INTERNATIONAL ENERGY AGENCY
INSIGHTS SERIES 2013

The IEA CHP and DHC Collaborative

CHP/DHC Country Scorecard: Japan

Araceli Fernandez Pales

INTERNATIONAL ENERGY AGENCY

The International Energy Agency (IEA), an autonomous agency, was established in November 1974. Its primary mandate was – and is – two-fold: to promote energy security amongst its member countries through collective response to physical disruptions in oil supply, and provide authoritative research and analysis on ways to ensure reliable, affordable and clean energy for its 28 member countries and beyond. The IEA carries out a comprehensive programme of energy co-operation among its member countries, each of which is obliged to hold oil stocks equivalent to 90 days of its net imports. The Agency's aims include the following objectives:

- Secure member countries' access to reliable and ample supplies of all forms of energy; in particular, through maintaining effective emergency response capabilities in case of oil supply disruptions.
- Promote sustainable energy policies that spur economic growth and environmental protection in a global context – particularly in terms of reducing greenhouse-gas emissions that contribute to climate change.
- Improve transparency of international markets through collection and analysis of energy data.
- Support global collaboration on energy technology to secure future energy supplies and mitigate their environmental impact, including through improved energy efficiency and development and deployment of low-carbon technologies.
- Find solutions to global energy challenges through engagement and dialogue with non-member countries, industry, international organisations and other stakeholders.

IEA member countries:

Australia
Austria
Belgium
Canada
Czech Republic
Denmark
Finland
France
Germany
Greece
Hungary
Ireland
Italy
Japan
Korea (Republic of)
Luxembourg
Netherlands
New Zealand
Norway
Poland
Portugal
Slovak Republic
Spain
Sweden
Switzerland
Turkey
United Kingdom
United States

The European Commission also participates in the work of the IEA.

International Energy Agency
9 rue de la Fédération
75739 Paris Cedex 15, France

www.iea.org

Table of Contents

List of Figures

List of Tables

List of Boxes

Acknowledgements

This report was prepared by Araceli Fernandez Pales and Kira West of the IEA. The consulting firm Delta-Energy & Environment provided research, analysis and drafting support. The author would like to thank Akiyuki Fujita of Advanced Cogeneration and Energy Utilization Center Japan (ACEJ), the Japanese New Energy and Industrial Technology Development Organisation (NEDO) and Yasushi Santo formerly of Osaka Gas for the assistance and expertise provided for this report. Thanks are also due to IEA colleagues such as Jean-François Gagné, Didier Houssin, Uwe Remme, Cecilia Tam, Robert Tromop and Christelle Verstraeten who provided thoughtful comments, and to Angela Gosmann for layout assistance.

Questions and comments about this document should be sent to:

Araceli Fernandez Pales

International Energy Agency

9, rue de la Fédération

75739 Paris Cedex 15

France

Email: araceli.fernandezpales@iea.org

Executive Summary

Japan is one of the most energy-efficient countries in the world. The government has supported increasingly ambitious energy efficiency targets as a strategy to reduce dependency on energy imports, to address climate change, and more recently to reduce the impact of electricity outages following the Fukushima accident.

Combined heat and power (CHP) deployment has increased over the past two decades. However, CHP capacity has remained stagnant at around 9.52 GW since 2007 and now provides less than 4% of the country's electricity production.[1] This slowdown has come about as a result of the adverse evolution of energy prices and a shift of policy focus towards residential micro-CHP.

Government support has been an essential driver of CHP deployment, including favourable subsidies and tax reductions for CHP. In addition, government-led research and development funding has helped create a cluster of specialised technology companies that mainly target the residential CHP sector with micro-internal combustion engines and fuel cells.

Since the publication of the IEA CHP/DHC Country Scorecard for Japan in 2008, by far the most important development has been the Great Earthquake of March 2011, leaving many of the nation's power plants damaged, most notably in the Fukushima region. It has also led to Japan's re-evaluation of nuclear power within the electricity sector, which has prompted greater attention towards other power generation sources, including renewables and natural gas (including gas-fired CHP) – especially since power utilities have begun raising electricity prices; and also since some end users are embracing energy-saving measures.

Looking forward, the market for CHP and DHC is likely to develop around a number of opportunities:

- The possible introduction of new policy incentives.
- The continued policy and gas industry focus on micro-CHP.
- The likely relevant role of 'flexible' CHP systems that can provide electricity system balancing as smart energy networks evolve. This could include an emerging role for district heating and cooling (DHC).

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

[1] Advanced Cogeneration and Energy Utilization Center Japan (ACEJ), 2012.

Energy Overview

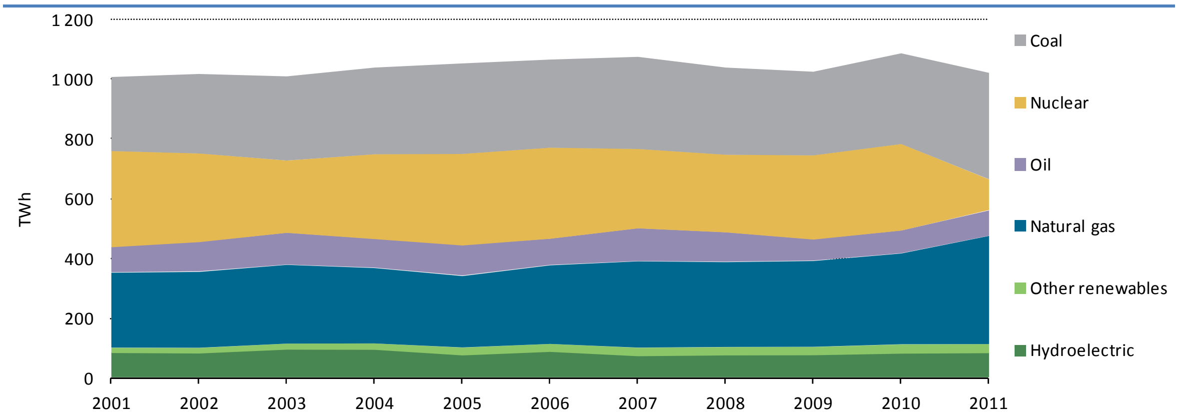
While Japan accounts for the most power consumption in OECD Asia, its electricity demand growth rate is amongst the lowest in the region (projected average of less than 0.7% pa from 2007 to 2018).[2] Government energy policy revolves around small indigenous energy reserves and a high dependency on energy imports. In 2011, Japan imported 89% of its net energy needs.[3]

Ten privately-owned power companies lead Japan's electricity industry accounting for 208 TW in 2012, 85% of the country's total installed generation capacity.[4] These companies also control Japan's transmission and distribution infrastructure – greater grids integration and competition is difficult provided electricity systems rely on different standards (west Japan grids are based on 110 V whereas east Japan use 220 V).

The role of nuclear power

On 11 March 2011, a 9.0 magnitude earthquake and tsunami hit the Japanese coastline, resulting in a series of plant failures at the Fukushima Nuclear Power Plant. This caused the immediate shutdown of over 10 GW of power generating capacity at several nuclear power stations, with the last reactor going offline in May 2012. Since then, Japan's nuclear power plants have been put offline for maintenance inspections, with increasing efforts to substitute nuclear generation with other sources, including natural gas, low-sulphur crude oil and fuel oil, as well as policy efforts to expand the use of intermittent renewables (Figure 1). Only Ohi Units 3 and 4 are in operation (as of March 2013).

