The IEA CHP and DHC Collaborative

CHP/DHC Country Scorecard: Republic of Korea

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Executive Summary

Korea is the world's thirteenth-largest economy. Over the past decade, the government of Korea has had to reconcile the country's rapid economic growth with increasing energy prices and stricter environmental targets. District heating and cooling (DHC) is now firmly ingrained in the fabric of Korea's energy policies, though the extent to which combined heat and power (CHP) within industrial and commercial applications can contribute to Korea's long-term "green growth" strategy is still unclear. The government already supports CHP through its planning policy and tax incentives, and some further measures are still under development.

Since 2008, the country has faced a series of rolling electricity load-shedding incidents and there is greater caution about the use of nuclear power owing to the Fukushima accident in Japan. This has spurred interest in both large-scale fuel cell applications (especially in Seoul) and wide-spread dissemination of residential fuel cell micro-CHP as a source of reliable power.

However, since the last IEA CHP/DHC Country Scorecard in 2008, overall progress has been relatively slow – CHP capacity as a share of total national electricity generation capacity has remained stagnant slightly above 7%, and some hurdles still exist, for example in the form of limited electricity and natural gas market reforms. Korea's energy markets are based on monopoly incumbents and efforts to open up competition have stagnated.

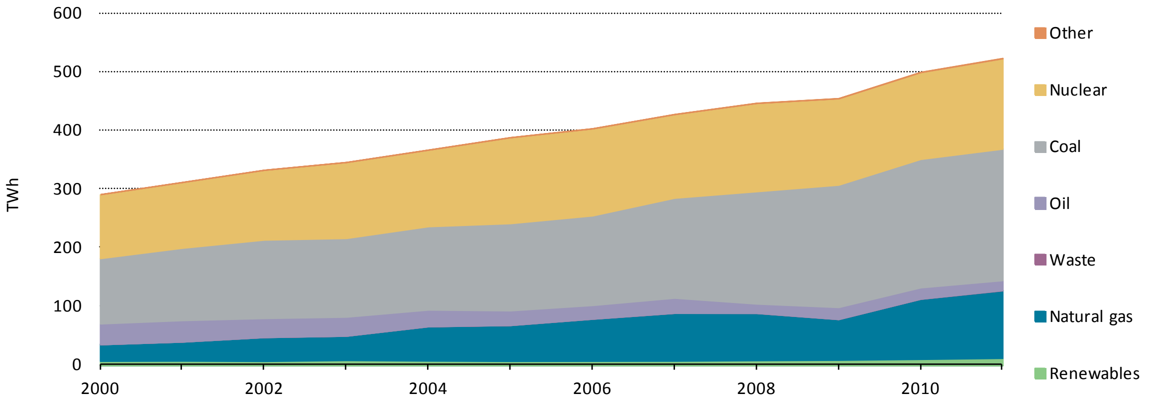
The scope and intent of this report is to summarise the current status of CHP and DHC applications in Korea, to review the impact that government policies have had on CHP and DHC uptake, and to offer possible solutions to the identified barriers currently being faced by the industry.

Overall, it is expected that the DHC market will continue to mature, with some new developments based increasingly on district cooling. Significant opportunities are also likely to arise in the residential and small commercial buildings sectors. The residential and commercial buildings sectors could also create some growth opportunities for CHP, mainly through continued deployment of high-efficiency fuel cell CHP based on government incentives - for instance, the 100 000 target for nation-wide deployment of residential fuel cell CHP by 2020.

Energy Overview

Since its rapid development in the 1970s and 1980s, Korea has become a major economic and industrial power in East Asia. Korea has maintained an annual average GDP growth rate of more than 4% over the past 10 years and emerged from the global economic crisis relatively intact.[1] This growth has been accompanied by a surge in energy demand, met mostly by imports – the country's net energy imports in 2011 totalled 87.4% of its total primary energy supply.[2] Korea is the world's second-largest importer of liquefied natural gas (LNG), behind Japan, and in 2011 consumed 46.8 bcm of LNG (an increase of more than 140% since 2000).[3] Korea is also the world's third largest coal-importer.[4] Korea's only indigenous energy resources include small deposits of anthracite coal and hydropower.

Figure 1 • Korea's gross electricity generation by source, 2000 to 2011



Note: Unless otherwise noted, all tables and figures derive from IEA data.

Key message • Coal, natural gas and oil are dominant in Korea accounting for 68% of total electricity generation.

Of the total 523.3 TWh of electricity produced in 2011, coal is the largest energy source (43%), followed by nuclear (30%), and natural gas (22%).[5] In 2011, CHP accounted for more than 4% of national electricity generation, the majority from CHP plants with integrated district heating and cooling (DHC) applications.[6] Conventional thermal capacity is currently still dominant in Korea (Figure 1), although nuclear power capacity is set to expand over the next decade according to the Fifth Basic Plan of Long-Term Electricity Supply and Demand 2010 (the Fifth BPE). The Sixth BPE 2013 conversely has been more ambiguous about the role of nuclear as a result of the 2011 Fukushima accident in Japan, and a more firm decision will be made by the government of Korea after the National Energy Basic Plan 2013 is released in August 2013.[7]

Korea's renewables market is currently not very active, with about 2% of electricity supply being sourced from renewables (including hydroelectric schemes).[8] The Sixth BPE estimates that within

[1] International Energy Agency (IEA), 2012.

[2] IEA, 2013a.

[3] IEA, 2012.

[4] IEA, 2012.

[5] IEA, 2012a.

[6] Korea Energy Management Corporation (KEMCO), 2013; IEA, 2012a.

[7] Korea Electric Power Corporation (KEPCO), 2012.

[8] KEMCO, 2013.

the period 2013 to 2027, renewable facilities with a total capacity of 27.9 GW are expected to be constructed (accounting for a 12% share of total electricity supply by 2027).[9]

Box 1 • Electricity sector reform efforts

In an attempt to liberalise the electricity market, Korea Electric Power Corporation's (KEPCO) generation assets were divided into six separate subsidiary companies and a cost-based pool bidding mechanism was introduced in 2001. The Electric Power Industry Structuring Plan was announced in 2010 aiming to improve efficiency and to promote competition within the sector. KEPCO, however, retains ownership of 93% of electricity generation capacity and has a total installed capacity of 67 006 MW as of 2011.[10]

In 2010, the average selling price for electricity was KRW 86.8/kWh (USD 0.08/kWh)[11] and the average purchasing price was KRW 75.82/kWh (USD 0.07/kWh), though this is likely to rise as a result of higher LNG, oil and coal prices.[12] Historically, however, end-use electricity tariffs for the industry sector have been low, unlike for residential customers, where electricity prices increase as their consumption grows (progressive scheme) so as to incentivise energy-efficiency.

Wholesale gas prices are determined by the government using a rate of return/cost of service regulatory mechanism. Furthermore, there is local regulation on profit margins of city gas companies. Gas retailing to consumers in Korea is managed by 33 city gas companies.

[9] Korea Institute of Energy Technology Evaluation and Planning (KETEP), 2013.

[10] KEPCO, 2012.

[11] USD 1 = KRW 1 088.84

[12] IEA, 2012.

Climate Change Context

The country joined the UN Framework Convention on Climate Change (UNFCCC) in December 1993, and ratified the Kyoto Protocol in November 2002. Korea has yet to join the 38 Annex 1 countries in committing to the mandatory greenhouse gas emissions (GHG) target. However, prior to the Copenhagen Conference of Parties (COP) in November 2009, the government of Korea confirmed its pledge to a low-carbon economy by declaring a mid-term target of a **30% reduction in GHG by 2020** compared to the forecast business as usual (BAU) scenario, estimated at 813 $MtCO_2$-eq in 2020. Since then, a range of strategies has been introduced and the Greenhouse Gas Inventory and Research Center (GIR), a national GHG emission mitigation think-tank, was formed in 2010. The GIR has set the following targets (see Table 1):

Table 1 • Sectorial GHG Reduction Target by 2020

Industry	Transport	Power generation	Buildings	Agriculture/ Forestry/ Fishery	Waste	Public	National
18.2%	34.3%	26.7%	26.9%	5.2%	12.3%	25.0%	30.0%

Source: Greenhouse Gas Inventory and Research Center, 2011.

