INTERNATIONAL ENERGY AGENCY

Cogeneration and District Energy

Sustainable energy technologies for today ...and tomorrow

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Cogeneration (also known as combined heat and power [CHP]) and district energy represent a proven, cost-effective and clean solution for delivering electricity, heating and cooling. Some regions have strategically invested in CHP and district energy as a tool to meet broader energy and environmental objectives. However, there are many more countries that could benefit from greater investigation into CHP and district heating and cooling (DHC). Most countries have significant potential for increased CHP development, but some key barriers prevent its realisation.

Cogeneration and District Energy: Sustainable Energy Technologies for Today...and Tomorrow shows that the key to unlocking this potential lies in the development and implementation of effective policies. The report documents, for the first time, the variety of CHP/DHC policy tools that are being used by leading countries and cities around the world. In this way, the report can be used as a "roadmap" for policy makers, providing examples of proven measures that can be adopted with confidence, in the knowledge that they will help to make an important contribution to the achievement of broader energy and environmental goals.

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The International Energy Agency (IEA) is an autonomous body which was established in November 1974 within the framework of the Organisation for Economic Co-operation and Development (OECD) to implement an international energy programme.

It carries out a comprehensive programme of energy co-operation among twenty-eight of the thirty OECD member countries. The basic aims of the IEA are:

- To maintain and improve systems for coping with oil supply disruptions.
- To promote rational energy policies in a global context through co-operative relations with non-member countries, industry and international organisations.
- To operate a permanent information system on international oil markets.
- To provide data on other aspects of international energy markets.
- To improve the world's energy supply and demand structure by developing alternative energy sources and increasing the efficiency of energy use.
- To promote international collaboration on energy technology.
- To assist in the integration of environmental and energy policies, including relating to climate change.

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The OECD is a unique forum where the governments of thirty democracies work together to address the economic, social and environmental challenges of globalisation. The OECD is also at the forefront of efforts to understand and to help governments respond to new developments and concerns, such as corporate governance, the information economy and the challenges of an ageing population. The Organisation provides a setting where governments can compare policy experiences, seek answers to common problems, identify good practice and work to co-ordinate domestic and international policies.

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Foreword

At the conclusion of the Group of Eight (G8) Summit in Heiligendamm, Germany in July 2007, the leaders issued a *communiqué* that, among other matters, directed countries to "...adopt instruments and measures to significantly increase the share of combined heat and power (CHP) in the generation of electricity." As a result, energy, economic, environmental and utility regulators are looking for tools and information to understand the potential of CHP and to identify appropriate policies for their national circumstances. This report, completed in April 2009, is a culmination of the IEA work in responding to the G8 request and helps regulators understand the potential of CHP.

A previous IEA study, *Combined Heat and Power: Evaluating the Benefits of Greater Global Investment* (March 2008), confirmed that significant economic, energy and environmental benefits would result from an increased policy commitment to CHP. This new report is designed to assist policy makers who would like to turn the conclusions of that first study into action by implementing policies and programmes to advance clean, efficient CHP. It concludes that CHP and district energy do not need significant financial incentives to compete in the market place. Rather, they require focused, consistent government attention to address a variety of barriers that can prevent the realisation of their full potential. The report includes a variety of "best practice" policy approaches for energy, environmental, finance and local officials that have been used successfully to expand the use of CHP and district energy. As such, this report can enable regulators and others seeking to implement the G8 Heiligendamm charge by adapting these policies to their particular situation and increasing the share of CHP in electricity generation.

Mr. Nobuo Tanaka
Executive Director

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- GE Energy
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- US Department of Energy
- US Environmental Protection Agency

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Section 1 • Introduction

Combined heat and power and district heating and cooling (DHC) represent a series of proven, reliable and cost-effective technologies that are already making an important contribution to meeting global heat and electricity demand. Due to their enhanced energy supply efficiency and use of waste heat and low-carbon renewable energy resources, CHP and DHC are already an important part of national and regional greenhouse gas (GHG) emissions reductions strategies.

However, while some countries have been able to achieve a high share of CHP in electricity production – up to 50% – through the use of effective policy and regulatory measures, most countries have been much less successful. This report has been designed to provide policy makers with a practical reference of "best practice" CHP policy examples from around the world.

This report follows the March 2008 report that highlighted the energy, economic and environmental benefits of CHP and DHC (IEA, 2008a). That report also provided a technical introduction to CHP/DHC and described its global status and potential.

Who should read this report?

This report is aimed at those policy makers (including energy, environment, electricity and heat network managers) and local governments who seek effective policy solutions and strategies that can reduce carbon emissions and promote energy efficiency.

How is the report structured?

This report is structured as follows:

Section 2 highlights the **benefits of CHP and DHC**, summarising why policy makers are investing in policies to advance these important technologies.

Section 3 includes a global overview of **policy best practices**, classifying policies into relevant policy types, and providing policy makers with specific case studies to aid in implementation.

Finally, Section 4, the **conclusions and recommendations**, sets out a practical "how to" guide on what options to consider when implementing the policies described in the report.

