Meeting Notes

Sino-Swedish Workshop on Alternatives to Ozone Depleting Substances and Hydrofluorocarbons – District Cooling and Heating

Shanghai, China 25-26 April 2017

Malmskillnadsgatan 39
Box 4100
102 62 Stockholm

www.devcco.se

+46 (0)8 210 110

Contents

1 About the Workshop

Sino-Swedish Workshop on Alternatives to Ozone Depleting Substances (ODS) and Hydrofluorocarbons (HFCs) – District Cooling and Heating.

Joint Workshop: Swedish Environmental Protection Agency (Swedish EPA) and Foreign Economic Cooperation Office of the Ministry of Environmental Protection of China (FECO/MEP)

In cooperation with: China Refrigeration and Air-Conditioning Industry Association (CRAA), Building Environment and Energy Utilization Branch of China Exploration & Design Association (BEEUB), Tsinghua University, China Architecture Design Group.

Time: 25-26 April

Venue: Majesty Plaza Shanghai

The workshop was followed up by a study visit to the Hongqiao airport on 26 April.

1.1 Introduction

One of the most cost efficient ways of reducing emissions and primary energy demand is development of modern district energy systems in urban areas. The Heating Ventilation and Air Conditioning (HVAC) sector is also one of the largest users of hydrofluorocarbons (HFCs) and ozone depleting substances (ODS). Though they represent a small fraction of the current total greenhouse gases (less than 1%), their warming impact is particularly strong and, if left unchecked, HFCs could account for nearly 20% of climate pollution by 2050.

At the 28th Meeting of the Parties to the Montreal Protocol in Kigali in October last year, the countries agreed to adopt an amendment to phase down the production and use of HFCs. The ambitious phase down schedule will avoid more than 80 billion metric tons of carbon dioxide equivalent emissions by 2050, avoiding up to 0.5° Celsius warming by the end of the century while continuing to protect the ozone layer. The possible energy efficiency gains are estimated to result in avoiding additional up to 0.5° Celsius warming.

Applied district cooling (DC) technologies, including not-in-kind (NIK) alternatives, thus offer a promising option in the move away from use of ODS and HFC in an energy-, resource -, and cost-effective manner with additional health benefits accruing from a cleaner urban air. Currently over 10 percent of the global electricity is used for cooling. Sweden, with its 20 000 km of piping network, represents one of the world's largest network of district heating and cooling per capita. The Swedish expansion of the DC market started in the mid-1990s and was spurred by the phase-out of ODS. The Swedish district cooling system has been developed mostly on a commercial basis. By 2014 district cooling had captured greater than 25 percent of the market. Use of modern district energy systems has helped Sweden to reduce its emission of green-house gases and ozone depleting substances and concurrently maintain a growth in its economy.

A first in a series of workshops on DC and NIK was held at the Swedish Environmental Protection Agency (Swedish EPA EPA) in Stockholm on 20 September 2016. The Workshop provided a platform to exchange views between policy makers, business, branch organizations, academia and financiers on developments and possible further action in their respective spheres to promote development and implementation of modern district energy systems including district cooling. China is the largest producer, exporter and consumers of HCFCs in the world. China is a key player for phasing down of HFCs as well as energy and resource efficiency. The Foreign Economic Cooperation Office (FECO) of the Ministry of Environmental Protection (MEP) and Chinese experts designated by FECO participated actively at the workshop in Stockholm. In conjunction, the Swedish EPA and FECO expressed the interest to continue the cooperation, and it was agreed, as a follow-up activity, to organize a workshop in China.

1.2 Objectives

The overall objective with the workshop is two-folded: 1) as an outreach activity to support and facilitate international cooperation with China on the phasing down of HFCs.2) to enhance an exchange between Sweden/Nordic countries and China among policy makers, business, branch organizations, academia and building designers on development and possible further action in their respective spheres to promote modern district energy systems including district cooling and "not-in-kind" (NIK) alternatives[1].

1.3 Reading guidelines and report status

The report disposition generally follows the headlines of the agenda for the workshop. While the notes in this report are kept brief, full presentations have been distributed to the participants separately.

The notes in this report are prepared by Devcco. Please note that the report is an attempt to reflect the statements, ideas and conclusions brought forward at the workshop based on Devcco's interpretation of the event. Commonly used abbreviations are included at the end of the report.

