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Energy Efficiency Activities in the DPRK and Opportunities for Rationalization of Energy Use

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The paper gives a brief description of activities and achievements of the energy efficiency project implemented in the DPRK in the period 1993 – 1998. The project was funded by UNDP and executed by the DPRK Government in cooperation with the United Nations, Department for Economic and Social Affairs (UNDESA). The paper starts with a brief characteristics of DPRK energy sector, followed by the description of the scope of technical assistance provided and activities performed during project implementation. The paper continues with delineation of achieved results and provides a list of opportunities for energy rationalization. Recommendations for the development of the energy sector, and proposals for technical assistance are also given.

The author is an expert in energy rationalization. He is a professor on Thermal Engineering at the Technical University of Warsaw/Poland, and was also serving as Senior Advisor on Energy for the United Nations (UN). During the period 1991 – 1999 he was involved in the UN technical assistance programmes for the DPRK. He drafted the Energy Efficiency Improvement Programme for DPRK and, during 1993 – 1999 was the Chief Technical Advisor for the UNDP project on Energy Rationalization at the End – use Sub-sector of DPRK.

Information and energy data given in the paper were collected from 1990s official documents and publications. Therefore, the paper does not necessarily reflect the current energy situation in DPRK.

1. Introduction

Energy, and specifically electric power, has a vital role to play in the development process of any developing country, with future prospects for economic growth being closely linked to the provision of adequate and reliable energy supplies. Due to the complexity of modern society, successful policy analysis, planning and implementation in the energy sector require an integrated approach. Energy efficiency is one of the key factors to be considered in such an integrated approach.

The prerequisites for energy efficiency include both:

- efficient production of energy, by ensuring the least cost supply mix ,and

- efficient consumption of energy, by ensuring optimal energy use and resources allocation.

DPRK has two major indigenous sources of energy, coal and hydropower. Both prime sources of energy are the main contributors in generating electric power, however, the entire economy is dominated by coal. Coal is the main commercial energy source in DPRK. It is estimated that about 40 per cent of its supply is consumed by the electric power sector and 35 - 40 per cent as fuel in industries. The transport sector is the main oil consumer.

DPRK relies heavily on coal for meeting its energy needs. About 85 per cent of the total primary energy consumed in the country is in the form of coal. From the environmental point of view, coal use is the primary cause of the high level of particulates in many urban and industrial areas of DPRK. It is also the main source of greenhouse gases; carbon, sulphur dioxides, and nitrogen oxides resulting from different combustion processes. Industries and the power sector consume about 75 per cent of all coal available and therefore they are the main contributors to the greenhouse gases generation in the country. It is estimated that the carbon dioxide emissions by both sectors account for approximately 60 million Tons per annum. The amount of ash and slag produced by them is 20-30 million Tons per annum.

The economy of DPR Korea is very energy intensive. The 1987 figure of the national energy-intensity exceeds 2 tons of oil equivalent (2 TOE) per US $ 1,000 of GNP generated. This figure indicates on existing energy-intensive industries as well as on applied technologies which are energy inefficient. It also reveals inefficient energy utilization in all sectors of the economy.

The primary energy consumption per capita is almost 2 TOE per year (1987).

There are large opportunities for energy rationalization and conservation in various sectors of the economy. It is estimated that the potential for energy conservation ranges from 20 to 60 per cent.

Main Characteristics of the Energy Sector:

From the conclusions drawn upon reviewing the DPRK energy sector, the main characteristics of the sector are the following:

a) Shortage of energy supply in general, and electric power in particular, relative to the growing demand.

b) High dependence on coal, the primary energy supply in the country, causing environment pollution.

c) Energy-intensive industries indicating old-fashioned and energy-inefficient technologies.

d) No single body or institution is responsible for the overall energy assessment and analysis.

e) Lack of a framework to relate energy development plans to the national economy plans.

f) Comprehensive energy planning is virtually non-existent

g) The information infrastructure is generally weak and the introduction of microcomputers in technical and administrative areas is limited.

h) Scarcity of qualified and skilled technical staff for design, implementation, and operation of energy projects. Trained policy-making and management staff is also lacking.

i) Lack of comprehensive energy rationalization policies and standards aiming to decrease waste to improve the efficiency of energy-use, and to curb the energy consumption.

j) Until 1999 the UNDP was the only source of external technical assistance to the energy sector.