The Framework Act on Low Carbon Green Growth entered into force in 2010. The Act is a Five Year Plan which covers the first five years of the larger long-term national strategy for green growth through 2050, integrating the country's medium-term climate change and energy efficiency targets and programmes into a single overarching legal framework. The national strategy's first Five Year Plan has a total budget of KRW 107.4 trillion (USD 98.6 billion)[13] for the period 2009 to 2013.[14] Within the plan, two climate change mitigation policies stand out:

- **Target Management System**, a command-and-control regulation that requires companies that emit more than 25 $ktCO_2$ annually to set an emissions reduction target. Penalties for non-compliance range from KRW 3 million (USD 2 755) to KRW 10 million (USD 9 184) and emission reduction credits cannot be carried forward to the following year. This will be extended to companies that emit more than 15 kt CO_2-eq per year in 2014.[15]
- **Carbon Emission Trading Scheme (ETS),** a cap-and-trade system which will be phased-in in 2015. Emission permits will be allocated through a "grandfathering" method so that 95% of all carbon permits will be offered for free by the government. Companies participating in the ETS do not need to comply with the Target Management System regulation.

[13] 1 USD = 1 088.84 KRW

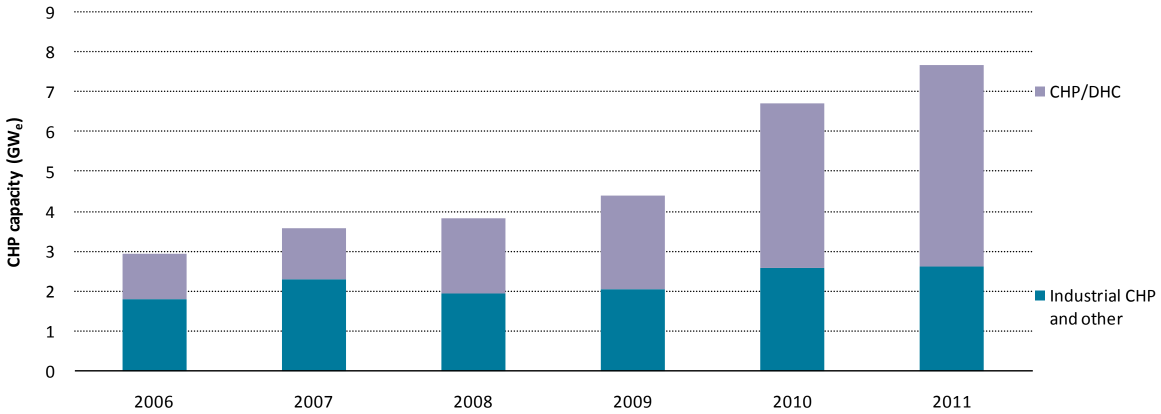
[14] Presidential Commission on Green Growth, 2010; Presidential Commission on Green Growth, 2013.

[15] Korea Institute of Energy Research (KIER), 2013.

CHP Status: Technology, Applications and Market Activity

According to the latest available data, Korea had 7.7 GW_e of installed CHP capacity in 2011, mostly supplying DHC applications.[16] It is estimated that CHP capacity represents over 9% of total net maximum electricity capacity.[17] Since mid-2006, a number of large scale DHC schemes have been developed, providing most of the overall growth, including the Hwaseong plant (512 MW) and Paju plant (515 MW). There has been no significant growth in industrial CHP in the environment of low electricity tariffs (Figure 2).

Figure 2 • Korea's CHP capacity, 2006 to 2011



Note: "Other" represents a minor share in "Industrial CHP and other," and includes small-scale CHP.
Source: KEMCO, 2013.

Key message • Accumulated industrial CHP capacity has remained stagnant since 2006, while CHP capacity additions have seen a surge in the DHC segment from mid-2006 onwards.

Many urban areas are already supplied by CHP/DHC systems, so growth opportunities for commercial and residential CHP systems are modest. However, recent targeting of this segment by developers of commercial-scale fuel cells could drive some additional growth in residential and commercial CHP/DHC capacity.

Industrial applications

Korea has a strong industrial base, and its chemical and metal industries have good potential for CHP. The iron and steel sector is the largest industrial energy consumer, accounting for 23% of the total final industrial energy consumption in 2010.[18] In 2011, total industrial CHP capacity

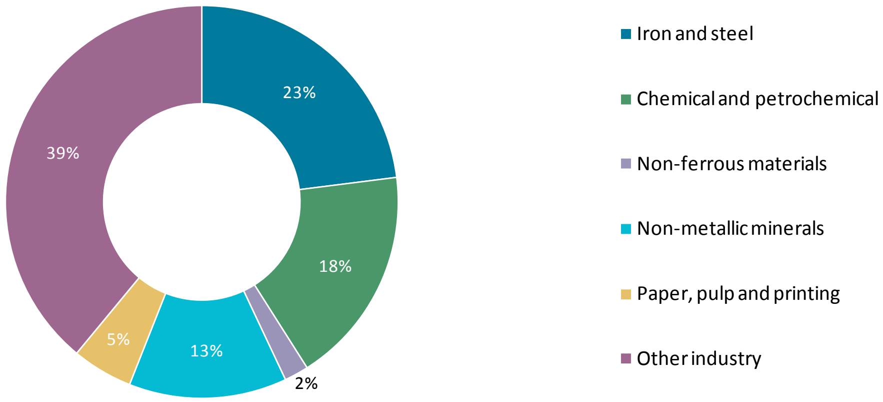
[16] KETEP, 2013.

[17] According to KEMCO statistics (2013), total CHP capacity in 2011 was 7.70 GW_e. IEA statistics (2013a) show that Korea's net maximum electricity generating capacity on 31 December 2011 was 84.7 GW_e [79.0 GW_e (main activity producers) + 5.7 GW_e (autoproducers)]. KEMCO CHP capacity data correspond to the Integrated Energy Network Industry (IEN) which includes other power and heat producers such as DHC suppliers, industrial complex energy suppliers and suppliers operating both kinds of businesses. Thus, KEPCO, commercial autoproducers and many small renewable-origin power producers are not included in the statistics. We therefore assume that national CHP deployment is underestimated in Figure 2.

[18] IEA, 2013a.

stood at 2 387 MW_e.[19] CHP activity in this market segment is, however, modest because of relatively low electricity and high gas prices. Between 2000 and 2010, industrial electricity demand has risen by about 50%; thus, as industrial CHP capacity has remained flat, the share of industrial CHP in overall industrial demand has fallen sharply.[20]

Figure 3 • Industrial final energy consumption by sector in Korea, 2010



Key message • The iron and steel and chemical sectors account for 41% of total industrial final energy use in Korea.

KOGAS (Korea Gas Corporation) is the sole wholesale gas supplier (whose wholesale and retail prices are government-set). Large energy users and owners of CHP plants (>100 MW_e) can purchase their fuel at wholesale prices through bilateral supply contracts with KOGAS, while companies with a portfolio of plants, such as Korea District Heating Corporation (KDHC), can also directly import LNG themselves at wholesale prices. However, only small volumes of gas are purchased on the global LNG market despite this favourable access, making larger sized CHP units much more economically attractive than smaller capacity plants. As of 2013, there are currently discussions being held on whether to extend these prices to smaller plants (<100 MW_e), but nothing has been finalised as of yet.

[19] KEMCO, 2013.

[20] KEMCO, 2013.

Box 2 • Case study 1 – Hyundai Steel waste energy recovery cogeneration project

The Hyundai Steel Waste Energy Recovery Cogeneration Project is a 400 MW plant located in Dangjin Province. It utilises waste gases from steel mill activities, including blast furnace gas and coke oven gas. Some of these are reused by the steel mill for internal uses and the balance is piped to the recipient facility operated by Hyundai Green Power, where it is combusted in boilers to produce steam, some of which in turn is sent back to Hyundai Steel for use in industrial applications and some used to produce electricity for export to the national transmission grid. Heat is also recovered from the electricity generation step for process use.