2 Workshop day 1

2.1 Opening Ceremony

Moderated by Ms. Ping Höjding, Senior Adviser, Swedish EPA

Opening remarks by:

Mr. Xiao Xuezhi, Deputy Director General, Foreign Economic Cooperation Office of the Ministry of Environmental Protection

Ms. Lisette Lindahl, Consul General, Consulate General of Sweden in Shanghai

Mr. Zhang Zhaohui, Secretary General, China Refrigeration and Air-Conditioning Industry Association

2.2 Keynote speeches

Moderated by Ms. Ping Höjding, Senior Adviser, Swedish EPA

2.2.1 Combating climate change and phasing down of HFCs – Kigali Amendment – near term work - policies and legal frameworks internationally, in EU and the Nordic countries

Dr. Husamuddin Ahmadzai, Swedish EPA:

- The Montreal protocol has been in effect for 30 years including 197 countries
- Hoping that including energy efficiency will contribute to up to an additional 0.5 °C reduction of global warming

[1]"Not-in-Kind" (NIK) alternatives in this context means use of non-ozone depleting (non-ODS) and non-HFC based techniques and practice.

- Importance of moving from replacing refrigerants to NIK technologies
- Refrigeration and Air conditioning largest HFC sector
- Kigali amendment aiming at 85% reduction by 2020-2026
- Estimated potential energy efficiency gains from implementation of Kigali amendment equal to current coal power production in China
- EU objective to cut GHG by 80% by 2050
- Several policies, strategies and regulations in place regarding energy efficiency in Sweden and in the EU
- Sweden has been successful in decoupling GHG and GDP
- Key conclusion that the Montreal protocol has been successful and that phasing down HFC can contribute with 0.5 – 1 °C reduction of the climate goal.

2.2.2 Key challenges and opportunities in implementing HPMP Stage II under Montreal Protocol in China

Mr. Zhong Zhifeng, Deputy Division Chief, Foreign Economic Cooperation Office of the Ministry of Environmental Protection:

- Summary of challenges of phasing down HFC in article 5 and non-article 5 countries
- GCC countries a slower phase down than other countries
- China focuses on synergized effects
- Changing production lines and developing new products not done overnight but will require 4-5 years
- CO_2 and NH_3 likely to take the lead in the refrigeration industry
- HPMP Stage II is a large challenge for domestic companies
- Shows examples where heat pumps have replaced coal fired boilers
- Different solution will have to be sought for large scale and small scale (household) applications
- NIK technologies need to be demonstrated

2.2.3 Role of centralized energy systems and district cooling in Sweden – an overview – including standards and policies

Mr. Peter Dahl, CEO, Sinfra, Sweden:

- Presentation of Swedish energy market development with oil crisis triggering energy efficiency
- Development of District Heating and district cooling in Sweden over the last 30 years including how fuels have changed over time
- Sinfra procurement process and sustainability rating of suppliers were described
- As a background to the Sinfra business model, typical procurement challenges encountered in Europe were described. Among those mentioned were varying market maturity, language barriers and differences in technical standards.
- Description of cross border co-operation (Sweden – Finland)

- EU and Swedish Energy Agency supportive of Sinfra's work and model

2.2.4 District energy system based on third generation of distributed energy

Prof. Long Weiding, Tongji University:

- 3:d generation consists of three parts: high demand of indoor climate, change to low temperature and low pressure
- Fluctuant building energy load in current post-industry era
- Conflict between high-density urban demand and low density renewable energy sources
- Conflict also between monopoly and internet of energy ideas
- Energy use in Chinese cities characterized by low efficiency but also low demand compared to more developed countries
- Description of different technologies and energy net configurations was provided
- Community grids could/should be interconnected with large utility grids and in combination with energy storage options to provide high energy efficiency.
- "Energy bus" and energy management central in new and efficient systems.
- Demand side energy planning vital in 3G on-site power generation
- In conclusion distributed heat pump solutions and "energy bus" are at the core of 3G district heating.

2.3 Best practices and know-how

Moderated by Mr. Zhong Zhifeng, Deputy Division Chief, Foreign Economic Cooperation Office of the Ministry of Environmental Protection

2.3.1 Introduction of various Not-in-Kind district cooling technologies

Mr. Joakim Nilsson, Partner, Devcco, Sweden:

- Company references and services were presented
- District cooling basics describing sources, production technologies, distribution and function of energy transfer stations (ETC) was provided
- System components and their function was generally described
- System design principles based on customer demand and available sources were described and an example from the city of Helsingborg was displayed
- Energy efficiency from different types of DC systems and examples were made. Ranging from 2-10 times more efficient than conventional cooling
- Mechanism of how DC significantly reduces refrigerants
- Benefits to multiple stakeholders due to DC was presented