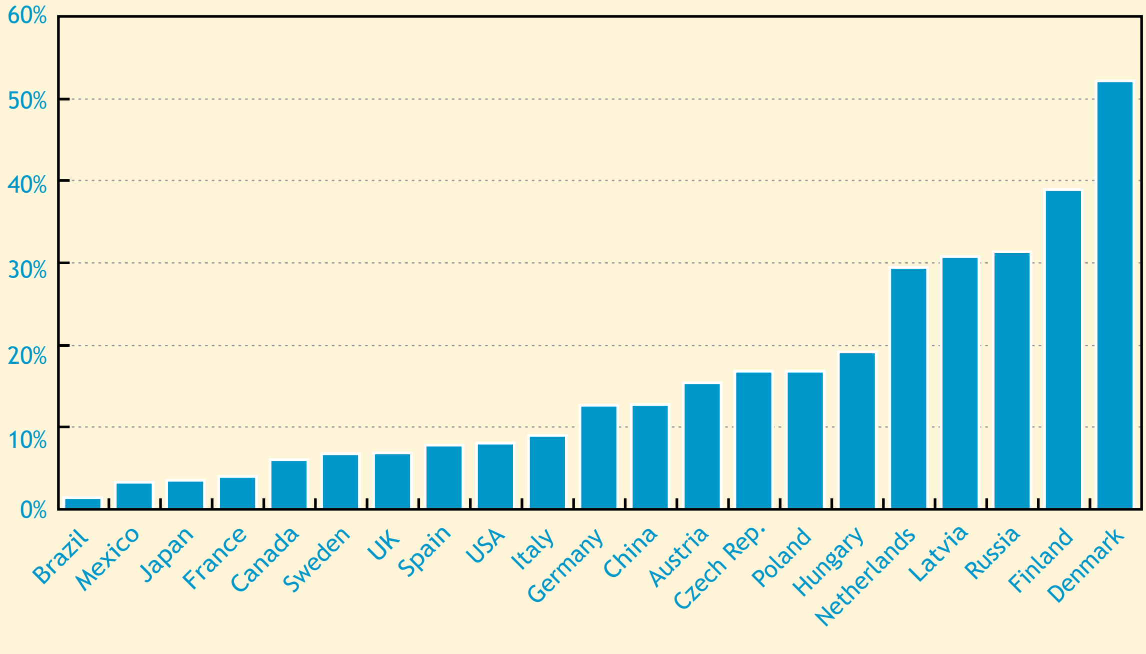
Section 2 • Policy makers should invest in CHP and DHC

This section explains why policy makers are investing in CHP to help achieve their energy and environmental policy goals. The importance of policy in promoting the development of CHP is also highlighted.

There is significant additional potential

CHP currently generates only around 10% of global electricity generation. Figure 2.1 shows that only a few countries have successfully expanded the use of CHP to between 30-50% of total power generation. Each of these countries has a unique approach, but one element has been common to all countries with successful CHP markets: there has been focused government policy on electricity and heat supply (see Section 4 for more on this point). Their collective experience demonstrates what can be achieved via thoughtful, well-implemented policy intervention.

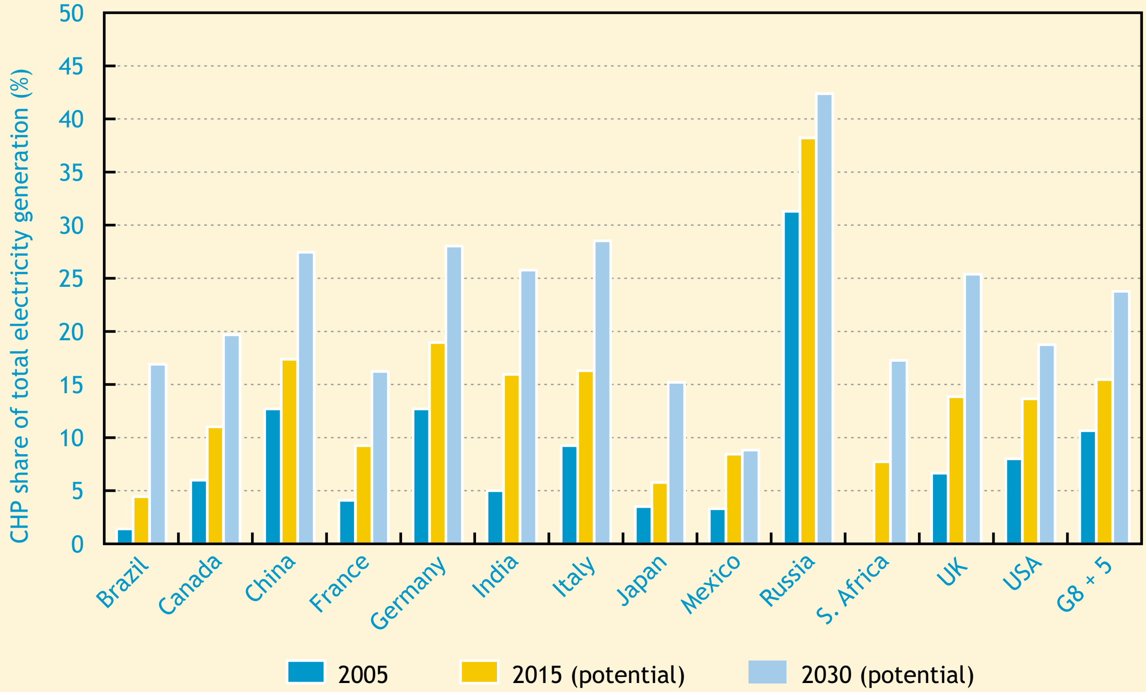
Figure 2.1 • CHP share of national power production



Source: IEA (2008a).