Figure 1 • Total electricity generation by source in Japan (inclusive of electric utilities and industry-owned plants)



Note: Unless otherwise noted, all tables and figures in this book derive form IEA data and analysis.
Source: World Bank, 2012; Japan Electric Power Information Center, Inc. (JEPIC), 2012.

Key message • Fukushima accident has re-shaped the electricity generation source mix in Japan.

[2] Federation of Electric Power Companies of Japan (FEPC), 2010.

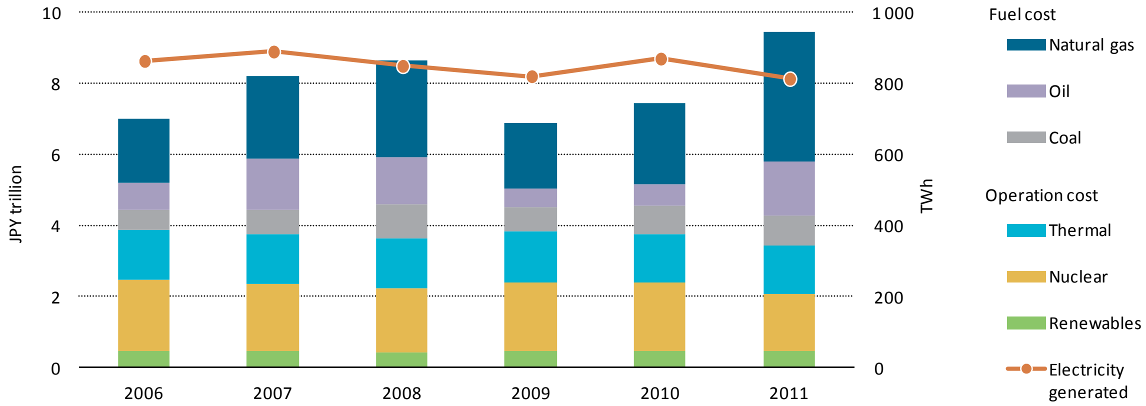
[3] World Bank, 2012.

[4] Japan Electric Power Information Center, Inc. (JEPIC), 2012.

However, since December 2012, the newly elected Liberal Democratic Party has taken a more optimistic view than its predecessor on restarting idle nuclear power plants once relevant safety checks have been confirmed. This view has been taken in light of high domestic electricity prices in 2011 (which increased by over 20% in commercial and industrial sectors)[5] and fossil fuel import costs which have contributed significantly to the trade deficits of 2011 and 2012.[6]

High fossil fuel costs for thermal power generation are the main reason for a rise in total electricity generation costs (Figure 2) – both in 2008 when crude oil prices soared and from 2011 onwards when nuclear power was offset by high-priced fossil fuel imports.

Figure 2 • Total cost of electricity generation (average of 12 utilities)



Source: Institute for Energy Economics in Japan (IEEJ), 2012.

Key message • Total electricity generation cost increased by a factor of 1.27 in 2011 compared to 2010 due to high fossil fuel costs.

[5] Shimizu, S., 2013.

[6] Okuya, T., 2012.

Climate Change Context

As a Party to the Kyoto Protocol under the United Nations Framework Convention on Climate Change, Japan pledged to reduce its greenhouse gas (GHG) emissions in the period 2008 to 2012 to 6% below its 1990 levels. Without carbon sinks and credits from Kyoto mechanisms, it has proved to be too difficult for Japan to meet this target, primarily because the country is already significantly energy-efficient, leaving limited potential for improvement and also because 2012 saw the highest GHG emissions of the commitment period from increased fossil fuel use in the power generation sector.

During the UN General Assembly in September 2009, then Prime Minister Yukio Hatoyama declared a 25% GHG emissions reduction target relative to 1990 levels by 2020, with increased nuclear power utilisation as a key strategy in achieving this. Due to post-March 2011 policy changes and public sentiment against nuclear power dependency in Japan, the current government will review this target and its strategies prior to the 19th Conference of the Parties (COP19).

Japan's climate change strategy depends on the promotion of technological innovation and energy efficiency, and includes the following programmes and targets:

- The **Cool Earth 50 – Innovative Technologies Development Project**, formulated in March 2008, is a strategy to move beyond Kyoto and set a GHG global target and roadmap for 2050.
- Japan's **voluntary emissions trading system** started in September 2005 with 32 participants in the first round and 59 participants in the second round. This trading scheme is a pilot experiment for a future mandatory emissions trading scheme and concluded in March 2013.
- The Japanese New Energy and Industrial Technology Development Organisation (NEDO) purchases GHG credits from the **Clean Development Mechanism** (CDM), as commissioned by METI. There is a JPY 139.1 billion (USD 1.4 billion) budget for credit purchase in the period 2008 to 2012.[7]

[7] New Energy and Industrial Technology Development Organisation (NEDO), 2013.

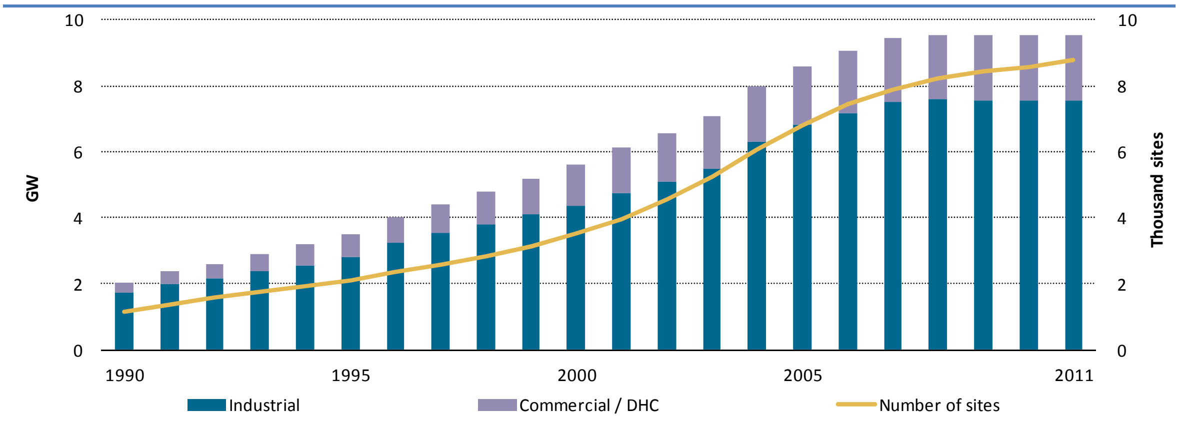
CHP Status: Technology, Applications and Market Activity

Japan has increased its CHP capacity substantially over the last 20 years (Figure 3), and CHP's share in total national capacity has also increased. By March 2012, over 9.5 GW of CHP (8 783 sites) provided about 3.5% of the country's electricity production.[8]

CHP capacity growth has decelerated since 2007 and new annual additions have been below 200 MW since 2008. This was caused by the relatively high LNG import prices and low electricity prices (pre-March 2011) that reduced the competitiveness of gas-fired CHP. The 2008 economic crisis had also significantly affected the industrial sector, slowing large-capacity CHP additions. In 2009 and 2010, losses of CHP capacity were recorded for the industry sector (11 MW and 37 MW respectively).[9]

Up to now, the development of CHP capacity in DHC systems has been very limited in Japan. ACEJ data suggests only around 300 MW_e of installed capacity exist.[10]

Figure 3 • CHP accumulated installed capacity and total number of sites in Japan



Source: Advanced Cogeneration and Energy Utilization Center Japan (ACEJ), 2012.

Note: CHP installed in DHC schemes has been added to the total accumulated commercial installed capacity.