2.3.2 Key issues for industrial waste heat applications in district heating system

Associate Prof. Xia Jianjun, Tsinghua University:

- Provided overview of district heating in China

- Main challenge being fast growing demand
- North China require building code improvements
- Residential buildings in China have 50% of demand compared to EU
- 2/3 of all energy goes to manufacturing
- Huge amounts of waste heat prevalent. Low grade flue gas/steam defined as < 150°C and liquid as < 100°C
- Thresholds to utilize waste heat are economical inefficiency and technological immaturity
- Existing low grade waste heat is equivalent to half of the heating demand
- One of the key issues is to get relevant regulations regarding waste heat
- Examples from steel and cupper mills were presented
- In summary industrial waste heat is an important source which can give social and environmental benefits.

2.3.3 The Technology of Heating with Waste Heat and Absorption Heat Exchange

Mr. Qiao Yu, Director of Marketing Department, Beijing Huayuantaimeng Energy-saving Equipment Co.Ltd

- A detailed presentation on absorption heat exchange was given
- A 2.6 million square meter example was presented where heating has been supplied by absorption technology and which has received a lot of attention and recognition
- Flue gas temperature recovery another application whereby also emissions to the air can be reduced

2.3.4 Environmental aspects of refrigerants and cooling

Mr. Torgrim Asphjell, Chief Engineer, Department of climatology, Norwegian Environment Agency

- Providing background on history of refrigerants
- NIK and district cooling provide opportunities to directly and indirectly reduce emissions of GHG and other emissions
- District cooling should be considered for large developments
- High initial investment often a disadvantage but district cooling normally cheaper in the long run where implemented.

2.3.5 Questions and answers

The Q&A covered the following topics:

- How district cooling can be up to ten times more efficient than conventional cooling
- Why district cooling and district heating is normally distributed simultaneously in 4-pipe systems
- How absorption cooling production can either be centralized or decentralized

2.4 Nordic Experiences - good examples and challenges

Moderated by Dr. Husamuddin Ahmadzai, Swedish EPA

2.4.1 Swedish cases Stockholm & Linköping – Integrated Systems and Businesses

Mr. Joakim Nilsson, Partner, Devcco, Sweden

- Development of DC in Stockholm from first phase of 60 MW to current 270 MW was described
- Fortum in Stockholm integrates production of heating, cooling and electricity
- Customer segments including mainly retail and offices
- Technologies used in Stockholm mainly heat pumps with various sources and free cooling from sea water
- Integrated electricity, district heating and district cooling in the city of Linköping mainly based on large scale waste to energy (WTE) plant.
- DC production in Linköping mainly based om absorption chillers powered by surplus heat from WTE plant.
- Other NIK technologies used in Linköping are NH3 chillers and free cooling from river.
- Reasons for choice of technologies were described
- Profitable and growing businesses common for Stockholm and Linköping.

2.4.2 Case Gardermoen Airport – Stand-alone performance

Mr. Sjur Vullum Lotveit, Project leader, Energy, Building and Construction, Oslo Airport, Avinor

- District heating is provided by special purpose vehicle that Avinor (owner of airport) helped start up
- System include thermal energy storage
- Drainage water is used for cooling in the summer
- Treated sewage is a heat source since 2012
- COP for the system is 5.78 (heating) and 7.25 (cooling)
- System also includes a snow storage
- Capacity is 54 MW heating and 20 MW cooling

2.4.3 Cases Chicago/Toronto – Results of phase down ODS

Mr. Bernt Andersson, Chairman, SweHeat & Cooling China Chapter:

- The district cooling system in Chicago was to a large extent triggered by the phase out of CFCs. It has been in operation for 22 years and is a good example of combining chillers and ice thermal energy storage (TES).
- Examples on how district cooling was developed and implemented were described for many systems including Houston, Baltimore and Toronto.
- The system in Houston serves 24 buildings since 1998, has a capacity of 103 MW cooling and includes an Ice on Coil TES.

- In Baltimore 50 buildings are served and the cooling capacity is in total 115 MW. This system also includes an Ice on Coil TES.
- The system in Toronto is based on deep lake water cooling and has been in operation for over 15 years.

2.5 Chinese experiences - good examples and challenges

Moderated by Mr. Xu Wenlong, Deputy Chief Engineer, China Architecture Design Group

2.5.1 Tianjin district heating & cooling system based on heat pump technology

Mr. Wu Xiaoting, Chief Engineer, Tianjin Architecture Design Institute (TADI)

- Tianjin is a part of China with cold climate in winter. Tianjin has big potential of geothermal resource.
- This district heating development started with a 300,000-square meter eco city on 2009
- The 13:th 5-year plan includes significant expansion of district heating and number of systems
- Heat pump technology is the base for further development
- Different business operation models were presented including self-construct & operate, self-construct & others operate and finally franchise.
- Several technologies and sources including heat pumps, energy storage and gas peak boilers were described.
- Several examples were presented including Tianjing cultural center which is a large development project with EER approximately 3.2 for both heating and cooling.