2. Activities on Energy Use Rationalization in the DPRK

Limited availability of energy in DPRK poses itself a serious constraint on development of the national economy. Energy shortages have presented at all levels in industrial, transport and in domestic sectors a serious problem.

This field has been a major concern of the DPRK Government as it become apparent to pertinent authorities that the methods and technologies of energy utilization at the consumer level are inefficient. This leads to burning of larger amounts of fossil fuels, and consequently, massive pollution of the environment. Particularly in industries, the energy conservation potential is high and is estimated to be 30 - 50 per cent of current consumption. There are very limited and uncoordinated activities on energy rationalization and enhancement of energy efficiency at the consumer level. Qualified staff and expertise are lacking.

Overall excessive energy loss at the industrial end use is estimated to exceed 6 million tons coal equivalent in the whole country, and it is reported that with the rational use

of only high temperature waste heat, about 400 MW of additional equivalent electricity generating capacity would be available.

Out-of-date technology and obsolete equipment cause large amount of energy waste due to hardware deterioration, and moreover inadequate energy management contributes to significant energy loss.

Most of the industrial furnaces exhausting waste gas of temperature higher than 500 °C are still not equipped with heat recovery installations. Thermal insulation of heat piping and furnace walls is not adequate due to lack of insulating materials. Therefore production and sales of high quality thermal insulation of various shapes and sizes, with different temperature ranges are essential for energy saving.

In general, inefficient furnaces (kilns, ovens) exhaust harmful waste gas with abundant heat causing not only heat loss but also severe air pollution. Modern heat exchangers using heat pipes, corrosion-preventing measures are not in use so far and heat pumps for heating, cooling and air conditioning, based on use of waste heat is not available in practice.

Substantial inefficiency of energy use is also recorded in other sectors of the economy i. e. residential, transport, commercial.

In particular, weakness of public awareness of the importance of energy conservation appears to be a negative factor in solving the energy problem. Insufficient energy statistics and lack of an energy data bank aggravate the situation, and do not allow to develop an exact energy strategy. In addition, the capability of the technical staff needs to be upgraded in all topics of energy rationalization and planning.

The Government of DPRK being aware on the low energy efficiency of the national economy requested for foreign assistance to rationalize the utilization of energy, in the first instance in the industrial sector. The project "Energy Rationalization at the End – Use Sub-Sector" was formulated by UNDESA in 1991, and its cost was supported by UNDP. The project was nationally executed during 1993 – 1998, in cooperation with UNDESA.

The project contains three development objectives:

- Set – up of the Center for Rational Use of Energy (CRUE) and strengthen its human and equipment capabilities,

- Set - up the national energy supply and energy demand data system, and develop the sectoral energy consumption diagnosis,

- Provide direct assistance to industries on energy rationalization by implementation of the energy audit and demonstration pilot project programmes.

The brief description of the project outputs is given in continuation.

a) Set – Up of the Center for Rational Use of Energy (CRUE)

The Center for Rational Use of Energy was considered as a state institution leading in all questions related to energy planning, and energy utilization on the governmental and end users levels.

The institutional set-up of CRUE had been completed in 1996. Its facilities are located in Pyongsong, Docsan Dong County on the grounds of the State Academy of Sciences of DPRK. CRUE occupies a new 7 floor building with the floor area of 2,300 sq m. CRUE is divided into seven departments as follows:

- Energy Data Bank and Energy Planning Dept.
- Energy Audit Dept.
- Industrial Techniques and Processes Dept.
- Total Energy Systems Dept.
- Instrumentation Dept.
- Technical Information and Training Dept.
- Environment Protection Dept.

In 1999, the total number of CRUE staff accounted for 104. The senior staff is experienced in their professional fields having been before senior staff employed by the Thermal Engineering Institute of the Academy of Sciences of DPRK. Junior staff is mostly graduates from the same Institute.