Key message • CHP capacity development in Japan has remained stagnant since 2007 despite the addition of sites with CHP installations, mainly due to adverse energy prices and reduced heat demand load.

Over the period since 1990, there has been a trend towards smaller projects – the average size of projects has decreased from around 2.4 MW_e in 1996 to around 0.25 MW_e in 2008.[11] This reflects a trend of moving from larger industrial projects to smaller commercial and residential projects.

Three major CHP technologies are used in Japan: gas turbines (43%), predominantly in industrial applications; diesel engines (31%) and gas engines (25%), mainly in commercial applications. The main fuel inputs for CHP in Japan are natural gas (49%) and oil (35%) consistent with Japan's import fuel mix, with others playing a lesser role.[12]

---

[8] Advanced Cogeneration and Energy Utilization Center Japan (ACEJ), 2012.

[9] New Energy and Industrial Technology Development Organisation (NEDO), 2013.

[10] Advanced Cogeneration and Energy Utilization Center Japan (ACEJ), 2012.

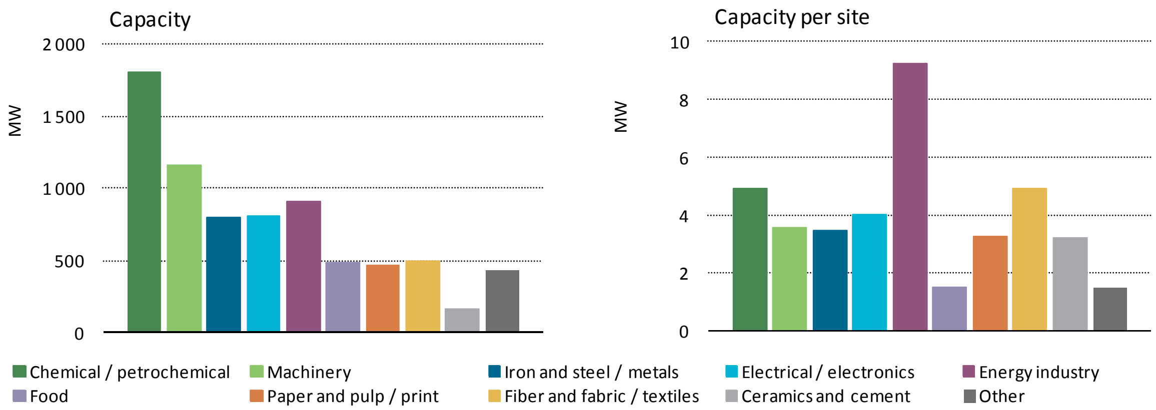
[11] Advanced Cogeneration and Energy Utilization Center Japan (ACEJ), 2012.

[12] Advanced Cogeneration and Energy Utilization Center Japan (ACEJ), 2012.

Industrial applications

Industrial CHP installations represent 79% of total national installed capacity.[13] The chemical and machinery sectors lead in terms of capacity (Figure 4), and the food sector has the highest number of installed units. Japan's largest CHP generating facilities are installed at oil refineries and other energy industry sites. Market activity in the industrial sector has been limited in recent years, because high oil prices have driven up the operating costs of oil-fired CHP. Also, the global economic crisis was a catalyst for some businesses with CHP facilities to transfer production from their factories in Japan to other countries within the region.

Figure 4 • Status of industrial CHP installations in 2012



Source: Advanced Cogeneration and Energy Utilization Center Japan (ACEJ), 2012.

Key message • Refineries and other energy-related industries in Japan install the largest capacity CHP units; however the greatest installed CHP electrical capacity is in the chemical/petrochemical sector.

Commercial and residential applications

CHP systems are installed in more commercial premises than in the industrial sector (in terms of site numbers) which represent 22% of the national installed CHP capacity.[14] Hospitals and other healthcare facilities comprise the largest CHP users, with 367 MW of commercial CHP capacity (Figure 5). The power disruption caused by the March 2011 earthquake has made many commercial end users seek back-up technologies that can act as an electricity supply hedge, for example using alternative more resilient power supply systems for data centres and hospitals. CHP is a potential beneficiary of such strategies even though gas distribution networks may also be affected in the event of a natural disaster.

Table 1 • Estimated number of installed micro-CHP units (as of end of 2012)

CHP technology type	Quantity (in units)	Average unit purchase price (USD)
1 kW Gas engines	126 000	8 000 to10 000
(0.70 – 0.75 kW) Residential polymer electrolyte fuel cell (PEFC)	50 000	20 000 to 25 000
(0.70 – 0.75 kW) Residential solid oxide fuel cell (SOFC)	>5 000	28 000

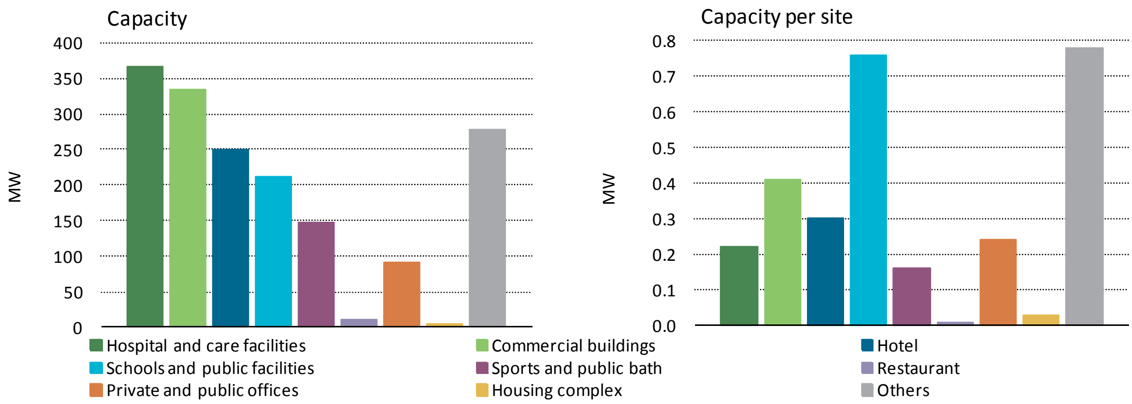
Source: Delta-Energy & Environment, 2013.

[13] Advanced Cogeneration and Energy Utilization Center Japan (ACEJ), 2012.

[14] Fujita, A, 2012.

Japan is the world leader in the development and implementation of micro-CHP technologies at the household level. Micro-CHP technologies are designed for single households, and are typically smaller than 5 kW_e. This includes gas-engine CHP and fuel cell CHP, among others. Japanese gas companies have installed over 170 000 micro-CHP systems in residential applications (Table 1), with an overall capacity of around 200 MW_e, or less than 3% of the country's installed CHP.

Figure 5 • Status of commercial CHP installations (1 696 MW_e capacity as of 2012)



Source: Advanced Cogeneration and Energy Utilization Center Japan (ACEJ), 2012.

Key message • Among commercial projects, schools and public facilities have the largest existing average capacity per site.

Box 1 • Case study 1: On-going performance improvements in residential micro-CHP systems

In Japan, gas engine micro-CHP accounts for the largest share of residential micro-CHP sales, though it is gradually losing its dominant position to fuel cell micro-CHP. In response, Japanese manufacturers have improved the performance of their gas engine products as a catalyst for higher sales. Example strategies include launching a newer model that can operate during a power cut (via a 'manually-operated recoil starter'); downsizing the main body by miniaturizing engine auxiliaries; or by promoting the utilization of complementary energy-saving water heaters. In terms of conversion efficiencies, there is limited room for improvements compared to fuel cell micro-CHP systems in the future. As of now though, residential gas engine micro-CHP units still have higher thermal efficiencies (typical thermal efficiencies of 59.0 to 66.0% and electrical efficiencies of 26.0 to 26.3%) than fuel cell micro-CHP units.