2.5.2 Case study on the district energy system using gas CCHP in Shanghai city

Mr. Ye Dafa, Deputy Chief Engineer, East China Architectural Design & Research Institute:

- There are more than 10 gas CCHP stations in the Shanghai area
- The driver for gas vs. coal is the environmental advantage
- A problem is that the stations are located relatively far from the city and the large heat demand
- 3 examples of projects in different stages of development were presented, all based on low-temperature design and including off-peak storage of some sort.
- Major benefits being less noise, improved urban landscape and self-generated electricity.
- The systems are designed as two-pipe systems for alternate distribution of heating and cooling depending on season.
- Energy savings achieved are approximately 28%

2.5.3 Q&A session

The following were discussed in the Q&A session:

- District energy systems as such are generally not patented due to locally very individual solutions on a system level, though specific parts and equipment may well be protected.
- Different contracting models may apply to CCHP stations depending on whether industrial or residential projects, and also depending on profitability.

3 Workshop Day 2

3.1 Technology suppliers and innovation

Moderated by Mr. Torgrim Asphjell, Chief Engineer, Department of climatology, Norwegian Environment Agency

3.1.1 Products for energy efficient solutions using natural refrigerants

Dr. Rolf Christensen, Product portfolio manager, Energy Division, Alfa Laval:

- The company and its product range was presented
- External change is typically driving the demand for new products, i.e. regulations have driven shifts to CO_2, HC Propane and new HFO for which new products are being developed.
- Norwegian Stavanger Forum with 9 MW cooling and 4 MW heating was presented as example of installation with NH_3
- Also the Alfa Laval manufacturing facility in Lund was described as successful example
- The performance of the products are licensed according to AHRI and the company has provide pressure breaking products for the ten highest towers in the world
- Control systems brought forward as essential in achieving high delta-T in DC and DH systems
- Pre-fabricated energy transfer stations have been delivered to e.g. Stanford and to the Pearl development in Qatar

3.1.2 Heat exchangers for HVAC and industrial applications

Mr. Henrik Rietz, Sales manager, SWEP International:

- Company history and district energy solutions were presented
- Designated mechanical rooms in each new building was highlighted as a desirable factor for successful implementation of district heating and district cooling
- Importance of focusing on entire system function was stressed, and for this the company has a proven design software tool
- Prefabricated ETS is part of the product range that can be delivered with functional guarantee for up to 10 MW cooling capacity
- Prefabricated ETSs are compact and installation time is short
- Examples from Saudi Arabia and Tele 2 Arena in Sweden were presented
- Products are AHRI certified aiming for best product LCC

3.1.3 Commercialization of new and innovative solutions for energy supply

Mr. Carl Wehlin, Chief Operating Officer, FVU AB:

- The company business profile was presented
- FVU is looking for new and innovative technologies and solutions that can help utilities to get a better and more sustainable business
- Main activities are education, testing and searching for innovations
- History and expansion of district cooling was described
- A mix of technologies available for district cooling were presented

3.1.4 Automatic controlling technology and energy efficiency management in distributed energy system

Mr. Song Qinfeng, Vice General Manager, Hangzhou Runpaq. Technology Co., Ltd.

- The company has delivered systems to several large airports in China
- Products are automation systems to stations with CCHP, cooling and thermal energy storage
- Not only efficient hardware but also automation systems are required to obtain high system energy efficiency and delta-T.
- Good automation systems also make it possible to monitor and diagnose systems and their performance
- The automation systems are compatible with financial systems and can be used for generating forecasts
- Several detailed examples and customized systems were described in detail.

3.1.5 The application of high temperature heat pump with natural working fluid NH3 in district heating

Mr. Yanrong Jin, Technology Director, Fujian Snowman Co., Ltd.

- Main parts of the presentation was growing trend in cooling, introduction of heat pumps, high temperature heat pumps and model planning of heat pumps
- Heat pump range for different refrigerants including NH_3, CO_2 and HC were presented
- Operating temperature ranges for different refrigerants were displayed and described
- Advantages of NH_3 heat pumps are that they are compact and have high COP
- A comparison of primary energy usage for heat pump vs. coal fired boiler was presented
- Advantages of heat pumps including large control range of 10-100% were presented
- Heat pump function and core component being high-pressure compressor were described.