Since the start of the project, CRUE acquired a large number of new equipment/instruments for energy audit and laboratories. To secure the mobility of staff in providing consultancy work and research services to the end users of energy, two vehicles were also procured.

b) Personnel Training

For smooth operation of CRUE various special training was provided to its staff.

b.1. In-country Training

A large number of CRUE professionals received in-house training on the subjects listed in continuation. This type of training was provided by the staff of the State Academy of Sciences of DPRK.

- Foreign language (English),
- Thermodynamics and heat transfer,
- Hydrodynamics and aerodynamics,
- Use of energy audit instruments,
- Use and application of computers,
- Electrical engineering.

It is foreseen that refreshment training on these subjects will continue after the termination of the project. A great deal of the in-country training had been performed by international consultants. The CTA and all consultants taught during their missions to DPRK on various topics in areas of their specialization. Almost 50% of their available time was devoted to training (lectures and on-the-job training). In addition, know-how on new energy related technologies had been transferred to Korean professionals.
An essential element of the training was also CRUE staff participation in all activities of the project

b.2. Overseas Training

Overseas training encompassed study tour and fellowship programmes.

(i) Fellowship Programme.

The fellowship programme anticipated that 29 Korean professionals will receive one month training on various energy topics in foreign countries. However, due to the availability of additional funds, three (3) more persons were able to participate in the programme. The entire fellowship programme was conducted in industrial, research and scientific institutions in China, Thailand, and Poland. The implementation period started in

1995 and concluded in 1998. The kind of training received under this programme, number of trainees, and host countries are given below:

- Energy Data Bank and Planning Software	5 persons	China & Thailand
- Total Energy Systems	2 persons	China
- Waste Heat Recovery	3 persons	China
- Heat Recovery Equipment	5 persons	China
- Industrial Steam Systems	3 persons	Poland
- Thermal Insulation	2 persons	Poland
- Energy Audit Techniques	5 persons	Poland &China
- Rational Use of Electricity	3 persons	Poland
- Industrial Furnaces	4 persons	China

(ii) Study Tours

Two study tours for senior Korean professionals were implemented during the run of the project in 1993 and 1996 respectively. China, Thailand, Sweden, Austria, and Poland were visited to familiarize with the state of art of efficient energy equipment, energy conservation research, and energy planning.

c) Development of the Energy Data Bank

One of the main target of this project was to implement and make operational an energy information system for DPRK and develop a diagnosis of sectoral energy consumption. The knowledge of energy-economy interactions in DPRK seemed to lag behind neighbors and developed countries, and the state of the art in this field showed a lack of up-to-date systematic approach. The most severe difficulty was the absence of properly structured energy information system and not-so-easy availability of required information and data. DPRK has a centralized information system, however, the real energy information

system in a well designed structure corresponding to the complexity of the energy system is not existing. During the project implementation, classification of the country's energy system has been developed. Properly structured presentation of the energy system had also been defined not only to reflect the real conditions of the country but also to provide consistency with worldwide or regional database and models.

As the result of efforts of the Energy Data Bank and Energy Planning Department of CRUE, it was constructed the energy database on a wide spectrum of the whole county's economy spanning from energy production including imports and exports, through transformation, to final consumption. The collected information is the energy time series and technical/economical data for the years 1989 to 1997. Based on the energy data bank established, the team developed the sectoral energy diagnosis system dealing with analytical tools to generate energy balance sheets and to analyze the sectoral indicators like, energy elasticicity, energy intensity, etc. However, due to the confidentiality of energy and economic data in the DPRK, the diagnosis of the sectoral energy consumption, had been developed in Korean version only and, therefore, was not available to foreign consultants. (these documents had been also classified as confidential)

d) Direct Assistance to Industries (Energy Audit and Demonstration Projects Programmes)

(i) Energy Audits

The energy audit program was implemented by CRUE according to the project schedule. It started early 1994 and was completed in December 1996. Ten (10) various industrial plants underwent detailed energy audit procedure. The plants where the energy audits were performed are:

1. Ponghak Foodstuff Factory, Pyong Song City
2. Daesong Ceramic Plant, Pyongyang

3. Sunan Furniture Manufacturing Factory, Pyongyang
4. Sang Won Cement Complex, Sang Won
5. Gang Son Steel Works, Gang Son
6. Kimjongtae Electric Locomotive Factory, Pyongyang
7. Pyongyang Textile Mill, Pyongyang
8. Power Plant at the Pyongyang Textile Mill, Pyongyang
9. Pyongyang Children's Confectionery Factory, Pyongyang
10. Aeguk Aluminium Window Factory, Pyongyang