The other main conclusion from Figure 2.1 is that in the great majority of countries, CHP plays only a marginal part in electricity and heat generation. Figure 2.2 shows the outputs of IEA analysis, in relation to the G13 group of countries, on the economic potential for CHP in a policy scenario (the "IEA Accelerated CHP Scenario") that mirrors policies used in some of the most successful CHP countries. By 2030, the CHP share of G13 electricity generation could rise from 10% to around 24% – if suitable policy regimes were to be introduced based on best-practice CHP policies. For fast-growing China and India, the CHP shares of electricity generation could rise to 28% and 26% respectively by 2030. Currently CHP makes up about 13% of electricity generated in China and 5% in India (IEA, 2008b). This provides an excellent opportunity for profitable investment in low-carbon technologies.

Figure 2.2 • Major economies' CHP potentials under an accelerated CHP scenario, 2015 and 2030



Source: IEA (2008a).

What is CHP?

CHP is the simultaneous generation of useful heat and power from a single fuel or energy source, at or close to the point of use. An optimal CHP system is designed to meet the thermal demand of the energy user – whether at **industrial**, **individual building** or **city-wide** levels (see Figure 2.3).

Figure 2.3 • CHP applications

District Heating: International Tech Park (Bangalore, India)

Industrial: Industrial site with CHP in northern Italy

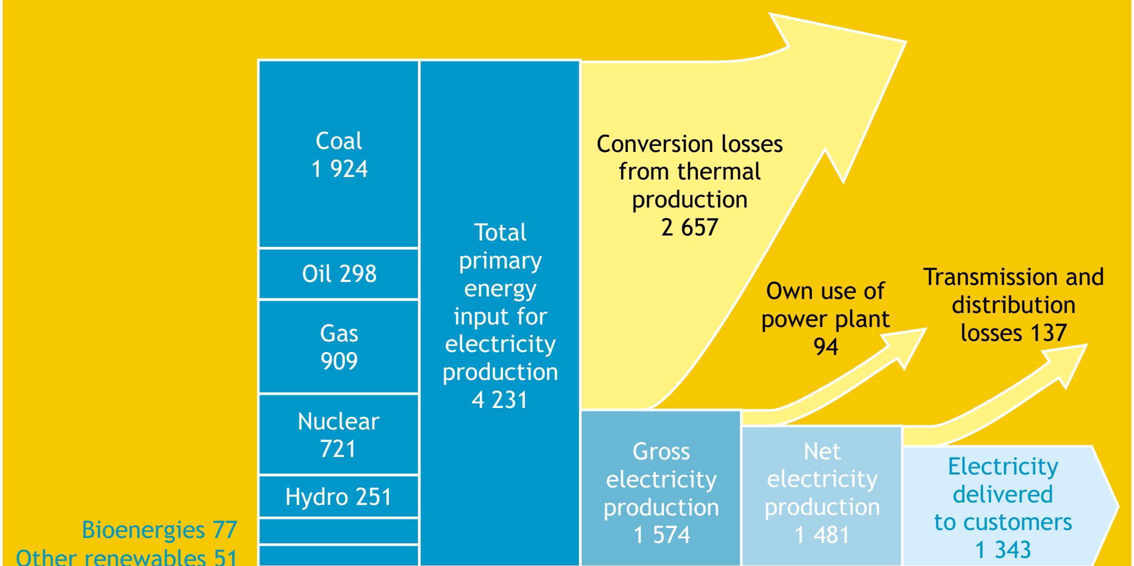
Source: IEA (2008b).

CHP encompasses a range of technologies, but will always be based upon an efficient, integrated system that combines electricity production and a heat recovery system.

By using the heat output from the electricity production for heating or industrial applications, CHP plants generally convert 75-80% of the fuel source into useful energy, while the most modern CHP plants reach efficiencies of 90% or more (IPCC, 2007). CHP plants also reduce transmission and distribution losses as they are sited near the end user.

The importance of the high efficiency of CHP is highlighted by the fact that the average global efficiency of traditional fossil-fuelled power generation is 35-37% (see Figure 2.4). The large yellow arrow corresponds to the roughly 2/3 of heat wasted during fossil-fuelled power generation; transmission/distribution account for an additional 9% of losses.

Figure 2.4 • Energy flows in the global electricity system (Mtoe)



Source: IEA (2008a).