Since its introduction, fuel cell micro-CHP technology in Japan has also been continually improved. The first PEMFC products only gained full-commercialization in Japan in 2009 - based around PEM stacks rated between 0.7 to 1.0 kW_e (0.9 to 1.4 kW_{th}). Since then, next-generation products have been released with higher efficiencies and greater estimated stack lifetimes. Typically, PEMFC have electrical efficiencies around 38.5 to 39.0% and thermal efficiencies of 55.5 to 60.0%. The use of a platinum catalyst in the PEMFC stack has a significant impact on the amount that stack / fuel cell module costs can fall in future.

SOFC, introduced later in 2011, achieves the highest electrical efficiencies of all the micro-CHP options in Japan – up to 45%+ (LHV). This sets it apart in terms of electrical output and as being an option for electrically-led micro-CHP; opening up new opportunities for the CHP market. SOFC shares the same issues with PEMFC with regards to the high product costs at present.

Fuel cells have the lowest pollution and particulate emissions of all the CHP technologies. Another performance comparison covers maintenance obligations – whereas fuel cells have less mechanical complexity, gas engine micro-CHP systems need relatively more maintenance due to more moving parts and fluids (oil, coolant, lubricant etc). Having said that, Japanese gas engine micro-CHP products currently offer the longest maintenance intervals of up to 10 000 hours. Similar products in other regions typically offer 3 500 to 8 000 hours.

Source: Delta-Energy & Environment, 2013.

Box 2 • Case study 2: St. Marianna University School of Medicine Hospital

The St. Marianna University School of Medicine Hospital in Kawasaki functions as both a healthcare facility and medical university. The hospital's main building has 28 sections for treatment and is able to accept up to 700 patients for hospitalisation. It operates 24 hours a day. Thus, it has heavy demands for energy and hot water. When the hospital/university's former energy centre, based on conventional separate generation, was experiencing wear-and-tear due to age, administrators installed two CHP gas engines. The new energy centre began operating in February 2008 and now supplies energy for the entire hospital/university's 130 000 m^2 area. The waste heat from this power generating system is used to produce hot and cold water as well as steam and, so far, the centre has achieved 14% primary energy savings and 24% less CO_2 emissions compared to previous operations.

Table 2 • St. Marianna University School of Medicine Hospital power generating system

Unit	Specification	Number of units
Gas engine CHP	Electricity output: 2 430 kW Fuel: City gas (adjusted natural gas) Power generation efficiency: 41.6% Waste heat recovery efficiency: 38.6%	2
Exhaust gas boiler	1.8 tonne/h	2
Absorption chiller (utilizing engine exhaust gas and heat)	Cooling capacity: 2 216 kW Heating capacity: 1 454 kW	2
Absorption chiller	Cooling capacity: 2 813 kW Steam consumption: 2.96 ton/h	2
Others	Boiler, turbochiller	

Sources: GE, 2013; Energy Advance Co., Ltd., 2013.

District heating & cooling applications

District heating and cooling (DHC) is currently uncommon in Japan, but it is slowly increasing in prevalence. The government is working to expand its role through Area Energy Networks, representing a combination of traditional small-scale district heating and cooling networks linked to existing distributed heat resources. These networks are included in Japan's Kyoto Protocol Target Achievement Plan and are incentivised through low-interest loans and subsidies.

An example of a DHC scheme is the Shinjuku development (2.2 million m^2) which is the largest DHC scheme in Japan as of 2013. It has two gas turbine CHP units installed (4.5 MW and 4 MW capacity) which generates 33 GWh electricity and 225 TJ heat annually.[15] It is aided by additional centrifugal chillers, steam absorption chillers, and boilers.

Since the construction of the first district heating and cooling system in 1970 at the Senri Chuo Area in Osaka, the number of licensed DHC utilities has increased to 81 as of 2011 (Table 3). The predominant fuel source for DHC is natural gas and cooling represents the bulk of end-use consumption of DHC (Figure 6).

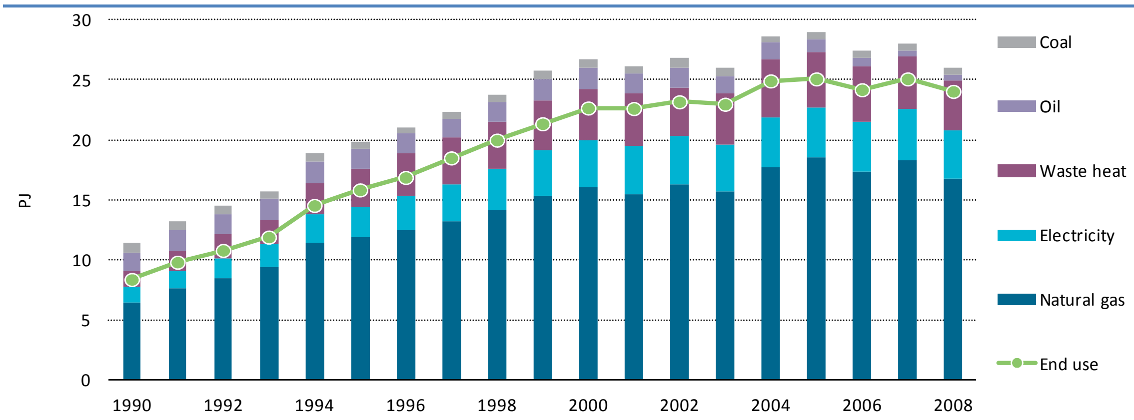
[15] Shimizu, S., 2013.

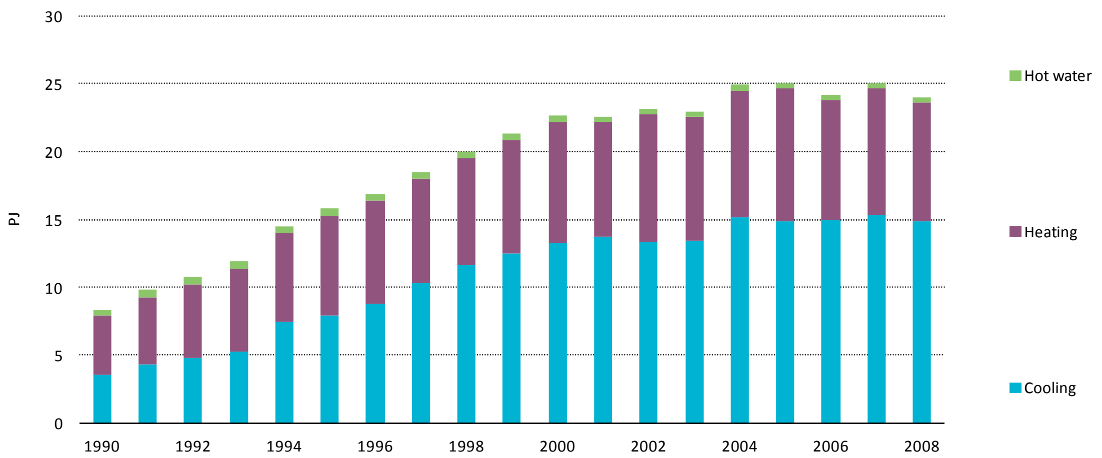
Table 3 • District heating and cooling in Japan (as of 2011)

Indicators	Unit	Quantity
Number of DHC utilities		81
Number of customers for buildings (business)		1 321
Total DH sales	TJ	21 958
Trench length for transport and distribution network (one way)	km	656
Total installed DH capacity	MW_{th}	4 248
Total installed DC capacity	MW_{th}	3 960

Source: Euroheat & Power, 2013.