Through this project, approximately 2.8 million MWh/year of electricity is exported to the grid; 1.29 Mt/year of steam is generated for Hyundai Steel; and an estimated annual carbon reduction of 1.7 Mt CO_2-eq is achieved, part of which is through the recovery of heat from the steam turbine.

However, the project would not have been considered financially attractive without Verified Emissions Reductions (VER) revenue from the voluntary carbon offset market. Compared to the KPX (Korea Power Exchange) Internal Rate of Return (IRR) benchmark for power generation (7.5%), this project's IRR would be about 5.5% without the VERs. Hence, the project voluntarily reduces emissions in exchange for carbon credits. The crediting period runs from March 2010 to March 2020.

Source: Verified Carbon Standard, 2012.

Table 2 • Hyundai Steel waste energy recovery cogeneration project

Financial indicators	Value
Total static investment	KRW 525.93 billion (USD 483 million)
Bus-bar tariff	KRW 81/kWh (USD 0.07/kWh)
Heat price	KRW 25 000/tonne (USD 22.96/tonne)
Income tax	25%
Depreciation	30 years
Maintenance cost	2%
Insurance	KRW 2 billion (USD 1.8 million)
Natural gas cost	KRW 583/Nm^3 (USD 0.54/Nm^3)
Expected VER price	KRW 4 000/ tCO_2-eq (USD 3.67/tCO_2-eq)
IRR without VERs	5.47%
IRR with VERs	7.09%

Note: USD 1 = KRW 1 088.84

Source: Verified Carbon Standard, 2012.

Small-scale CHP applications

At the end of 2011, small-scale CHP capacity was 253 MW_e.[21] The market for small-scale CHP in commercial and public buildings is relatively modest compared to many countries, because many potential sites are already served by CHP/DHC systems. Commercial companies outside these areas mostly use individual gas boilers, which were strongly promoted by city gas companies

[21] KEMCO, 2013.

when LNG became available from 1990. As low power reserves threaten stable power supply during summer peak season, policy-makers recently have more interest in decentralized generation systems like small scale CHP or fuel cells. FuelCell Energy Inc., for example, announced plans in 2012 to fit an accumulated 10 MW of fuel cell CHP systems in hospitals and data centres, and 30 MW in high-rise residential developments.[22]

District heating and cooling applications

DHC is firmly rooted as the main market for CHP within Korea, with a CHP capacity of 5 058 MW_e in 2011.[23] Since the first DHC plant was built in 1985, 22 areas and districts had deployed CHP/DHC by 2012.[24] The DHC sector supplied 2.2 million households with heat, power and cooling in 2011 (14.5% of the population) and the market, though mature, continues to gradually expand, with a growing focus on district cooling in the major towns and cities.[25] District cooling schemes provide cooling services in summer (using the existing heat supply network to drive absorption chillers and cooling towers).

Table 3 • District heating in Korea

Indicators	2007	2009	2011
Total installed DH capacity (MW_{th})	25 456	31 658	38 321
Number of new households connected	106 000	152 000	170 000
Number of DH utilities	30	46	82
Number of DH systems	46	67	112

Source: Euroheat & Power, 2013.

Table 4 • District cooling in Korea

Indicators	2007	2009	2011
Total installed DC capacity (MW_{th})	61	167	1944
Total DC sales (in MWh)	24 073	87 527	181 495
Available DC storage (in MW)	44	44	76.3

Source: Euroheat & Power, 2013.

DHC schemes are usually initiated by the government as a part of the development plan for new urban areas, creating dedicated DHC zones with a single supplier, as it can be difficult to create a competitive market in local heat supply because of the fixed supply infrastructure.

The Korea District Heating Corporation (KDHC) is the main CHP/DHC investment company in Korea. In 2012, it supplied 9 TWh of power and heat sales totalled over 12 million Gcal, 90% of which were to residential consumers.[26]

[22] Combined Heat and Power Association (CHPA), 2012.

[23] KETEP, 2013.

[24] Korea District Heating Corporation (KDHC), 2013.

[25] KETEP, 2013a.

[26] KDHC, 2013.

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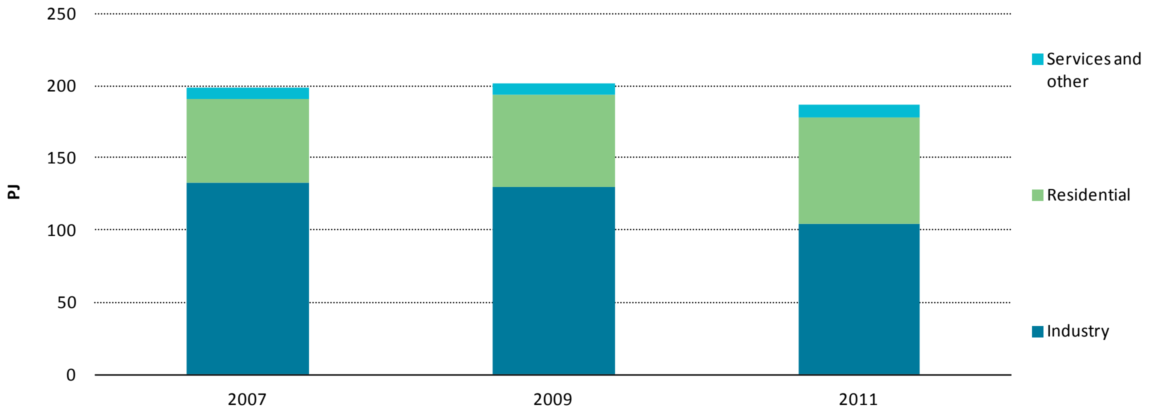
Figure 4 • District heating sales segmented by end-user in Korea

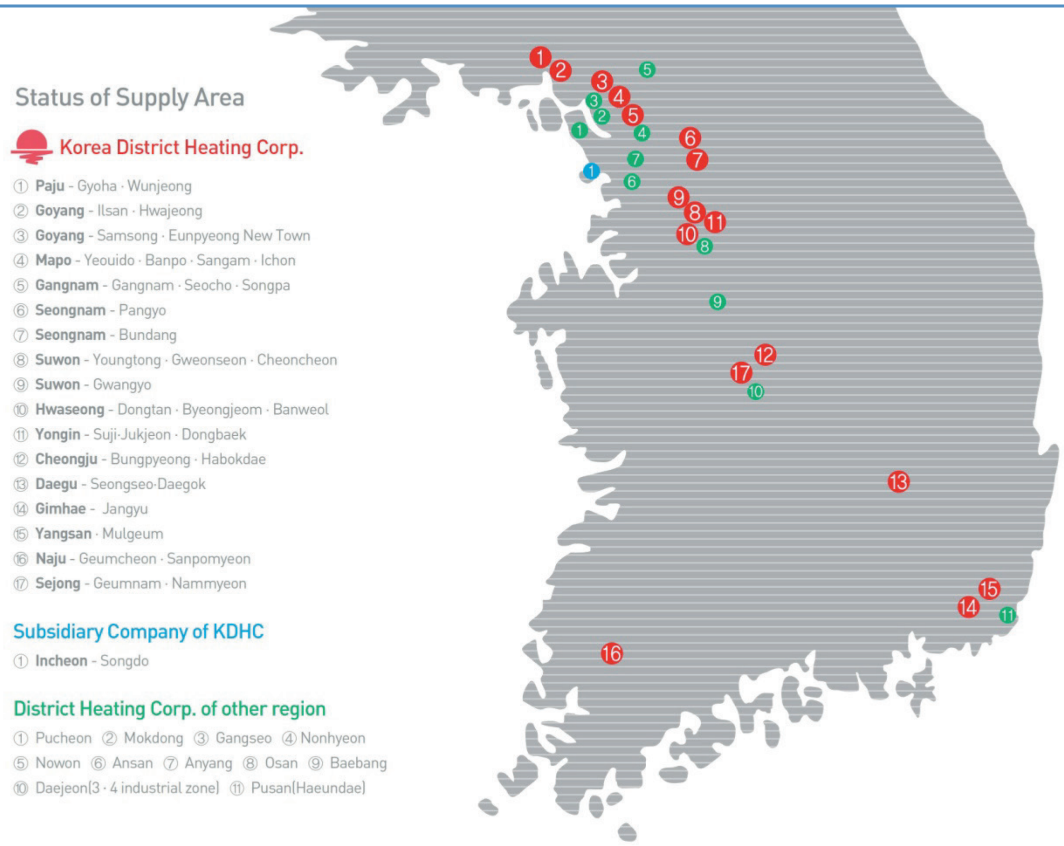


Note: The major increase of CHP/DHC capacity in 2010 and 2011 (see Figure 2) results from new CHP capacity for the New Administrative Complex City which is still under development. 1 GW_e is its authorized total capacity. However, its heat supply in 2011 is still at an early stage, and will increase as development of housing sites progresses. Its full heat supply will likely come after several years, and thus is not captured in Figure 4.