CHP and DHC deliver a range of policy objectives

CHP systems are attractive to policy makers and industry because they deliver a variety of energy, environmental and economic benefits. These benefits stem from the fact that these applications are inherently energy efficient and produce energy where it is needed. Their benefits include:

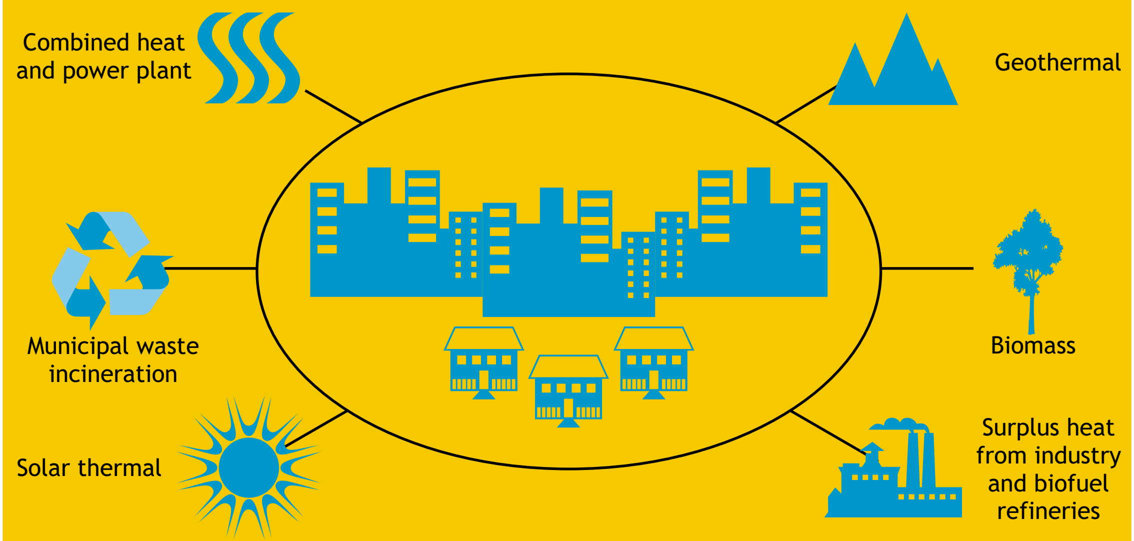
- dramatically increased fuel efficiency (see Figure 2.4);
- reduced emissions of CO_2 and other pollutants;
- cost savings for the energy consumer;
- reduced need for transmission and distribution networks; and
- beneficial use of local energy resources (particularly through the use of waste, biomass, and geothermal resources in DHC systems), providing a transition to a low-carbon future (see box below).

DHC infrastructure: a flexible platform for CHP and renewables

DHC networks provide a major opportunity for CHP deployment. DHC with CHP can provide the double benefit of reducing costs and impacts of both electricity generation and heat supply. District cooling offers the same opportunity for decarbonising cooling supply.

While DHC network development requires an initial investment, it provides a long-term asset that enables a transition to a low-carbon energy system. It can take heat from any source, and so can recycle “waste” heat streams that are difficult to use otherwise, and it can change to renewable heat sources over time as new technologies become available. Combined with CHP, these networks can therefore create a bridge towards future low-carbon energy supply systems.

Figure 2.5 • DHC as a flexible platform for CHP and renewable heat sources

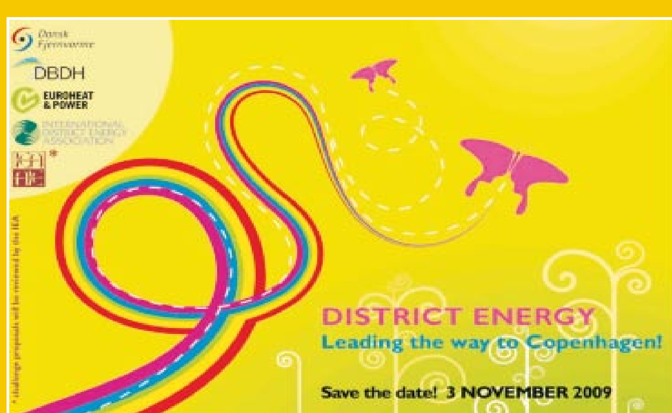


Source: Froning (2009).

The *City Challenge*: facilitating renewables in urban environments

The IEA, together with Euroheat & Power, the International District Energy Association, Dansk Fjernvarme and the Danish Board of District Heating (DBDH) are highlighting the opportunities for synergies between DHC and renewables through the *City Challenge* – a series of events culminating in a District Energy Summit in Copenhagen on 3 November 2009. More information on the *City Challenge* can be found at www.copenhagenenergysummit.org.

Figure 2.6 • District Energy Initiative



Source: Froning (2009).

With this wide range of benefits, CHP/DHC can help deliver important policy goals for a range of policy makers. For example:

- **National governments and energy agencies**: reduced reliance on imported fossil fuels, improved system efficiency.
- **Environmental regulators**: reduced GHG emissions.
- **Financial and fiscal departments**: increased cost-effectiveness of financial measures to reduce GHG emissions.
- **Regional and local governments**: improved energy and environmental performance of individual buildings and urban zones.
- **Network planners and regulators**: improved network stability, deferred need for expensive infrastructure investment.