Figure 6 • Fuel input for district heating and cooling and end-user consumption





Note: Data only available to 2008.

Source: Japan Heat Supply Business Association (JHSBA), 2012.

Key message • The dominant fuel input for district heating and cooling in Japan is natural gas. The bulk of the energy provided by district heating and cooling schemes in Japan is used for cooling.

Government CHP and DHC Promotion Policies

Overall energy policy context

For many years, Japan's energy policy put equal importance on the three core areas of energy security: supply, efficiency and sustainability. The Strategic Energy Plan, introduced in June 2010, sets out specific supply and demand-side measures in achieving a national energy self-sufficiency ratio of 36% by 2030 (from 18% in 2010). This is an ambitious target given that Japan is reliant on energy imports for 89% of its energy needs. One of the R&D priorities in order to help achieve the targets includes increasing the efficiency of buildings and appliances in the residential and commercial sectors (an area where micro-CHP can be beneficial).

After the March 2011 Fukushima accident, priorities had to change towards more aggressive demand reduction and the development of new forms of electricity generation. The government mandated that all businesses other than the smallest ones must reduce their consumption by 15% in energy-constrained areas. "Setsuden" (power-saving) campaigns were also launched to cut energy use during peak times in summer and winter.

For electricity generation, a Feed-in-Tariff (FiT) mechanism was introduced in 2012 to encourage renewable energy deployment. Under the scheme, power utilities must buy electricity produced from applicable renewable sources generated at certified facilities at a premium price for a given period. This does not include fossil fuel-based CHP. However, this is stimulating greater activity in the biomass-fuelled CHP market. For example, the Japan Paper and Pulp Co. recently announced plans to develop a 5 MW_e fluidised bed gasification project based on timber from forest thinning, with its generated power sold to Kyushu Electric under a FiT scheme (rates for which are USD 0.4/kWh for gasification, USD 0.1/kWh for use of recycled wood, and USD 0.3/kWh for other biomass fuel types).[16]

Support for CHP

CHP support schemes have in the past tended to focus on capital rather than operating expenditure. For example, investment subsidies, grants and low-interest loans for emerging CHP technologies are used as the main tools, rather than a feed-in tariff approach. Most of the support has been applied to micro-CHP, and examples are given later in the report.

Subsidies are regularly reviewed in light of technological and economic developments, but the government is committed to some continued support for CHP. For example, in October 2012, the criteria of the Electric Power Act was revised to enable owners of large CHP plants to sell electricity generated to contracted third party users as long as their supply capacity exceeds 50% of the end-users' demand capacity. Previously, such plants could only sell electricity if they could provide all the electricity needed by the end-user.

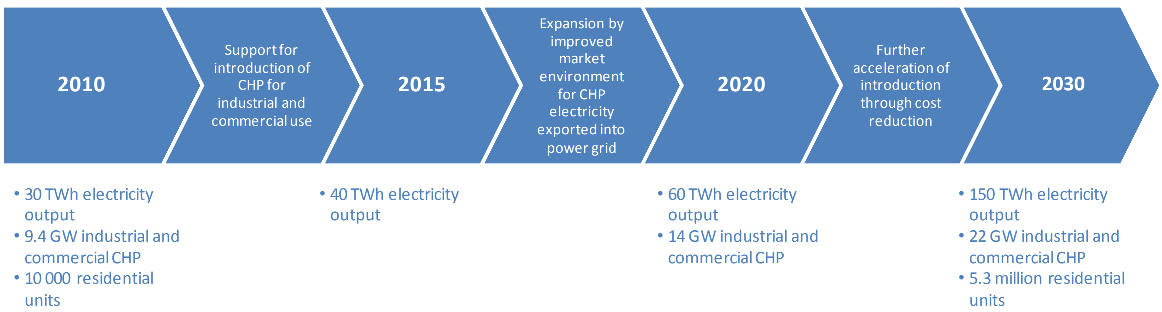
In July 2012, the Japanese Ministry of Economy, Trade, and Industry (METI) identified key issues to be addressed for further CHP promotion. This involves improvements in the value of CHP-produced electricity through reform efforts of the electricity markets and reduction of fuel prices. A strategic office within METI has also been established to focus specifically on the promotion of CHP installations in Japan. In September 2012, the Energy and Environment Council defined a CHP roadmap for 2030 (Figure 7).

[16] Asia Biomass Office, 2012.

This Roadmap aims to more than double existing industrial and commercial CHP capacity to 22 GW in 2030. To achieve this, an average investment of JPY 0.2 trillion (USD 2 billion) per year (during the period 2010 to 2020) and JPY 0.4 trillion (USD 4 billion) per year (2020 to 2030) will be required.[17] The highlights of this roadmap are as follows:

- Up to a five-fold increase in CHP output based on a 250% increase in capacity – the electrical efficiency of CHP will have to increase greatly, likely based on gas engine and fuel cell systems.
- A dramatic increase in residential systems, potentially providing almost half of the new capacity.
- Industrial CHP will grow as part of this trajectory, but the great majority of the market development will be in non-industrial sectors.
- The achievement of these targets will require either significant improvement in energy price conditions, and/or strong policy intervention.

Figure 7 • CHP expansion roadmap to 2030



Source: Energy and Environment Council, Government of Japan, 2012.

Key message • The CHP expansion roadmap in Japan foresees a fivefold increase in electricity generation based on CHP by 2030.

Project to develop a distributed power system

One important new initiative is the promotion and installation of distributed power generation systems which will contribute to grid stabilisation, energy efficiency and electricity supply-demand balance. Assistance is to be prioritised for commercial and industrial facilities able to supply electricity to the grid. For FY2013, the proposed project budget is JPY 24.97 billion (USD 250 million).[18] From this budget, JPY 6 billion (USD 60 million) will be allocated to grants promoting the development of high-efficiency natural gas CHP systems that can contribute to electricity supply security in the commercial and industrial sectors.

[17] Okuya, T., 2012.

[18] METI, 2013.

Green investment tax incentive

In order to promote the further introduction and development of renewable energy and energy-saving equipment (including CHP) in small and medium-sized businesses, two support options have been provided: a 7% acquisition cost tax exemption (only firms whose paid-in capital is JPY 30 million (USD 307 690) or less are eligible); or an accelerated tax depreciation of the total purchase value of the CHP equipment. The eligible period is 30 June 2011 to 31 March 2015. Furthermore, there is a one-sixth discount on the amount of base tax payable for three years (applicable to CHP).[19]