The energy audits revealed various inefficiencies in energy use in plants investigated. The potential for energy savings in the plants audited ranges from 15% to 60% of energy consumed. Measurements performed and energy audit reports developed for each plant satisfied international standards. The deficiencies of energy use were typical and mostly common at all plants audited. The list of deficiencies confirmed by observations, measurements and calculations includes: inefficient combustion of fuels, poor air / fuel ratios, lack of waste heat recovery, excessive energy losses at energy conversion equipment, lack or incomplete thermal insulation and its poor quality, steam and gas leaks, low condensate return rate, lack of basic instrumentation for efficient equipment operation, etc., The inefficiencies of plant, and/or equipment were listed in individual energy audit reports and respective recommendations for improvement were outlined. In general, good housekeeping and low cost measures were recommended.

Apart of the benefits to industrial plants, the performance of the energy audit programme was also an excellent training provided to CRUE staff.

(ii) Demonstration Projects

The results of energy audits performed in a number of industrial plants in DPRK made possible the proper selection of plant installations which would undergo a modernization in order to achieve substantial and measurable energy savings, and to be the

demonstration energy saving projects. Three (3) demonstration projects had been selected for implementation. All of them fall in the low/medium cost category. The projects are:

1. Waste Heat Recovery at the Forging Furnace.
   Implemented at the Kimjongtae Electric Locomotive Factory, Pyongyang.

In the Factory are installed several forging furnaces to preheat steel pieces before they are forged to a desired shape (mostly railway axles). The furnaces are coal fired. Large volumes of hot stack gas are leaving the furnaces, without further utilization, resulting in substantial energy losses. The average temperature of the stack gas is about 1000^0C. The thermal efficiency of these installations does not exceed 15 per cent.

To demonstrate practical opportunities for waste heat recovery, one of these furnaces had been selected for modernization and retrofitting. To reduce the energy losses and enhance the efficiency of the installation, the furnace had been reconstructed and a waste heat recovery boiler (WHRB) installed. The flow of high temperature flue gas generates steam in the WHRB. In addition to this, to maximize the utilization of the flue gas energy potential, a combustion air preheater had been also added. The implementation of these measures resulted in a dramatic decrease of the stack gas temperature. The stack gas temperature is now about 400^0C, and the thermal efficiency of the furnace increased to about 50 per cent. Operating the furnace at full load, the annual energy savings resulting from the implementation of the project would account for 700 Tons of coal per year.

2. Improvement of Steam Utilization in the Beer Brewing Process.
   Implemented at the Ponghak Foodstuff Factory, Pyongsong

One of the departments of the factory is a brewery. Steam is used for the brewing process. Excessive heat losses in this process result from an extensive steam network, lack of thermal insulation of steam pipes and process equipment, and a non existing system for condensate return to boilers.

The reconstruction carried out for steam system improvement included:

- Re-arrangement of the steam pipe network,
- Arrangements for condensate piping,
- Installation of steam traps, strainers, and sight glasses,
- Installing thermal insulation on pipes, heat exchangers, and the condensate tank,
- Installing a steam meter for monitoring the steam consuption.

Reducing heat losses from the steam pipes and process equipment, and the collection of condensate followed by its return to boilers resulted in energy (steam) savings in the order of 35%.

3. Improvement of Electricity Use (VSD application)

Implemented at the Ponghak Foodstuff Factory, Pyongsong.

An electronic frequency control system (Frequency Converter) was applied to the elecric motor rated 40 KW driving a fan supplying combustion air to the steam boiler at the Ponhak Foodstuff Factory.
Under the boiler's routine operation with variable demand for combustion air, the application of the Variable Speed Drive system resulted in electricity savings up to 30%.