CHP benefits: the evidence

There is a growing range of evidence that the wider development of CHP in the future is a cost-effective means of reducing CO_2 emissions in the near term:

- A study by consultancy McKinsey & Co. highlighted the part that can be played by CHP in achieving emission reductions in the United States. CHP alone provides around 13% of all identified negative cost CO_2 emission reductions (70 megatons) for buildings by 2030 and fully 53% of all negative cost reductions (80 megatons) for industry by 2030 (McKinsey & Co., 2007).
- By 2007, the US Environmental Protection Agency (EPA) CHP Partnership had supported the installation of 335 CHP plants, achieving CO_2 emissions reductions equivalent to taking 2 million cars off the roads, or planting 2.4 million acres of forest (US EPA, 2008).
- In a study to assess the cost of carbon abatement policies in the Netherlands, CHP was identified as one of the least-cost solutions at EUR 25/tonne (t) CO_2, lower than building insulation, condensing boilers and wind power (Boonekamp *et al.*, 2004).

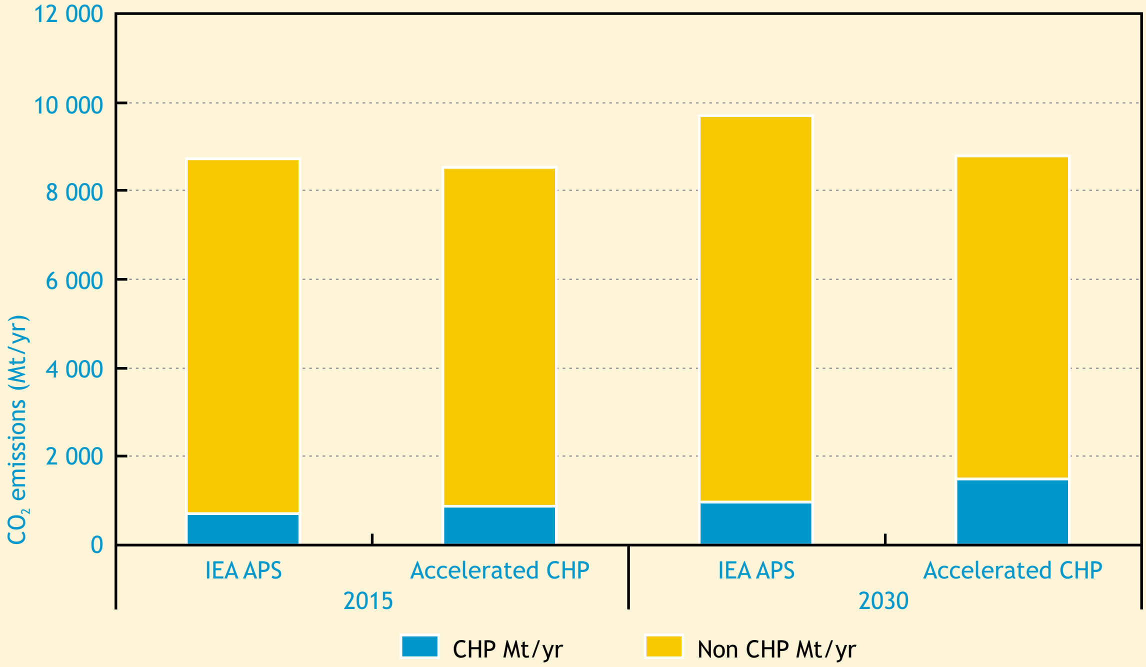
In the "IEA Accelerated CHP Scenario" there would be a 3% reduction in overall capital investment in the power sector by 2015, amounting to USD 150 billion of investment savings (IEA, 2008a). By 2030, these cost reductions could climb to 7% (USD 795 billion). These savings are largely derived from savings from avoided transmission and distribution (T&D) network investment. These savings in capital costs have a direct link to the reduction in consumer retail costs that the IEA modelling also projected.

Similarly, CO_2 emissions are projected by 2015 to be reduced by more than 4% (170 Million tonnes (Mt)/year), comparable to around 40% of the EU-25 and US Kyoto targets.[1] In 2030, this saving could increase to more than 10% (950 Mt/year). To put this in perspective, this emissions reduction is comparable to one and a half times India's total annual emissions of CO_2 from power generation (see Figure 2.7).

CHP also reduces emissions of some atmospheric pollutants, including NO_x and SO_x. This can contribute to improving air quality, particularly important in urban areas. For example, the Houston Advance Research Center estimates that adding 2 600 Mega watts (MW) CHP in the Houston-Galveston-Brazoria region would reduce NO_x emissions by 4 700 to 5 440 tonnes per year (HARC, 2008).

1. The difference between 1990 Kyoto base year emissions and the respective targets.

Figure 2.7 • Estimated carbon dioxide emissions reductions, 2015 and 2030



Note: APS = Alternative Policy Scenario.
Source: IEA (2008a).

Policy makers in various countries have already realised the benefits of CHP and promoted its further uptake to achieve policy goals, such as costs savings and carbon reduction targets. The IEA CHP/DHC Collaborative Country Scorecards published in 2008 describe the ways in which several countries have achieved CHP benefits through policy change (IEA, 2008b). The next section highlights why policy for CHP is so important.

The opportunity for CHP/DHC in emerging economies

Emerging economies represent some of the best opportunities to achieve the benefits CHP/DHC can bring, and as a result, many have started to promote these technologies. In India, CHP plants have become commonplace in the food processing and manufacturing industries, like at Arvind Textile Mill. China is using the efficiency saving CHP can bring to optimise its use of natural gas, like in the headquarters of the Beijing Gas Group (IEA, 2008b).