R&D on high-efficiency natural gas CHP and fuel cells

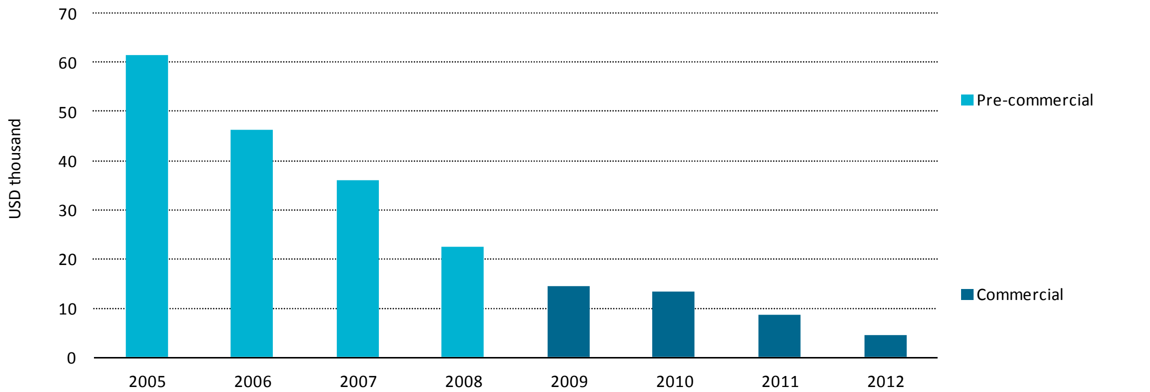
The Japanese government actively supports R&D, demonstration and commercialisation of gas-engine and fuel cell CHP systems for residential use. A budget of about JPY 25 billion (USD 257 million) has been assigned to residential fuel cell systems.[20]

Box 3 • Development of fuel cell CHP technology

The main demonstration programme in Japan was the *Large-scale Stationary Fuel Cell Demonstration Project*. Beginning in 2005, it ran for 4 years until the commercialisation of PEFC in 2009. This included a high-profile installation at the Japanese prime minister's residence in 2005. The Project was funded by METI and administered by NEDO and the New Energy Foundation (NEF). METI aims to replicate its PEFC success with SOFC (solid oxide fuel cell) systems which has higher electrical efficiencies. SOFC-based systems entered mass-field trial deployment in 2007 and started commercial sales in 2011-2012.

While the total amount of subsidy allocated for residential fuel cell systems has increased – due to the increase of installed fuel cell units whose subsidy applications have been accepted the subsidy given for each unit has been gradually declining on an annual (and now even an intra-annual) basis (Figure 8). Further reduction is anticipated, with complete phase-out by 2016.

Figure 8 • Residential fuel cell systems subsidy per unit – commercial and pre-commercial systems



Note: The subsidy value relates to what was available per installation at the end of the year. USD values derived from original JPY figures via exchange rate on 30 April 2013, USD 1 = JPY 97.44.

Source: Delta-Energy & Environment, 2013.

[19] Shimizu, S., 2013.

[20] Shimizu, S., 2013.

Administrative procedures for grid connection

The government has introduced special procedures for grid connection of CHP systems. This includes the development of guidelines for the administrative arrangements required for electricity supply to third parties. While this is a move in the right direction, some critics have argued that the guidelines require excessively technical specifications, artificially raising the cost of CHP in the market place.

Residential CHP systems still have to meet technical standards for grid connection, but do not require on-site inspection by the utility. Simplified network access is particularly important for supporting the emerging market for small and micro-CHP systems to avoid high administrative overheads during the installation. While residential micro-CHP units can be grid-connected, the selling of power to the grid has historically required the consent of utilities, which is not normally given.

Low-interest loans for district energy

This scheme provided by the Development Bank of Japan consists of low-interest loans for DHC projects. The objective is to reduce costs and accelerate investment in DHC. The scheme targets electricity utilities in particular.

Reform of the electricity sector

In February 2013, a METI panel of experts compiled a report proposing the reform of the electricity sector, which recommended the liberalisation of power retailing, the separation of power generation and transmission, and wide area operation of the power transmission network. These proposed policy changes have high potential to change the current energy industry's structure (which is partly characterised by strong competition between power companies and gas companies) and the role of and expectations for CHP in the next years. The impact of energy market liberalisation on CHP development globally has been mixed. For example, since energy market reforms took place in Europe after 1995 to 2000, the CHP deployment has barely grown. Much depends on the details of implementation, such as licensing rules relating to the ease with which self-generators can export electricity to third parties.

Stakeholders

Government

The **Ministry of Economy, Trade and Industry (METI)** is responsible for CHP policy in Japan, and has a range of documents and resources available on its website. The **New Energy and Industrial Technology Development Organisation (NEDO)** is responsible for the government's programmes on new CHP technology development and promotion, such as fuel cells. Japan's electricity policies are administered by the Agency for Natural Resources and Energy, a subdivision of the Ministry of Environment and METI.

Industry

Many companies are involved in the CHP market. These include: Panasonic, ENEOS Celltech, Toshiba, Yanmar, Honda, Toyota-Aisin, JX Nippon Oil & Energy as manufacturers and after-sales service providers – and Tokyo Gas, Osaka Gas, Toho Gas, Saibu Gas, Hokkaido Gas, Nippon Gas, Nippon Oil, Cosmo Oil, Showa Shell Sekiyu, Eneurge, and Saisan. Tokyo Gas and Osaka Gas account for around 70% of the Japanese gas market. In Japan, an integrated gas value chain has been driving gas utilities to bring fuel cell-micro CHP to market.

Non-governmental organisations

The **Advanced Cogeneration and Energy Utilization Center Japan (ACEJ)** and **Japan Gas Association (JGA)** are the main industry bodies providing information on CHP and promoting its successful development in the future. These organisations, in cooperation with the CHP industry, launched the CHP/DHC Promotion Consortium of Japan in March 2008, to support the IEA CHP/DHC Collaborative at the G8 meeting in Hokkaido in July 2008.

CHP/DHC Challenges

The relative costs of CHP alternatives have an important impact on the commercial viability of CHP. In Japan, the energy sector is characterised by a dependence on primary energy imports and high fuel prices. Both of these factors improve the payback and energy efficiency benefits of CHP systems relative to power only generation based on fossil fuels, but also increase **operation costs**, which are substantially higher than in other G8 countries.

Barriers for industrial CHP and commercial CHP

The key barrier to the wider deployment of industrial and commercial CHP has been the adverse trend in energy prices (fuel prices rising relative to electricity prices) that has significantly reduced the economic incentive for energy users to invest. In particular, there has been no incentive to size CHP systems to export electricity because of the low prices paid for that energy. Most Japanese CHP plants, therefore, only generate heat and power for their own consumption, even though larger benefits could be achieved if they could supply heat and power to other users or the network.

Also, many industrial areas have limited access to natural gas pipelines, which has a significant impact on the diffusion of large capacity gas-fired CHP (Figure 9).

Barriers for micro-CHP

The limited availability of competitively priced micro-CHP units is the key barrier for the residential CHP sector. For residential fuel cells, reducing the cost and increasing the lifetime and efficiency of the units is particularly important. A possible solution to this is system simplification and improvements in manufacturing. For example, Toshiba claims to have reduced costs by 30% between 2009 and 2012 by reducing the number of cells by 15%, the amount of platinum by 20%, and particularly the number of BoP (balance of plant) components by 40%. Overall, installed fuel cell micro-CHP costs need to fall by at least another 50% to become cost-competitive at today's energy prices without subsidy.