Source: KEMCO, 2013.

Key message • Industrial end-users represent more than half of district heating sales in Korea, though decreasingly so, while the residential segment has seen a rise in DH sales.

Figure 5 • District heating and cooling schemes in Korea



Source: Korea District Heating Corporation, 2013.

Key message • The majority of DHC schemes are located in urban areas in the north west region of Korea and are operated by KDHC.

Box 3 • Case study 2 – KDHC Daegu biomass DHC cogeneration project

KDHC has been operating a 46.5 MW CHP plant (along with a bunker C oil boiler) in its Daegu district heating facility since March 1997. As pro-renewable energy policies strengthened in Korea, KDHC's Daegu branch increasingly utilised renewable energy sources in heat production.

The site has gradually expanded over the years to include a waste incineration system and additional boilers fuelled by liquefied natural gas (LNG) and landfill gas (LFG). The LFG is sourced from the Bangchun-ri Sanitation Garbage Landfill (garbage area 435 096 m^2) managed by Daesung Environment Energy Co, Ltd. Furthermore, in November 2010, KDHC installed a 3 MW_e biomass CHP plant that utilises forest waste (e.g. damaged pine wood nematode) and industrial/municipal waste (e.g. construction woodchips). Auxiliary equipment includes woodchip and ash handling systems.

Since the unit cost of heat generated by LFG or incineration heat is cheaper than that of heat generated from woodchip CHP, LFG and incineration heat are utilised as priority-run heat sources all year long. The wood-chip CHP is not operated during May to October.

In totality, the entire DHC scheme serves 101 712 households (as of December 2012). With the addition of the wood-chip CHP and LFG boiler, the Daegu DHC facility has reduced its carbon emissions by an average of over 86 $MtCO_2$-eq per year since 2011 and reduced its annual energy consumption by an average of over 40 Mtoe (compared to using the LNG boiler to top up the existing facility needs).

Table 5 • KDHC Daegu biomass DHC cogeneration plant

Technology	Power capacity (MW)	Heat capacity (Gcal/h)	Date of completion
CHP	43.5	71	1997
Wood-chip CHP	3	14.5	2010
Waste incineration	-	27	1998
Boiler (only for heating)	(Bunker oil C)	204	1997
	(LNG)	34	2006
	(LFG)	33	2006
Total	46.5	383.5	-

Source: Clean Development Mechanism, 2013.

Biogas CHP

Biogas production is currently limited to landfill gas sites and industries that produce methane as a by-product, such as waste-water treatment plants. Methane recovery is a suitable fuel source for Korea given the country's high population density, rapid economic growth and high degree of urbanisation. These factors contribute to large volumes of refuse along with steady flows of solid wastes into landfill sites which are vital for viable methane recovery projects. As of 2011, 53 large waste-to-energy plants for municipal solid waste are in operation in Korea with a capacity ranging from 50 tonnes per day to 900 tonnes per day, half of which are CHP schemes.[27] Most projects use gas engines or small turbines, with micro-turbine technology being used at smaller landfills and in niche applications.

- Korea has around 296 landfill sites (as of 2009).[28] Most suitable sites already use their gas for power generation, and many for CHP where a suitable heat-load is available.

[27] Ryu, C. and Shin, D, 2013.

[28] Ministry of Environment, 2012.

- Korea had 22 methane-based power stations as of 2010.[29]
- Agricultural biogas production is limited, because anaerobic digestion technology is not common and many farmers are not yet aware of the opportunity. Given that allowing organic wastes and livestock manure to be discharged into waterways was recently banned in 2012 (in keeping with the Waste Resources and Biomass Energy Utilisation Initiatives announced in 2008), this may represent a future modest opportunity for renewable-based CHP using anaerobic gas.

Fuel cell CHP

Fuel cells are considered a new and renewable energy (NRE) source by the Government and are thus not in direct competition with gas turbines and internal combustion engines to power CHP systems. Since the IEA CHP/DHC Korea Scorecard in 2008, this technology has represented an important focus for CHP promotion and market development.

So far, fuel cell CHP systems totalling over 62 MW_e have been installed in Korea.[30] In 2012, POSCO Energy, Korea Hydro Nuclear Power (KHNP), and Samchully Gas Co. began constructing a 58.8 MW_e fuel cell park which involves a series of 2.8 MW natural gas-fuelled fuel cells in the city of Hwaseong.[31] Fully operational in 2013, the fuel cell park is generating 464 GWh of electricity and 227 GWh of heating annually.[32] The power output will be enough to supply 135 000 households within the area and allow KHNP (a subsidiary of KEPCO) to meet the Renewables Portfolio Standard (RPS) requirements.[33]

Overall, there has been growing interest in fuel cell CHP within the business and industrial community who have historically relied on secure grid electricity. This shift stemmed from the unanticipated technical glitches at two KEPCO nuclear power plants in 2011 and the larger-scale Fukushima nuclear plant accident in Japan that same year. Both these incidents have been catalysts for public concern over the reliability of the nation’s electricity supply.

[29] Korea Energy Economics Institute (KEEI), 2013.

[30] Hayes, D., 2012.

[31] Nuclear Energy Agency/Organisation for Economic Cooperation and Development (NEA/OECD), 2012.

[32] NEA/OECD, 2012.

[33] NEA/OECD, 2012.

Government CHP and DHC Promotion Policies

Overall energy policy context

In an attempt to reduce Korea's dependency on fossil fuel imports, the government has developed a number of plans to increase the role of nuclear power and renewable energy. The expansion roadmap of nuclear power generation will prioritise power plant safety and the sustainable use of nuclear energy, which in turn will help position Korea as a global leader in the deployment of nuclear technology, as per the Fourth Comprehensive Nuclear Energy Promotion Plan (CNEPP).[34]

The Renewable Portfolio Standard, introduced in 2012, mandates electric utilities and independent power producers with more than 500 MW of generating capacity to install new and renewable energy (NRE) technologies or to buy renewable energy credits.[35] Overall, they must produce 2% of their electricity via renewable energy in 2012, increasing to 10% by 2022, or purchase credits. The qualifying NREs include: solar, biomass, wind, hydro, fuel cell, gasification or liquefaction of coal, ocean, waste, geothermal, and hydrogen energy. A non-compliance fee is set at no more than 150% of the credit price. This is in line with Korea's target of increasing the share of national electricity generated using NRE sources to 20% by 2020.

The Korean government also initiated a programme to partly subsidise installations (up to 80% of costs) of NRE systems in one million private residential houses, multi-family houses, and public rental houses.[36]

CHP financial support mechanisms

The measures below have contributed to the significant recent development of CHP/DHC, but have had no material impact on the development of industrial CHP, the market for which has not grown significantly since 2000.

Tax reduction on CHP investment costs

Registered businesses are allowed to deduct 10% of the investment they make in Integrated Energy Facilities (IEF) from their taxable profits in the first year of operation, under the Restriction of Special Taxation Act. The corporate tax rate in Korea ranges from 11% to 24.2%, depending on the taxpayer's tax base.