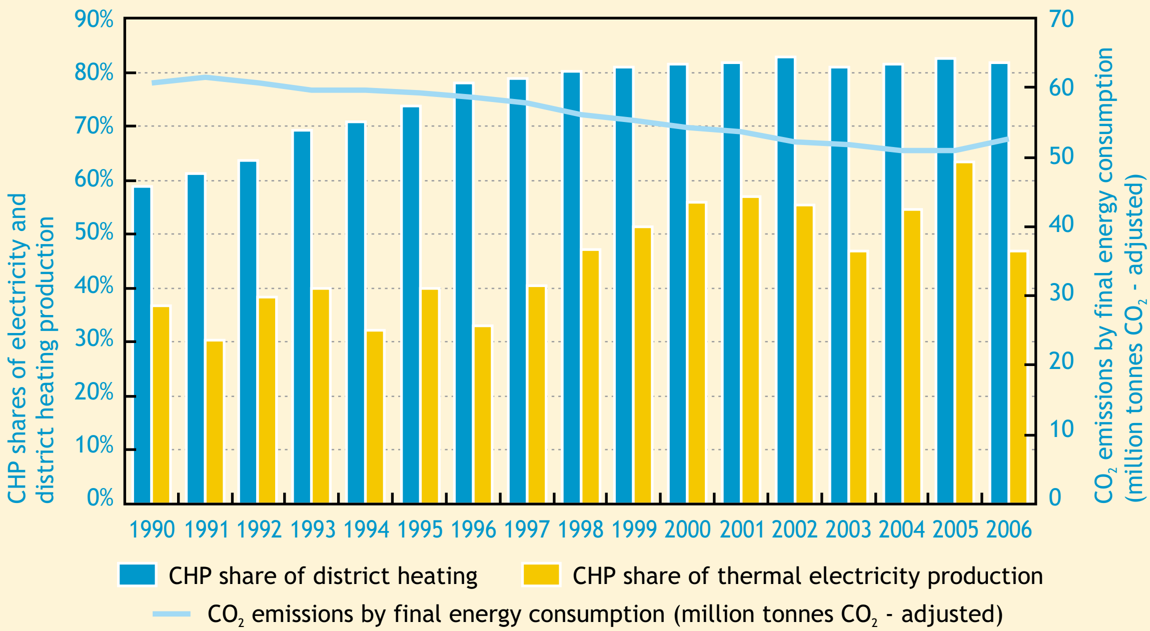
Figure 2.8 • CHP plant at Arvind Textile Mill, India

Source: IEA (2008b).

Why is policy important for CHP?

In 2008, the IEA undertook a series of country profiles for CHP/DHC, analysing the policy framework to better understand the keys to success (IEA, 2008b). This analysis discovered that barriers exist in many places that prevent CHP/DHC from reaching its full potential, and that targeted policy measures are needed to remove these obstacles to achieve the benefits of CHP/DHC. Experience from these countries also indicates that the most effective approaches were in countries that made a strategic decision to invest in CHP or DHC as a key energy security/climate solution. These countries set targets and created dedicated government departments to achieve these targets. These departments were charged with identifying CHP/DHC potential, including the barriers that prevented the realisation of this potential. They were given the authority to then develop policy tools and solutions to address these barriers in a systematic way. This approach has enabled Denmark, for example, to use CHP/DHC to reduce energy imports and GHG emissions simultaneously (Figure 2.9) (IEA, 2008b).

Figure 2.9 • Increase in CHP capacity and reduction of CO_2 emissions in Denmark



Source: IEA (2008a).

Well-chosen policy can overcome barriers to CHP

The evidence from many of the countries highlighted in the previous section is clear: CHP does not need substantial financial incentives to make it happen. Rather, it requires the effective use of often modest, targeted policies to systematically address barriers and allow for full realisation of the potential for CHP and DHC. Common barriers include:

- Economic and market issues, relating to the difficulty in securing fair value prices for CHP electricity that is exported to the grid.
- Regulatory issues, relating to non-transparent, inconsistent interconnection procedures and backup charges.
- Social/political issues, particularly in relation to a lack of knowledge in society about CHP benefits and savings.
- Difficulties in integrating the GHG emissions benefits into emissions trading or other regulations, due to CHP/DHC's status as combined technologies that include heat and power.

World-class policies: lessons learned from country analysis

The IEA analysis of country profiles found several common elements in the strategies used in countries that have addressed these barriers most successfully (IEA, 2008b). From this finding, the IEA has identified a consistent set of "world-class" policies that can be used to address the barriers faced by CHP and DHC. They are:

- Financial and fiscal support – page 20
- Utility supply obligations – page 21
- Local infrastructure and heat planning – page 23
- Climate change mitigation (emissions trading) – page 24
- Interconnection measures – page 26
- Capacity building – page 28

These individual policies have often proved to be most effective when combined in comprehensive CHP/DHC strategies implemented by a central policy department or agency (see Annex 2* for examples).

Table 2.1 provides a summary of which policy types are relevant for specific policy makers, and can thus be used as a reference for policy makers. Section 3 describes these policy types, with case studies provided in Annex 1*. Annex 2* offers examples of how leading CHP countries have created comprehensive CHP/DHC strategies tailored to their own circumstances.