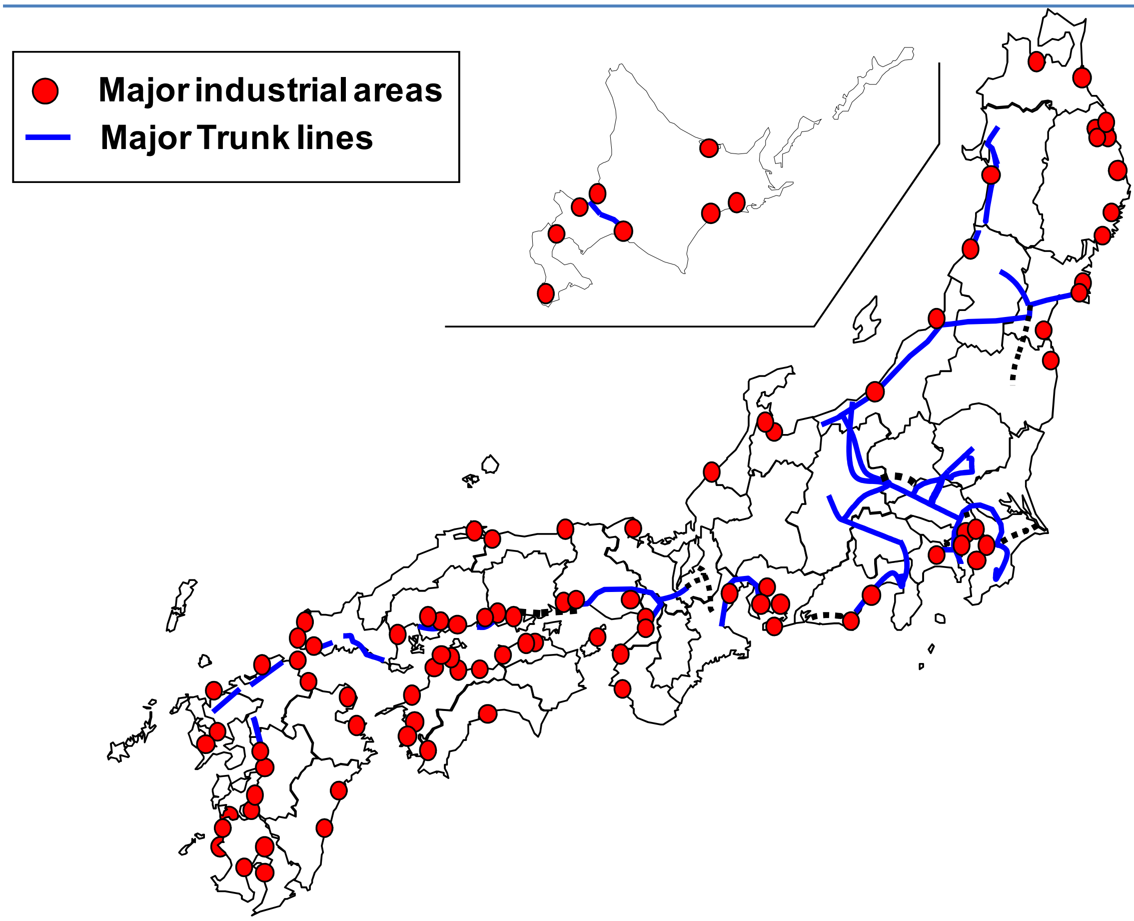
Barriers for district heating and cooling/energy area networks

City gas utilities are interested in promoting CHP/DHC for smart energy networks and have already submitted proposals. However, the relatively high capital costs associated with DHC infrastructure development represent the main challenge. The current approach of targeting smaller heating networks, for example the stand-alone energy network project at Roppongi Hills, provides one mechanism for overcoming this barrier. Opportunities are also being explored to use CHP and waste heat from several sources in cities – for example, from garbage or waste treatment station biogas.

Lack of an approved method for crediting the efficiency of CHP in environmental policies

The environmental benefits, and in particular, the CO_2 emissions reduction of CHP systems, have not yet been accurately defined in Japan. This lack of an approved methodology, which could serve as a basis for new incentives, reduces the likely impact of CHP as a GHG reduction solution.

Figure 9 • Natural gas pipeline network in Japan



Source: Japan Gas Association, 2013.

Key message • Many industrial areas are dispersed in locations outside the reach of major natural gas trunk lines.

CHP/DHC Potential and Benefits

In its 2008 report on the global potential for CHP, the IEA identified a potential of 26 GW_e of CHP by 2030, delivering more than 20% reduction in CO_2 emissions from new CHP compared to new alternative forms of heat and electricity supply.[21] That study identified only around 10% of the new potential to exist in industrial applications, with the great majority existing in residential and commercial buildings. There is also opportunity for new CHP/DHC development, though this will depend on the availability of suitable heat demand, the relative prices of oil and gas, the further cost reductions for renewables, and the longer term scale of nuclear plants in the generation mix, as well as the degree of financial support available to correspond with the high capital costs of DHC infrastructure.

Since March 2011, there has been a much greater sense of value attached to energy supply security. In the aftermath of the earthquake and tsunami, it was not only the nuclear power plants that were susceptible; several thermal power plants were also damaged, causing electricity blackouts. In certain affected areas, CHP systems continued to provide electricity to healthcare facilities and evacuation centres - a good example of the diversification provided by CHP plants. Thus, many industrial and commercial businesses are currently installing CHP (gas engine and turbine).

This trend may continue at least for several years but, ultimately, the delivery of the potential figure given above, or the roadmap target identified earlier, will likely require both policy intervention and a reverse in the trend towards more adverse energy price conditions for CHP plants.

METI has ambitious long-term targets for fuel cell micro-CHP sales. These are to have 1.4 million units installed by 2020, and 5.3 million by 2030 (both cumulative). To hit 1.4 million by 2020, an annual growth rate of 27% from 2013 onwards will be required. Given present expansion rates, METI's targets are achievable, in spite of its intention to gradually phase-out subsidies and hence eliminate one of the strongest drivers for uptake of fuel cell micro-CHP in Japan. By then the subsidy will have completed its role of creating demand for the technology and stimulating economies of scale for manufacturers.

[21] IEA, 2008.

Summary Policy Recommendations

Up until around 2005, CHP was a success story in Japan, based largely on its ability to significantly reduce energy costs for industrial and commercial users. Since then, energy prices have moved in such a way as to erode these benefits. The IEA believes that Japan can again realise CHP growth opportunities, and realize sizeable additional benefits, by:

- Ensuring transparent gas and electricity prices and credit for GHG mitigation for electricity exported from CHP projects;
- Evaluate a feed-in tariff for high efficiency CHP, similar to the FiT in Germany;
- Continuing to support R&D programmes, particularly to create even more efficient and competitively-priced fuel cell micro-CHP; and
- Launching programmes to support the adoption of a broader portfolio of CHP technologies, including the development of 'smart' CHP systems.

Higher prices for CHP exported electricity

Over time, the most significant barrier to most CHP projects in most countries has been the low prices paid for electricity exported to the grid from CHP projects. Electricity market reform, including greater price transparency and competition in generation and wholesale markets is critical to ensure that greater value is associated with exported electricity.

Ensuring the place of CHP within electricity and gas sector reform

With the government's plans to reform the country's energy sector being discussed, it is important for international experience and lessons on the impacts on CHP market development to be taken into account to ensure that the technology can flourish and not be constrained.

Assessment of feed-in tariffs for high efficiency CHP

Another means of ensuring higher value for exported electricity is through the introduction of feed-in tariffs for electricity generated by and exported from high efficiency CHP systems, similar to those applied in Germany, Slovenia and elsewhere. The introduction of a tradable certificate system, like the systems used in Italy and Belgium, should be analysed.

Continuing to support R&D that will reduce costs of fuel cell micro-CHP systems

SOFC micro-CHP systems can operate with electrical efficiencies up to 60%, compared to a maximum of 30% for internal combustion engine-based micro-CHP – hence the commitment in Japan to commercialise fuel cell products. But fuel cell micro-CHP costs have further to fall before they achieve full competitiveness with conventional systems. It is likely that this can be achieved but continuing support will likely be needed. If so, Japan will likely see the benefits of a strong export industry as other global markets for micro-CHP develop.