Soft loans for energy-saving facilities

Companies investing in energy-saving facilities can receive a government loan. Loans cover up to 80% of capital investment costs, and support up to 100% for small businesses or non-profit organisations. The annual interest rate follows the Energy Resources Business Special Accounts Management Act and the loan repayment period is five to seven years, with a three-year grace period.

[34] NEA/OECD, 2012.

[35] KIER, 2013.

[36] KEMCO, 2013a.

District heating and cooling support

Integrated energy supply policy

Under the country's Integrated Energy Supply Policy (IESP), once an area has been designated as an 'integrated energy supply area' by the Ministry of Knowledge Economy (MKE) and local municipal authorities, local town-planning must include a heat supply network and all buildings and apartments within the area must be connected either to a DHC network or a community energy system.

Private companies will then bid for the exclusive right to supply heat and electricity within this area.[37] While this regulation does not offer a direct financial incentive, it creates a captive market for CHP and the provision of heat.

Third Basic Supply Plan of District Energy

As part of the Third Basic Supply Plan of District Energy (2009 to 2013), the government of Korea has prioritised the following issues as the backbone of district energy deployment:

- **Resetting of supply criteria** – improving supply efficiency and fuel diversification (including the usage of NRE) and promoting waste-heat utilisation from nearby industrial complexes;
- **Stimulating a competitive environment** – increasing participation of the private sector and reviewing the admission scope of auxiliary heat production plant installations on the customer side, as well as relaxation of market entry barriers;
- **Strengthening district cooling infrastructure** – evaluating all feasible technologies for district cooling and expand network reach. In 2011, a grant programme for district cooling was introduced for firms that work on facility designs and for those who install the equipment (see Table 6).

Table 6 • District cooling grant programme

	Cooling capacity		
	< 704 kW	704 – 1 760 kW	> 1 760 kW
Installation subsidy	17.73 USD/kW	12.66 USD/kW	7.60 USD/kW
Design grant	2.53 USD/kW		

Note: Subsidy amounts and ranges are originally cited in USRt; 1Rt = 3.52 kW.
Source: Korea Institute of Energy Research, 2013.

[37] KIER, 2013.

District heating energy welfare system

To aid low-income households and multi-child families with their energy bills, a support programme has been developed for these specific target groups living in an apartment with heat supplied by KDHC. Table 7 breaks down the available heating bill support programme further. As a consequence of this, since 2010, over USD 9 million has been spent through this programme (Table 8).

Table 7 • Heating bill welfare support programme

Target recipient	New/replaced system	Existing system
Recipient of basic living allowance	USD 9/month	Reduction of USD 2 to 4.5/month, contingent on living space area
Disabled persons (1 to 3 grades)	USD 4.5/month	
Person of national merit		
Independence patriots		
Lower-income families	USD 6.4/month	
Multi-child families	USD 3.6/month	
Small rented housing	Reduction of base rate	Reduction of base rate
Social welfare facilities		

Source: Korea District Heating Corporation, 2013.

Table 8 • Number of applications and funding received through the heating bill welfare support programme

Year	Number of households	Funding support (USD)
2010	118 430	2 670 909
2011	133 286	3 796 364
2012	137 835	4 402 727

Source: Korea District Heating Corporation, 2013.

Apart from the measures listed above, according to KETEP, there are currently other various governmental plans and intentions to continue to stimulate CHP and DHC development. One example is the MKE aim to reinforce and develop the integrated energy business in the Third Master Plan of Integrated Energy Supply (IES) to induce more active participation from private businesses in IES. The government plans to examine measures to compensate plant owners with an electricity selling price that takes into account the 'business value' benefits of CHP, as well as compensation on transmission facilities costs.

Fuel cell strategy

Korea's 2008 National Roadmap for Fuel Cells covers the period from 2009 to 2030. In spite of heavy investment in fuel-cell technology, however, Korea's technological level is still behind that of Japan.[38] For example, Japan introduced fully commercialised residential PEM fuel cell units by 2009 (over 3 000 units had been installed by then around the country) and manufacturers have now moved on to second and third generation polymer electrolyte fuel cell (PEMFC)

[38] Fuel Cell Today, 2010.

technologies, or switched their focus towards residential solid oxide fuel cells (SOFC) which have higher overall efficiencies.[39]

Korea also suffers from an incomplete supply-chain of core parts and materials for fuel cells. Hence, according to the Roadmap, the first priority for the country is to obtain price competitiveness by building national capacity for the development process of core technologies and introducing mass production.[40] This is outlined in the Third Basic Plan for New and Renewable Energy Development and Deployment (2008) along with the government's aim to support the development of 100 kW_e SOFC systems for power generation. As of 2009, the government of Korea has so far spent a total of USD 260 million (35% of the National NRE budget) subsidising research and development initiatives and promotion of fuel cells for both the residential and commercial sectors.[41]

Box 4 • Domestic fuel cell support through the Green Homes Programme

The government has a target for 100 000 one kW fuel cells to be installed in residential areas by 2020 as part of the One Million Green Homes Programme. The government is subsidising 80% of the purchase price of the fuel cell micro-CHP, plus up to an additional 10% subsidy is available from local governments.

The size of the subsidy is falling to 50% between 2013 and 2016, and will then drop to 30% from 2017 to 2020. The Government hopes that the subsidy – intended to lead to greater sales and increased economies of scale for manufacturers – will help reduce the unit price of systems, currently at KRW 35 to 47 million (USD 32 144 to 43 165). Moreover, after sales support is available for households in the form of free warranties (3 to 5 years) and a free one-time change of stack. The roadmap sees trials continuing until 2014, then commercial sales rapidly expanding from 2015 onwards. As of the end of 2012, over 1 000 domestic polymer electrolyte fuel cell (PEMFC) units have been installed.

Since April 2011, all new-builds and recently refurbished or reconstructed public buildings (> 3 000 m^2) must install at least 10% NRE technologies. This mandate will be increased gradually to 20% in 2020, and, since 2012, it applies to buildings over 1 000 m^2. Concurrently, fuel cells have been given the highest weighted value (2.0) in the RPS, which means that power generated by fuel cells will receive a higher premium for electricity produced than other forms of renewable energy. This will drive fuel cell micro-CHP within the next few years.

Note: USD 1 = KRW 1 088.84

Source: Fuel Cell Today, 2010.

At the municipal level, the government of Seoul is supporting the construction of fuel cell-CHP power plants in the city.[42] This started in 2012 and will run to 2014, and the municipal government is targeting an additional total installed capacity of 230 MW. To further support the scheme, some of the fuel cell power plants will be built on city government-owned land. The possibility of introducing a feed-in electricity tariff to CHP operators selling surplus power generation is also being considered by city government officials.

[39] Delta – Energy & Environment, 2013.

[40] KEMCO, 2013a.

[41] KEMCO, 2013a.

[42] City of Seoul, 2009.

Stakeholders

Government

Ministry of Knowledge Economy (MKE) (as of 2013, replaced by the Ministry of Trade, Industry and Energy) is responsible for energy policy. MKE deals with energy policy planning, energy industry regulation, climate change issues, energy sector reform and energy price control. The MKE has a central role in developing and supporting new and efficient energy technologies, including CHP. It is therefore responsible for various support mechanisms. Provincial governments are responsible for regulating retail gas supply, covering roughly the same tasks that MKE has nationally.

The Korea Electricity Commission (KOREC) is in charge of regulating the electricity supply sector, including licensing, supervising market operation, facilitating competition, and restructuring the electricity market. The Commission has a chairperson and eight commissioners, one of whom is permanent and nominated by the MKE, and confirmed by the President.[43]

Public research institutes that support ministries with analysis and development of policy measures include:

- The Korea Energy Economics Institute (KEEI) – KEEI's activities include modelling and forecasting of energy trends to support the development of National Energy Plans and Energy Policy. It deals with the electricity and gas sectors, and has teams specialised in CHP and renewable energy.
- The Korea Institute of Energy Research (KIER) – KIER tests new energy technologies as part of the certification process of the government.
- The Korea Energy Management Corporation (KEMCO) – KEMCO is responsible for collecting data on the energy sector, as well as developing energy policy for the government. This includes DHC and CHP.
- The Korea Gas Safety Corporation (KGS) – KGS is a certification body on gas safety. This organisation tests fuel cell systems of less than 200kW.