3. Opportunities for Energy Rationalization

Numerous opportunities for energy rationalization/conservation exist in all sectors of the economy of DPRK. They are very typical and their full list can be found in handbooks on energy conservation. Therefore, the intention of the author is not to provide a complete checklist but only to address selected problems that might be solved in the country. In particular, the problems are addressed to **industries**, however, some of them may apply to other sectors (e.g residential). Areas for improvements are:

- inefficient combustion of domestic coal and low combustion efficiency in boilers and furnaces,
- insufficient, or lack of waste heat recovery systems in industries,

- inefficient steam and condensate utilization,
- poor thermal insulation of pipes and energy installations,
- excessive radiation and convection losses of industrial and residential buildings structures,
- lack of instrumentation for efficient of energy use, and for overall energy management of a plant,
- inadequate skills of plant staff in solving energy rationalization problems.

The quantity of energy could be saved depends on applied energy rationalization measures. The energy rationalization measures are classified into three categories.

Category I. Housekeeping measures, which require little or no investment since they generally involve improvement in maintenance and operating procedures. The expenditure Simple Payback Periods (SPPs) are usually less than one year.

Category II. Process improvement measures to the existing process equipment. They require moderate capital expence, generally to retrofit the existing equipment and the SPPs may range feom 1 to 3 years.

Category III. Major equipment changes. These are measures which provide for the addition of new equipment or the replacement of existing equipment by more efficient.They require larger capital expenditures. Generally, the investment SPPs are more than 5 years.

Due to a difficult economic situation of DPRK, it is not expected that major improvements in energy use will be achieved by implementation of Category III measures (major equipment changes). Priority will be given to the energy improvement measures falling into the Categories I and II (no cost and low cost measures). A list of respective energy improvement measures is given in continuation:

- enhancement of combustion efficiency in boilers and furnaces,
- steam, air, water, and gas leakage elimination in plants,
- loss reduction in steam generation, distribution, and use,
- collection and reuse of condensate,
- heat loss reduction in energy transforming installations,
- improvement of thermal insulation of the plant pipework and installations,
- applications of waste heat recovery systems,
- reduction of heat losses from the structure of industrial and residential buildings,
- application of instruments to support plant energy management and to monitor energy use,

It is estimated that implementation of energy rationalization measures, qualified under Categories I and II, may reduce by at least 40% the excess of energy consumed.

4. Conclusions and Recommendations

The Energy Rationalization Program in DPRK was initiated in 1990s by establishing the Center for Rational Use of Energy, and its successful work in the industrial sector of DPRK. To have further smooth developments in energy rationalization more efforts have to be done. It is expected that the recommendations listed in continuation may facilitate decisions of respective authorities of DPRK, and potential donors to develop and finance of future projects.

1. To absorb the know- how and new trends in world's developments in energy rationalization, the knowledge of foreign languages by DPRK professionals is essential. The current status is unsatisfactory, and the expansion of intensive English language training is recommended.

2. CRUE would continue energy planning activities, and should aim at upgrading the infrastructure of the existing energy information system followed by the development effective tools for it's collection. Therefore, it is recommended that expatriate donors may consider a funding assistance for follow up of this work, particularly for establishment of energy information intranet system linking energy related institutions, major energy producers and consumers, and national information offices.

3. CRUE would continue its energy audit program in industries. However, the expansion of the energy audits to other sectors of economy (Residential, Transport, etc) is recommended. Foreign technical and financial assistance would be required.

4. A number of industries were established in the 1950s (or before). In many cases the technologies applied are outdated and very energy intensive. Therefore, it is recommended to perform a detailed review of the industrial sector to identify plants where old and energy intensive technologies could be replaced by new and energy efficient. Technology replacement may bring large energy savings in a factory, however, its implementation requires considerable investments.

5. It is also recommended to continue research on efficient combustion of local fuels, and develop efficient combustion installations for stoves, boilers, and furnaces.

6. A large number of office and residential buildings had been constructed in DPRK. Most of them are constructed of prefabricated concrete panels without any thermal insulation. Windows are mostly single glazed. Heating installations are of outdated technology, energy inefficient, and material intensive. The potential for energy savings in existing buildings may exceed 50%. The development of a project oriented to energy savings in buildings through reduction of heat losses is recommended.

7. It is stressed that most of materials and equipment (eg. thermal insulation, instruments, etc) required for implementation of energy rationalization projects is not available on the local market, and has to be imported.

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