Table 2.1 • Policy types and relevance to policy makers

Policy type	Policy makers				
	Energy	Environment	Financial	Local authorities	Network planners
Financial and fiscal support (see p. 20) can provide the additional push to enable CHP/DHC development and help countries meet policy goals, like environmental and efficiency targets.	✓	✓	✓	✓	
Utility supply obligations (see p. 21) are a market-based mechanism using certificate trading to guarantee a market for CHP electricity.	✓		✓		✓
Local infrastructure and heat planning (see p. 23) relates to heat planning policy and building regulations.	✓		✓	✓	
Climate change mitigation (emissions trading) (see p. 24) places a limit on allowances to emit GHGs and a market price for their emissions is thereby derived.	✓	✓	✓	✓	
Interconnection measures (see p. 26) provide developers with clear, consistent and reasonable rules for connecting to the grid network, as well as incentives for selling electricity generated to the grid network.	✓				✓
Capacity building (see p. 28) relates to outreach and education and support for R&D.	✓	✓	✓	✓	

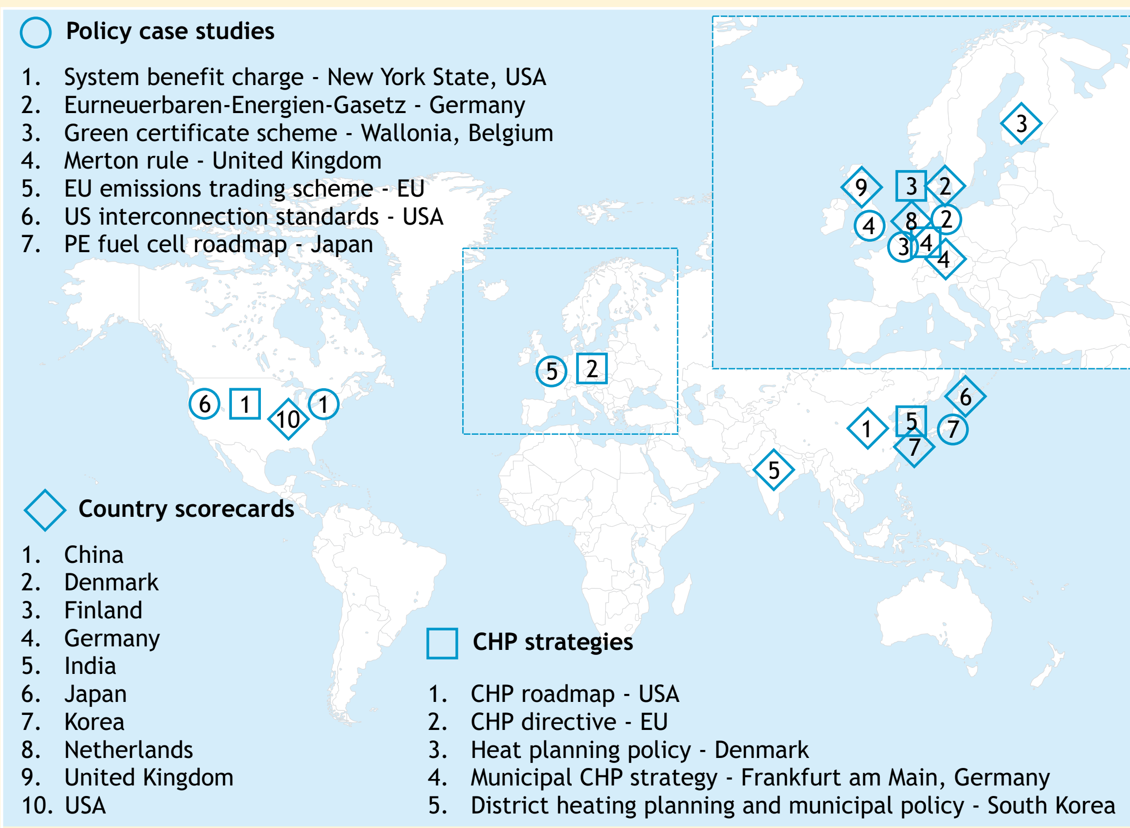
* Annexes can be found at www.iea.org/files/CHPbrochure09annex.pdf.

Section 3 • CHP/DHC policy profiles

This section highlights some of the most successful policies for advancing CHP/DHC. It provides a summary of the six main policy types introduced in the previous section and presents a series of case studies that illustrate each of them. This is structured as follows:

1. *Financial and fiscal support*
   - Capacity Grants, New York State
   - Feed-in Tariff, Germany
2. *Utility supply obligations*
   - Green Certificate Scheme, Belgium
3. *Local infrastructure and heat planning*
   - Building Regulations, United Kingdom
4. *Climate change mitigation (emissions trading)*
   - EU Emissions Trading Scheme
5. *Interconnection measures*
   - Interconnection Standard, United States
6. *Capacity building and outreach*
   - Fuel Cell CHP Research & Development Programme, Japan

Figure 3.1 • Best-practice CHP/DHC policies and strategies covered by the IEA CHP/DHC Collaborative



Source: IEA analysis.

Financial and fiscal support for CHP

What is it?