Accelerating the development of 'smart' CHP systems

There has been a growing focus in recent years on the development of 'smart energy networks' in Japan, integrating renewable energy systems with automated electricity and heat supply networks, alongside 'smart building' energy management systems. CHP systems that can, for example, be optimised to operate according to electricity and heat price signals in coordination with other flexible energy technologies as heat storage, could have an integral role to play in such networks, and could likely represent an attractive export opportunity for the country.

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

Japan's CHP Policy Rating Benchmarked against Global Best Practice: 3.5

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.

Annex: Japan CHP and DHC Background Data

Table 4 • CHP installed capacity, 2000 to 2030

		2000	2006	2008	2009	2010	2011	*2015*	*2020*	*2030*
Total CHP installed capacity (GW_e)		**5.63**	**9.04**	**9.55**	**9.55**	**9.52**	**9.55**	***12.00***	***15.00***	***25.00***
CHP installed capacity by sector (GW_e)	*Industrial*	4.38	7.18	7.58	7.57	7.53	7.53	*8.40*	*8.00*	*10.00*
	Residential & Commercial	1.25	1.86	1.97	1.98	1.99	1.70	*3.22*	*6.20*	*13.00*
	DHC	incl. in R&C	incl. in R&C	incl. in R&C	incl. in R&C	incl. in R&C	0.32	*0.38*	*0.80*	*2.00*
CHP installed capacity by size (GW_e)	*1 kW_e – 10 MW_e*						2.00	*2.45*	*2.50*	*3.50*
	10 MW_e – 100 MW_e						5.55	*6.82*	*8.50*	*11.50*
	100 MW_e – 500 MW_e						2.00	*2.73*	*4.00*	*10.00*
CHP installed capacity by application (GW_e)	*Steam turbines*						0.05	*0.11*	*0.15*	*0.20*
	Gas turbines						4.16	*4.91*	*6.00*	*8.00*
	Internal combustion engines						5.33	*6.98*	*8.85*	*16.80*
Total national net maximum electricity generating capacity on 31 Dec. (GW_e)		**260.49**	**278.71**	**280.53**	**284.49**	**287.03**				
CHP as % of total installed capacity		**2.2%**	**3.2%**	**3.4%**	**3.4%**	**3.3%**				

Note: Data on CHP total heat production and electricity production were not available for Japan. IEA statistics were used for national capacity only; ACEJ provided all other data. Figures for 2015 to 2030 are estimates by IEA.

Sources: ACEJ, 2013; IEA, 2012.

Table 5 • DHC fuel inputs (GWh) – by fuel type, 2000 to 2030

		2000	2006	2008	2009	2010	2011	*2015*	*2020*	*2030*
Total DHC fuel input (GWh)		**7 420**	**7 631**	**7 229**	**-**	**-**	**-**	***7 500***	***16 000***	***40 000***
DHC fuel inputs (GWh)	*Natural gas*	4 450	4 820	4 650	-	-	-	*5 000*	*12 000*	*32 000*
	Coal	180	177	160	-	-	-	-	-	-
	Oil	508	207	127	-	-	-	-	-	-
	Biogas/Biomass	-	-	-	-	-	-	*200*	*1 500*	*5 500*
	Other	2 282	2 428	2 292	-	-	-	*2 300*	*2 500*	*2 500*

Note: No data available for 2009 to 2011. Figures for 2015 to 2030 are estimates by IEA.

Source: Japan Heat Supply Business Association, 2012.

Acronyms, Abbreviations and Units of Measure

Acronyms and abbreviations

ACEJ	Advanced Cogeneration and Energy Utilization Center Japan
BoP	Balance of plant
CHP	Combined heat and power
CO_2	Carbon dioxide
DHC	District heating and cooling
FEPC	Federation of Electric Power Companies
FiT	Feed in tariff
GHG	Greenhouse gases
IEEJ	Institute for Energy Economics in Japan
JGA	Japan Gas Association
LPG	Liquefied petroleum gas
METI	Ministry of Environment and Ministry of Economy, Trade and Industry
NEDO	New Energy and Industrial Technology Development Organisation
PEFC	Polymer electrolyte fuel cell
SOFC	Solid oxide fuel cell

Units of measure

km	kilometre
kW	kilowatt
kW_e	kilowatt electric
MW	megawatt
MW_e	megawatt electric
MW_{th}	megawatt thermal
GW	gigawatt
GW_e	gigawatt electric
GWh	gigawatt hour
m^2	square metre
V	volt
¥	yen

References

Aisin Seiki (2011), "Towards the realization of an energy-saving and comfortable lifestyle," *Aisin Report 2011 Digest Edition,* www.aisin.com/finance/ir/report/11annual/pdf/aisin_ar2011_0912_e.pdf.

Asia Biomass Office (2012), "Japan's Feed-in Tariff System to Start on July 1, 2012," www.asiabiomass.jp/english/topics/1206_06.html.

Delta-Energy & Environment (2013), *Evaluation of fuel cell cost evolution*, Edinburgh, www.delta-ee.com.

Energy Advance Co., Ltd. (ENAC) (2013), "Customer Solution Case Studies: St. Marianna University School of Medicine, System Flow," www.energy-advance.co.jp/onsite/case04/.

Energy and Environment Council, Government of Japan (2012), "Innovative Strategy for Energy and the Environment," www.un.org/esa/socdev/egms/docs/2012/greenjobs/enablingenvironment.pdf.

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

Federation of Electric Power Companies of Japan (FEPC) (2010), *Electricity Review Japan,* www.fepc.or.jp/english/library/electricity_eview_japan/__icsFiles/afieldfile/2010/09/07/ERJ2010_2.pdf.

Fujita, A. (2012), *CHP market and policy movements in Japan*, Advanced Cogeneration and Energy Utilization Center Japan (ACEJ), Tokyo.

General Electric (GE) (2013), "Jenbacher engine turns waste into value," www.ge-cities.com/files/projects/ge_japancasestudy0.pdf.

International Energy Agency (IEA) (2008*), Combined Heat and Power: Evaluating the benefits of greater global investment*, OECD/IEA, Paris.

IEA (2012a), *Electricity Information (2012 Edition)*, OECD/IEA, Paris.

Japan Electric Power Information Center, Inc. (JEPIC) (2012), "Operating and Financial Data," www.jepic.or.jp/en/data/EPIJJapanData.pdf.

Japan Gas Association (2013), *CHP market and policy movement in Japan*, www.iea.org/media/workshops/2013/chp/SeitaShimizu.pdf.

Japan Heat Supply Business Association (2012), "District Heating and Cooling in Japan," www.jdhc.or.jp/en/area.html.

Matsuo, Y., Yamaguchi, Y. and T. Murakami (2012), *Historical trends in Japan's power generation costs and their influence on finance in the electric industry*, Institute for Energy Economics in Japan (IEEJ), Tokyo.

Ministry of Economy, Trade, and Industry (METI) (2013), *FY2013 Budget Request,* Ministry of Economy, Trade and Industry, Tokyo.

Okuya, T. (2012), *Direction of Japan's energy policy*, Ministry of Economy, Trade and Industry (METI), Tokyo, www.brookings.edu/~/media/events/2012/10/05%20japan%20energy/05%20japan%20energy%20okuya.pdf.

Shima, M., New Energy and Industrial Technology Development Organisation (NEDO) (2013), Personal Communication.

Shimizu, S., Manager of Energy System Planning Division, Japan Gas Association (2013), Personal Communication.

World Bank (2012), World Databank: World Development Indicators, http://databank.worldbank.org/data/home.aspx.

IEA Publications
9, rue de la Fédération, 75739 Paris cedex 15

Printed in France by IEA, September 2013