The government also partially owns the wholesale energy production and supply companies, including the Korean National Oil Corporation (KNOC), KOGAS and KEPCO.

Industry and the energy sector

The Korea District Heating Corporation (KDHC) – KDHC is the main CHP/DHC company in Korea, and has been closely involved in supporting its further development. Furthermore, together with a Finnish company called Electrowatt-Ekono, KDHC established the Korea District Heating Engineering Corporation (KDHEC) in 1991, which provides district energy-related engineering services and plant construction supervision.

Korea Gas Corporation (KOGAS) – KOGAS is the dominant wholesale supplier of natural gas in Korea, with exclusive responsibility for LNG import, storage, and gas transmission. KOGAS also conducts research on gas-related technologies, and has played a significant role during the fuel cell micro-CHP field trial monitoring.

[43] Korea Electricity Commission (KOREC), 2013.

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Korea Electric Power Corporation (KEPCO) – KEPCO is responsible for power transmission, distribution and sales, while six private companies have been operating its previous generation assets independently from KEPCO since the power sector reform in 2001. The state-owned KEPCO retains ownership of all of these assets and owns the companies that operate these plants. Numerous reform programmes and privatisation plans have been abandoned over the past decade, due to financial hurdles for potential buyers and uncertainty over investment returns. Around 40 other licensed independent power producers exist, but together they have only a 15% share of the generation market.

Pohang Iron and Steel Company (POSCO) – POSCO is the main iron and steel producer and has recently increased its energy related business. POSCO Energy (a subsidiary) is currently Korea's largest independent power producer (with a total installed capacity of 3 344 MW as of 31 December 2011)[44] and a leading supplier of fuel cell CHP systems.[45]

STX Energy – STX Energy is an independent power producer that operates CHP plants in Banwol and Gumi, supplying commercial and small industrial facilities with process steam and electricity.

Fuel cell manufacturers – Korea is home to some of the world's leading fuel cell developers and manufacturers such as Fuel Cell Power, Hyundai Hysco, Hyosung, SK E&S (of SK Group), KEPRI (KEPCO), Samsung, and POSCO among others.

[44] POSCO Energy, 2012.

[45] Fuel Cell Today, 2012.

CHP/DHC Challenges

Low and regulated electricity prices

The existing system for setting wholesale and retail electricity prices does not reflect the full cost of electricity generation, nor reflect its market value. This electricity tariff structure results in cross-subsidisation among different end-user segments, and this, among other aspects, makes it more difficult for CHP project development; for example:

- Low and regulated tariffs in the industrial CHP market do not recognise or reward efficiency measures, so industrial CHP is often not economic;
- CHP/DHC and commercial CHP are less affected, because commercial and residential heat revenues and electricity prices are higher for these sectors than for industries, and can compensate for higher gas prices.

The overall recovery rate of electricity supply (the unit price as a share of the total unit cost) has fallen from 93.8% in 2007 to 90.2% in 2010.[46] In the future, it is possible that the government could slowly increase electricity prices to cover supply costs and reduce differences between tariffs, which could make CHP, particularly in industrial applications, more attractive.

High natural gas prices

The Korean government has regulated gas prices in the hopes of curbing inflation. But with higher LNG import costs, the Korean government has pushed up gas prices since 2011 to help KOGAS, the world's largest buyer of LNG, to recoup hefty losses. Gas prices increased by 17% from November 2010 to October 2011, by another 5.2% in June 2012, and by an additional 4.6% in February 2013.[47, 48] This has worsened the economic viability of CHP, because electricity tariffs for cogeneration in some sectors are not high enough to cover rising fuel costs. As Korea imports almost all its gas, tariffs will continue to follow the upward trend of global market prices, so the situation is unlikely to improve in the short-term. This is paired with a growing trend towards higher seasonal gas consumption due to increasingly frequent severe weather – lower temperatures in winter and higher temperatures in summer – which has boosted energy demand.

[46] IEA, 2012.

[47] KEEI, 2013.

[48] Since July 2012, prices have been charged based on heat calories (MJ) instead of volume (m^3).

CHP Potential and Benefits

There is not yet a comprehensive study of CHP potential in Korea, but if governmental plans for CHP are fully implemented, there is likely be an opportunity for hundreds of new MW_e of CHP, particularly in industry. Only around 2.4 GW_e of industrial CHP is installed, which amounts to about 2.8% of total national electric capacity. This is relatively low compared to other industrialised countries including Germany (4%) and the UK (6%).[49]

Due to limited historic data collection on CHP capacity for the residential and commercial sectors, it has been difficult to monitor progress. However, the projected additions highlighted in Table 4 of the 2008 IEA CHP/DHC Korea Scorecard have been far exceeded for DHC.[50] This is in contrast to Japan, where almost all new CHP capacity has been in industrial and commercial applications, and very little in DHC.

Industrial applications

Many large industries have already successfully developed CHP, but technical potential for more industrial CHP still exists. While little of this is economic under present electricity tariff arrangements, retail electricity prices are projected by KETEP to follow an upward trend – which are set based on cost-of-service and regulation, and thus will be affected by planned power plant capacity expansion – in which case the commercial viability of CHP will improve.

District heating and cooling applications

The continuing growth of urban populations creates an excellent market for CHP/DHC, and the Integrated Energy Policy facilitates this by creating a captive market. The best potential for new CHP/DHC schemes is in Integrated Energy Supply Areas, with district cooling increasingly being the focus of new development. As part of the Third Basic Supply Plan of District Energy, strategies are being developed to expand the usage of district cooling for peak demand reduction during summer. There are ongoing and expected government district cooling pilots to install desiccant chillers in individual apartment blocks that extract moisture from the air to remove humidity. KDHC is exploring ways of using the company's existing heat distribution pipes to supply district cooling in apartment buildings due to the challenges of installing dedicated distribution pipes for cooling only.

Owing to a downturn in Korea’s real estate market, it may prove challenging to significantly increase the rate of distribution of DHC schemes in the next few years. However, considering the growing demand for electricity in metropolitan areas and the saturation of high voltage transmission networks, there will likely have to be increased attention towards locally-generated electricity from CHP/DHC.

Small-scale CHP applications

Interest in commercial CHP is growing, driven by rising city gas prices, which have improved the viability of small CHP systems compared to individual gas boilers, but the wide coverage of DHC in urban areas limits the potential for CHP in individual buildings.

[49] KIER, 2013.

[50] IEA, 2008.

However, individual CHP systems can serve offices, apartment blocks and public buildings in existing cities, where building new DHC schemes may not be economic. According to the Fourth Rational Energy Utilisation Basic Plan (2008 to 2010) and the Green Energy Strategy Roadmap, the government plans to disseminate small-scale CHP units up to a total accumulated capacity of 2 700 MW by 2017.[51] This will be linked to existing NRE policies, which will see the emergence of small-scale CHP using biogas in the foreseeable future. The targeted 100 000 domestic fuel cell systems as part of the One Million Green Homes programme will also increase uptake of micro-CHP.

Biogas CHP

Korea has good biomass and biogas resources, particularly wood, waste and agricultural residues that could be used for CHP. KIER has been testing biomass and biogas CHP systems to license them for the Korean market. Biogas production from industrial and municipal waste processing is rising, supported by government and municipal subsidies, research programmes and feed-in tariffs. This is especially so in the case of refuse-derived fuel (RDF), with CHP systems of less than 100 MW capacity being considered for construction. Growing amounts of biogas should therefore become available for CHP over the next five years, including from the agricultural sector.

[51] KETEP, 2013a.

Summary Policy Recommendations

Overall, there has been good progress in implementing measures to promote efficient DHC, as shown by the growth in the DHC market compared to industrial CHP. The IEA believes that by following these recommendations, Korea can create cost-effective CHP growth opportunities, and realise sizeable additional benefits.