3.1.6 Q&A session

Topics raised and discussed were:

- COP in theory and practice
- Risk of freezing using cold sea water as source in the winter

- How lack of room for ETSs in individual buildings can be remedied
- How ETS adaptive to weather forecasts work

3.2 How to promote cooperation in this field

Moderated by Mr. Shou Weiwei, Deputy Chairman, Building Environment and Energy Utilization Branch of China Exploration & Design Association (BEEUB)

3.2.1 Introduction of 3iPET (International Platform for Environmental Technology) and some thoughts on the cooperation

Mr. Yun Jinqi, Senior Project Manager, Foreign Economic Cooperation Office (FECO) of the Ministry of Environmental Protection (MEP):

- 3i stands for International, intelligent and integrated. The construction of the platform was presented.
- 3iPET is a platform initiated in 2015 by FECO/MEP with focus on promoting international cooperation on environmental technologies in the areas of water and air pollutions, soil contamination remediation, clean production, energy efficiency and pollution reduction as well as implementation of multilateral environmental agreements.
- Main activities in 2016 were presented.

3.3 Site visit arrangement

Moderated by Mr. Shou Weiwei, Deputy Chairman, Building Environment and Energy Utilization Branch of China Exploration & Design Association (BEEUB)

3.3.1 Introduction to the site visit to Hongqiao airport

Mr. Ying Kangxi, Section chief, Energy Supply Department of Shanghai Hongqiao International Airport Company:

- The area serviced is 350,000 square meters
- Heating and cooling is supplied to two terminals
- The cooling system consists of York chillers (5/13°C) and of two 22,000 m3 chilled water accumulator tanks.
- The chillers are equipped with BAC cooling towers.
- The buildings are directly connected to the heating and cooling system (i.e. no heat exchangers in the ETSs)
- The heating system consists of high temperature oil fired boilers
- The system was built in 2009 and taken in operation in 2010
- Improved preventive maintenance is expected to minimize future breakdowns
- A planned activity is to reduce the discharge to sewage (from cooling towers)

3.4 Concluding of the workshop

Moderated by Mr. Shou Weiwei, Deputy Chairman, Building Environment and Energy Utilization Branch of China Exploration & Design Association (BEEUB)

3.4.1 Concluding remarks

Dr. Husamuddin Ahmadzai, Senior Advisor, Swedish EPA:

- Fruitful days and exchange of information
- Legislation being important driver
- The Kigali amendment poses many challenges but also offers several alternative solutions
- Importance of how to go about procurement
- A successful interpretation and implementation of Kigali amendment is crucial for reaching the climate target.

Prof. Li Xianting, Tsinghua University:

- Observations of the workshop being: successful sharing of knowledge and know-how, different kinds of technologies to be further discussed.
- Similarities between Chinese and Swedish experiences are: strong governmental support; design, construction and operation experiences; strong in providing solutions in terms of equipment and automation.
- Differences are: climate, where the Nordic countries have one climate and China has many different zones; development level where the Nordic countries are at the same level while in China there are different levels in terms of energy sources, prices and policies.
- Summary: Technology solutions and business models for district heating and cooling need to be adapted to local conditions (climate and other conditions). The cooperation between China and Nordic countries can result in solutions which are applicable not only in China and the Nordic countries but also in other parts of the world.

4 Abbreviations

ABS:	Absorption (cooling)
A5C:	Article 5 Countries - beneficiaries under the MP regime
CCAC:	Climate and Clean Air Coalition
CHP:	Combined Heat and Power
COP:	Coefficient of Performance
CO_2:	Carbon dioxide
DC:	District Cooling
DH:	District Heating
EE:	Energy efficiency
GCF:	Green Climate Fund (UNFCCC mechanism)

GEF: Global Environment Facility

GWh: Giga Watthour

HFC: HydroFluoroCarbons

IFI: International Finance Institution

KPI: Key Performance Indicators

FECO/MEP: Foreign Economic Cooperation Office of the Ministry of Environmental Protection Protection (China)

MLF: Multilateral Fund of the Montreal Protocol

MP: Montreal Protocol

NH_3: Ammonia

NIK: Not in kind, i.e. non-ODS, non-HFC alternatives (NOHFC)

NOHFC: Non ODS, non-HFC

ODS: Ozone Depleting Substances

R & D: Research and development

SEPA: Swedish Environmental Protection Agency

TES: Thermal Energy Storage

TR: Tons Refrigeration

WTE: Waste to Energy