity space which is often lack of in the dense urban environments
- Offer opportunity to develop urban agriculture

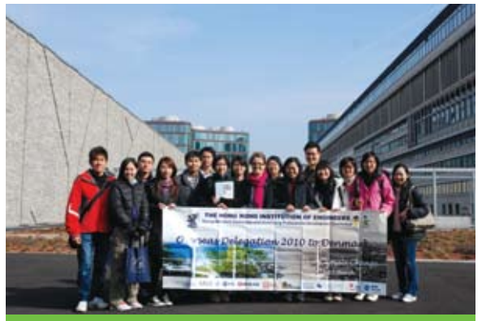

Fig. 3.79 Group photo at Det Kongelige Rigsarkiv

Summary of Engineering in Practice

As an engineer, one always says "being practical" is very important and that is why under the engineering graduate training, engineering graduate has to work on site to obtain site experience. In this delegation, delegates not only had the opportunity to understand the Danish energy policies and the engineering technologies being developed by different organizations of Denmark, but also experienced the practical climate solutions. These practical solutions include

the use of renewable energy, combined heat and electricity to increase energy efficiency, waste-to-energy incineration, carbon-free building, low energy building, use of solar panels and green roofs.

3.2.4 Participation by Danish Citizens

Due to the tight schedule, delegates were not able to visit every organization to find out all policies and technologies in relation to climate change. Nevertheless, in preparation for the delegation, delegates conducted a preliminary research about Denmark's effort in climate solutions and found that in addition to energy policies, Danish Government has put lots of effort in other aspects such as greener transportation planning and increase in waste recovery.

Although a city has a lot of provisional climate policies and engineering technologies, one never knows whether the policy or technology is practical and successful without the participation and cooperation by her citizens. During the stay in Copenhagen, delegates witnessed the high participation by the Danish citizens. This section presents from a visitor's point of view, the discovery Denmark of a sustainable Copenhagen.

City of Cyclists

In 2008, Danish politicians unanimously decided to work towards a cleaner, healthier and more environmentally friendly City of Copenhagen. Four main objectives were set out to be achieved by 2015. One of these is to convert Copenhagen into the "World's best city for cyclists".

Nowadays, a total of 350km cycling tracks and 40km green cycling routes are there in Copenhagen. About one third of the commuter trips are generated by bikes which gives a total travel of 1.2 million km/day. This is equivalent to cycling to the moon and back twice. This brought in various benefits to big city like Copenhagen.

Figs. 3.80a & b In Copenhagen, bikes are all around

Fig. 3.81 Double-deck parking for bikes

Fig. 3.82 The cyclist motorways

Fig. 3.83 Stop line for cars setting back from stop line for cyclists

Figs. 3.84a & b Train cabinet for bikes

In order to achieve the goal of having 50% commuters using bike to work or study by 2015, Copenhagen has put cycling as the priority in city's planning and has established a safer and more accessible cycling network. An example is the development of the Green Cycle Routes which is described as "cyclist motorways" by the Copenhagen citizens.

The Green Cycle Routes separates the cyclist route from the infrastructure. By providing widen cycling track with minimal contact with traffic, it allows a quicker flow along the routes. Moreover, in order to minimize the risk of accidents, many road junctions in Copenhagen have been restructured to give priority to cyclists. Stop line for cars are being pushed back 5m behind the stop line for cyclists. At intersections with separate traffic lights for bikes, the cyclists get a green light 4 seconds before the car drivers. In some cases it is up to 12 seconds which make the cyclists far more visible in the traffic.

From the perspectives of climate and energy, more cyclists mean less energy consumptions and less carbon emissions. It is estimated that when 50% of commuters chose to cycle to work or study, an additional 80,000tCO2 could be saved annually.

Recycling of Plastic Waste

In the supermarket adjacent to delegates' accommodation, delegates found a reverse vending machine collecting empty plastic bottles.

The reverse vending machine is managed by the Dansk Retursystem A/S. It is a private non-

Fig. 3.85 Reverse vending machine collecting empty bottles at the end of corridor

profit organization supported and regulated by the Danish Environmental Protection Agency on behalf of the Danish Ministry of the Environment. Based on this partnering initiative, Denmark pioneered the handling of one-way packaging system, namely the Danish Deposit and Return System and the machine is a part of it [3.22].

Fig. 3.86 Close view of the reverse vending machine

The System came into force in 2002. The Danish Ministry of the Environment is responsible for specifying the types of packaging covered by the system and the cash value of the deposits and refunds, whereas Dansk Retursystem A/S handles one-way packaging (cans, glass and bottles that are only used once) bottles and cans containing drinks as mentioned in the next paragraph.

The deposits apply to both one-way packaging and refillable bottles. Under Danish law, all beer, soft drinks, alcopops, energy drinks, mineral water, iced tea and cider products sold on the Danish market in one-way packaging must be labelled with a Danish deposit label. There are three types of labels for deposit Type A, Type B and Type C.

Figs. 3.87 Label Type A, Label Type B, Label Type C

Fig. 3.88 Label Type C (above bar code) on one-way packaging

The following table shows the refundable deposit for one-way packaging:

One-way packaging	Deposit
Type A: Cans, glass and plastic bottles under 1 litre	1.00 DKK (about HK$1.50)
Type B: Plastic bottles of 0.5 litre	1.50 DKK (about HK$2.25)
Type C: Cans, glass and plastic bottles of 1 litre and over	3.00 DKK (about HK$4.50)

Fig. 3.89 Delegate returning empty plastic bottle to the Machine

Fig. 3.90 Refund notice printed by the Machine for reimbursement at cashier counter

The main advantage of the system is that sorting and recycling of plastic waste can be successfully achieved as people is likely to return the empty bottles and cans so as to get the refunds. Reduction in plastic waste will help reduce emission of CO2 in connection with reduction in disposal of oil-based product.