Restructure the regulated electricity and gas tariff systems

An alternative price regulation structure could reward industries adopting energy efficiency measures. It is possible to preserve the overall aim of the regulated electricity price structure and maintain low electricity prices, while incentivising high efficiency CHP. Enabling recipients of very low electricity prices, especially in the industrial sector, to invest in CHP is likely to be one of the most cost-effective ways for the country to achieve its emissions and energy security objectives. Also, extending the wholesale fuel price of natural gas to smaller CHP systems would also have a positive market impact.

Fundamentally, an electricity market reform programme is needed that encompasses the following:

- greater restructuring of KEPCO and revisiting the design of the wholesale market;
- strengthening the independence of the market regulator to enable fair competition, including the removal of barriers to new entrants and third-party access to network infrastructure; and
- creating clear roles for publicly owned and private entities.

Reform of the electricity market should be accompanied by a complementary programme of change in the natural gas market.

Consider specific CHP support options

Feed-in tariffs are a CHP support mechanism which can effectively reward its efficiency benefits. For example, the German CHP Law, based on feed-in tariffs, is one suitable model. Other European countries, including Slovenia, Slovakia and the Czech Republic, have designed feed-in tariffs that vary according to the wholesale electricity price to ensure a specific internal rate of return for CHP projects. All are proving effective.

The government of Korea is preparing the launch of its Emissions Trading System (ETS) which according to Bloomberg financial analysis, could possibly result in the Korean carbon price reaching the penalty level of EUR 90/tCO_2 – surpassing carbon prices in any other existing emission trading scheme. To effectively impact CHP deployment, consistently high permit prices need to be ensured. If the currently proposed system is implemented, a high carbon price is likely. Low-cost options for abatement in the energy and industry sectors are limited and would not be sufficient to meet the target of 30% emissions reduction below BAU levels by 2020.[52] Furthermore, there are restrictions in place on the employment of offset credits from overseas. The rigid and heavily-regulated structure of the Korean energy sector (as discussed above) would also prevent the ETS from being fully effective. Additionally, the effects of carbon pricing on

[52] Bloomberg New Energy Finance, 2013.

industrial competitiveness should be assessed, particularly in export-based economies with strong industrial bases. Thus, priority should be given, in terms of government actions, to the restructuring of the energy sector.

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CHP/DHC Scorecard

To aid in comparing amongst countries, the IEA has developed a scorecard of national CHP and efficient DHC policy efforts that takes into account the effectiveness of the policy framework to create an **energy efficiency rewarding environment which enables realising cost-effective CHP/DHC potentials** from the perspective of past and existing policies, as well as statements and commitments of intent in respect to future related policies.

Each country is given a scorecard rating as follows:

No material policy effort or intent to promote CHP/DHC. The market is not expected to grow for the foreseeable future. Rating: 1

Some minor recognition of the benefits of efficient CHP/DHC, but policies are not fully effective or are otherwise insufficient to promote CHP/DHC deployment. Rating: 2

There is recognition of the benefits of efficient CHP/DHC, accompanied by the introduction of some measures to accelerate the deployment of CHP/DHC, but these technologies are not effectively prioritised compared to other energy solutions. In addition, the country lacks an integrated CHP/DHC policy strategy. As a result, realised CHP/DHC potentials are likely to be modest. Rating: 3

Efficient CHP/DHC and cost-reflective heat and electricity tariffs are an energy policy priority and a series of effective policies are implemented as part of a coherent energy strategy which rewards energy efficiency. Significant growth is expected in the deployment of CHP/DHC. Rating: 4

A world reference in realising CHP/DHC potentials, with a clear and proven strategy for rewarding energy efficiency and ensuring cost-reflective heat and electricity tariffs. CHP/DHC role is expected to remain important with a CHP/DHC policy integrated policy strategy where renewables and energy efficiency support policies complement each other to continuously seek for further deployment opportunities. Rating: 5

Korea's CHP Policy Rating Benchmarked against Global Best Practice: 3

The IEA CHP and DHC Collaborative and IEA-supported Related Initiatives

The IEA CHP and DHC Collaborative was initiated in 2007 with the goal of accelerating deployment of cost-effective, clean CHP and efficient DHC technologies leading to reduced CO_2 emissions and increased overall efficiency of the energy system by an increased use of waste heat and low-carbon renewable energy resources; and of providing a platform for stakeholders to share best practices, policies, experiences and applied solutions on these technologies. Collaborators of this initiative include governments, international organisations, regional industrial associations and the private sector, including equipment suppliers and utility companies.

This initiative has completed so far several publications which provided a vision of CHP and district energy potential, along with an overview of policy best practices and recommendations of options to consider when implementing these policies. The Collaborative results also highlighted the benefits of an integrated energy system approach with CHP technologies assisting in balancing electricity production from variable renewables. For more information about the Collaborative, please visit www.iea.org/chp/.

The Implementing Agreement for a Programme of RD&D on District Heating and Cooling, including the Integration of Combined Heat and Power (DHC IA) is a multilateral technology initiative supported by the IEA. The nine member countries of the DHC IA deal with the design, performance and operation of distribution systems and consumer installations. In operation since 1983, the DHC IA is dedicated to helping make DHC and CHP powerful tools for energy conservation and the reduction of environmental impacts of supplying heat. For more information, please visit www.iea-dhc.org.

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Annex: Korea CHP and DHC background data

Table 9 • CHP installed capacity, electricity production, and heat production, 2000 to 2030

		2000	2006	2008	2009	2010	2011	*2015*	*2020*	*2030*
CHP installed capacity (GW_e)		**3.16**	**5.20**	**5.85**	**5.98**	**6.25**	**7.70**	***9.50***	***10.50***	***12.00***
CHP installed capacity by sector (GW_e)	*Utility*									
	Industrial	1.82	2.43	2.22	2.12	2.37	2.39			
	Small-scale CHP		0.15	0.20	0.21	0.23	0.25			
	DHC	1.33	2.62	3.43	3.64	3.65	5.06			
Total national installed capacity (GW_e)		53.69	70.08	79.86	80.61	84.70	84.65			
CHP installed capacity as % of national total		5.9%	7.4%	7.3%	7.4%	7.4%	9.1%			
CHP total electricity production (TWh)		**11.45**	**17.24**	**21.70**	**22.23**	**18.56**	**23.90**	***31.00***	***34.00***	***39.00***
Total national electricity production (TWh)		290.13	404.02	446.43	454.50	499.51	523.29			
CHP electricity production as % of national total		3.9%	4.3%	4.9%	4.9%	3.7%	4.6%			
CHP total heat production (TWh)		**28.26**	**52.57**	**53.01**	**52.84**	**41.17**	**44.99**	***58.00***	***64.00***	***73.00***

Note: Total CHP heat production statistics from KEMCO include all heat produced by CHP plants. IEA defines CHP total heat production as only heat sold from CHP. CHP heat production as a percentage of the national total is not included, because of this inconsistency between IEA's national production statistics and KEMCO's CHP heat production total.

CHP totals (capacity, heat production, and electricity production) include district heat suppliers, industrial complex energy suppliers and suppliers operating both kinds of businesses. Commercial autoproducers and many small renewable-origin power producers are not included in KEMCO's CHP statistics.

Figures for 2015 to 2030 are estimates. Projections of CHP electricity and heat production consider efficiency improvements over time driven by better optimisation of plants using improved automated control systems as well as technical advancements, and greater flexibility of CHP systems driven by an increasing role for thermal storage, and a growing share of CHP systems in commercial and buildings applications.

Sources: Korea Energy Management Corporation (KEMCO), 2013; International Energy Agency (IEA), 2013.

Table 10 • DHC final supply, 2000 to 2030

		2000	2006	2008	2009	2010	2011	*2015*	*2020*	*2030*
DHC final supply by sector (TWh)	*Industrial*	35.06	53.03	52.29	52.52	47.96	48.27			
	Commercial	0.86	1.62	1.79	1.60	1.89	1.91			
	Public services	0.26	0.49	0.51	0.61	0.59	0.67			
	Residential	12.46	15.90	17.09	17.67	20.06	20.40			
Percentage of population served by DHC		**8.5%**	**11.0%**	**12.3%**	**13.1%**	**13.5%**	**14.5%**			

Source: Korea Energy Management Corporation (KEMCO), 2013.

Acronyms, Abbreviations and Units of Measure

Acronyms and abbreviations

5^{th} BPE	Fifth Basic Plan of Long-Term Electricity Supply and Demand
6^{th} BPE	Sixth Basic Plan of Long-Term Electricity Supply and Demand
BAU	Business as usual
CHP	Combined heat and power
CNEPP	Comprehensive Nuclear Energy Promotion Plan
COP	Conference of Parties
CO_2	Carbon dioxide
DHC	District heating and cooling
ETS	Emissions trading system
FiT	Feed in tariff
GDP	Gross domestic product
GHG	Greenhouse gases
GIR	Greenhouse Gas Inventory and Research Center
H2FC	Hydrogen Economy Fuel Cell
IEF	Integrated Energy Facilities
IES	Integrated Energy Supply
IESP	Integrated Energy Supply Policy
IRR	Internal rate of return
KDHC	Korea District Heating Corporation
KDHEC	Korea District Heating Engineering Corp
KEEI	Korea Energy Economics Institute
KEMCO	Korea Energy Management Corporation
KEPCO	Korea Electric Power Corporation
KETEP	Korea Institute of Energy Technology Evaluation and Planning
KGS	Korea Gas Safety Corporation
KHNP	Korea Hydro Nuclear Power
KIEnergy.net	Korea Integrated Energy Network
KIER	Korea Institute of Energy Research
KNOC	Korea National Oil Corporation
KPX	Korea power exchange
KOGAS	Korea Gas Corporation
KOREC	Korea Electricity Commission
LNG	Liquefied natural gas
LFG	Landfill gas
MCFC	Molten-carbonate fuel cells
MKE	Ministry of Knowledge Economy
NRE	New and renewable energy
PEMFC	Polymer electrolyte fuel cell
POSCO	Pohang Iron and Steel Company
RDF	Refuse-derived fuel
RPS	Renewable Portfolio Standard
SOFC	Solid oxide fuel cell
UNFCCC	United Nations Framework Convention on Climate Change
USRt	United States Refrigeration Ton
VER	Verified emissions reductions

Units of measure

bcm	billion cubic meter
Gcal	gigacalorie
Gcal/h	gigacalorie per hour
GW	gigawatt
GW_e	gigawatt electric
$ktCO_2$	kiltonne of CO_2
$ktCO_2$-eq	kilotonne of CO_2 equivalent
kW	kilowatt
KRW	South Korean won
m^2	square metre
MJ	megajoule
Mt	megatonne
Mtoe	million tonne of oil equivalent
$MtCO_2$-eq	million tonne of CO_2 equivalent
MW	megawatt
MW_e	megawatt electric
MW_{th}	megawatt thermal
Nm^3	normal cubic metre
tCO_2	tonne of CO_2
tCO_2-eq	tonne of CO_2 equivalent
toe	tonne of oil equivalent
TWh	terawatt hour
USD	US dollar

References

Bloomberg New Energy Finance and Ernst & Young (2013), "South Korea's Emissions Trading Scheme," White Paper, 10 May 2013, http://about.bnef.com/white-papers/south-koreas-emissions-trading-scheme/.

The City of Seoul (2009), *Master Plan for Low-Carbon, Green Growth*, Seoul, www.fuelcellseminar.com/media/5505/kim_10_19_2010.pdf.

Clean Development Mechanism (CDM) (2013), "KDHC Daegu Biomass Cogeneration Project" http://cdm.unfccc.int/Projects/DB/TUEV-SUED1314347134.39/view.

Combined Heat and Power Association (CHPA) (2012), "South Korea plans 29 fuel cell CHP parks," www.chpa.co.uk/south-korea-plan-29-fuel-cell-chp-parks_840.html.

Delta Energy & Environment (2013), *Evaluation of fuel cell cost evolution*, Edinburgh.

Euroheat & Power (2013), *District heating and cooling - Country by Country Survey*, Euroheat & Power, Brussels.

Fuel Cell Today (2010), "Korean Fuel Cell R&D Roadmap," Survey of Korea 2010, www.fuelcelltoday.com/media/1156544/2010_survey_of_korea.pdf.

Fuel Cell Today (2012), "FuelCell Energy announces fuel cell manufacturing agreement with POSCO Energy," Fuel Cell Today, www.fuelcelltoday.com/news-events/news-archive/2012/november.

Greenhouse Gas Inventory and Research Center (2011), *Roadmap for Realization of 2020 Low Carbon, Green Society*, Seoul, www.gir.go.kr/eng/main.do?language=en_US.

Hayes, D. (2012), "South Korea's ambitious plans for fuel cell CHP capacity," Cogeneration & On-site Power Production (COSPP), www.cospp.com/articles/print/volume-13/issue-4/features/south-koreas-ambitious-plans-for-fuel-cell-chp-capacity.html.

International Energy Agency (2008), *CHP/DHC Country Scorecard: Republic of Korea*, OECD/IEA, Paris.

IEA (2012), *Energy Policies of IEA Countries: The Republic of Korea 2012 Review*, OECD/IEA, Paris.

IEA (2013), *Electricity Information (2013 Edition)*, OECD/IEA, Paris.

IEA (2013a), *Energy Balances of OECD Countries (2013 Edition)*, OECD/IEA, Paris.

Kang, J., Korea Energy Economics Institute (KEEI) (2013), Personal Communication.

Kim, B., Korea District Heating Corporation (KDHC) (2013), Personal Communication.

Korea Electricity Commission (KOREC) (2013), "Organization and Duties," http://korec.go.kr/.

Korea Energy Management Corporation (KEMCO) (2013), www.kemco.or.kr/.

Korea Energy Management Corporation (KEMCO) (2013a), *Overview of New and Renewable Energy in Korea 2013*, Gyeonggi-Do, Republic of Korea.

Korea Electric Power Corporation (KEPCO) (2012), *2012 Annual Report*, http://cyber.kepco.co.kr/kepco/EN/C/htmlView/ENCBHP003.do?menuCd=EN030204.

Korea District Heating Corporation (KDHC) (2013), "Status to Supply – Korea," www.kdhc.co.kr/eng/.

Korea Institute of Energy Research (KIER) representative (2013), Personal Communication.

Korea Institute of Energy Technology Evaluation and Planning (KETEP) (2013), "6th Basic Plan for Long-Term Electricity Supply and Demand," Activities: News, www.ketep.re.kr/english/activities/view.jsp?str_page=1&bbs_sid=8549&bbs_cd=energy&flag=1.

KETEP (2013a), www.ketep.re.kr/english/index.jsp.

Ministry of Environment (2012), *Environmental Statistics Yearbook 2011 Vol.2*, Seoul, http://eng.me.go.kr/board.do?method=list&bbsCode=law_law_statistics.

Nuclear Energy Agency (NEA)/Organisation for Economic Cooperation and Development (OECD) (2012), *Nuclear Energy Data 2012*, OECD, Paris.

POSCO Energy (2012), "World Best + Green Energy Company: 2011 Sustainability Report," POSCO Energy, Gyeonggi, www.poscoenergy.com/_ui/pdf/report_eng.pdf.

Presidential Commission on Green Growth (2010), *Road to Our Future: Green Growth, National Strategy and the Five-Year Plan (2009-2013)*, Seoul.

Presidential Commission on Green Growth (2013), "5개년계획" (Five Year Plan), www.greengrowth.go.kr/?page_id=2450.

Ryu, C. and Shin, D. (2013), "Combined Heat and Power from Municipal Solid Waste: Current Status and Issues in South Korea," Energies, Vol. 6, No. 1, pp. 45-57.

Verified Carbon Standard (2012), "Hyundai Steel Waste Energy Cogeneration Project, South Korea," https://vcsprojectdatabase2.apx.com/myModule/Interactive.asp?Tab=Projects&a=2&i=786&lat=36%2E982852&lon=126%2E70322&bp=1.

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