The main types of financial and fiscal support relevant to CHP are as follows:

- **Up-front investment support:** Appropriate when financing for CHP projects is difficult to secure, either because potential developers do not have access to capital or because project returns do not correspond to the short timeframes used by commercial investors. Examples include grants (direct support) and accelerated depreciation (fiscal).
- **Operational support:** Operational support can be used to reflect the full value of CHP electricity and/or heat, for example, by internalising its environmental benefits. Feed-in tariffs (direct) and fuel tax exemptions (fiscal) are common types of operational support.
- **R&D funding:** Government funding for low-carbon CHP technologies, like fuel cells, can help an industry to develop commercial CHP products for a sustainable energy system in the future (discussed further below in the section on outreach and capacity building policy).

These can be implemented as feed-in tariffs, up-front support or as fiscal measures as described below:

- **Feed-in tariffs (FiT)** are a market-based policy mechanism providing direct operational support for CHP/DHC:
    - FiT usually take the form of a bonus added to the market electricity price paid to plant operators for each kilo watt hour (kWh) of electricity supplied to the public network. Sometimes electricity used on-site is also covered.
    - FiT can also be fixed independently from the electricity price.
    - FiT can be combined with an obligation on the network operator to buy CHP electricity.

  Net metering is similar in guaranteeing the purchase power price for CHP electricity supplied to the grid.
- **Up-front financial support** facilitates the installation of CHP/DHC systems when up-front costs present a barrier to investment. For example, installation grants can provide a one-off subsidy.
- **Fiscal support** can offer tax relief for CHP/DHC:
    - Accelerated depreciation of CHP/DHC investments against corporate tax offers up-front support.
    - Exemption from fuel or carbon taxes supports CHP.

How can financial support help CHP?

Financial support can help to trigger CHP development in a number of situations:

- **To cover additional investment costs:** CHP systems, including DHC supply networks, often require higher up-front investment than conventional alternatives, even though running costs can be lower. Some energy consumers may not have the capital to make this investment. Grants or low-interest loans can help bridge this gap by covering part of the additional costs.
- **To internalise externalities:** Financial support can be granted to reflect the environmental and social benefits of CHP. For example, GHG emissions trading can reward CHP for the CO_2 emissions saved relative to separate heat and power generation.
- **To address market imperfections:** Energy markets are not always open and competitive, and may not value all forms of generation consistently. For example, generation in high demand areas has a higher value, because it is often difficult to site new generation. As a result, one strategy to address high demand is to provide additional financial support for CHP electricity. For example, generation in high demand areas has a higher value than that elsewhere. As a result, CHP sometimes receives less for its electricity than society would have to pay for electricity from other new power plants. Financial support can help adjust such inefficiencies in electricity markets.

Table 3.1 outlines the main types of financial support for CHP, their relevance and effectiveness, and gives examples of jurisdictions that have implemented them successfully.

Table 3.1 • Financial support mechanisms for CHP

	Financial support		
	Feed-in tariffs	**Capacity grants**	**Fiscal support**
Policy goals	• To provide greater certainty for investors in CHP. • To increase the operational efficiencies of new and existing CHP plants.	• To help capital-constrained organisations invest in CHP to improve energy performance. • To facilitate the market introduction of emerging low-carbon technologies, such as renewable CHP and micro-CHP.	• To provide greater certainty for investors in CHP/DHC. • To incentivise organisations to invest in efficient CHP/DHC systems.
Success factors - What makes it work?	• The value of tariffs should allow for a sufficient return to attract investment. • Long-term contracts to provide investor security; *i.e.* 10 to 20 years.	• Target potential developers that lack access to financing. • Regularly evaluate the level of subsidy to reflect changing technological and market conditions.	• Use accelerated depreciation for investment support and fuel or carbon tax incentives for operational support. • Minimise administrative overhead for CHP/DHC developer.
Where has it been used?	**Europe** - including Portugal, Spain, Germany, the Netherlands, the Czech Republic, Denmark, Hungary **North America** - Ontario **Asia** - including India (Maharashtra State)	**Europe** - including the Netherlands, Italy, Spain, Belgium **North America** - Various US States, Canada **Asia** - including China (Shanghai), India, South Korea, Japan	**Europe** - including the Netherlands, Sweden, Belgium, Italy, Germany, the United Kingdom **North America** - the United States (Federal) **Asia** - including South Korea, India, Japan
Best practice examples	• **Germany**: Biogas CHP receives a FiT through the Erneuerbare-Energien-Gesetz (EEG) (2009), adding up to EUR c27.67 per kWh to the electricity price. This policy has been the main factor supporting biogas capacity growth from less than 200 mega watts of electricity (MWe) in 2000 to over 1 200 MWe in 2007 (see case study in Annex 1*). • **Maharashtra, India**: 2003 saw the introduction of a FiT of IND 3.05 per kWh for bagasse-fuelled CHP. Other Indian states have now adopted similar policies.	• **New York**: Annual CHP installations in New York City tripled after subsidies became available in 2001, supported by high electricity prices (see case study in Annex 1*). • **Japan**: Government subsidies have made Japan the first country in the world with a commercial micro-CHP market - over 60 000 units have been installed (see case study in Annex 1*).	• **The Netherlands**: CHP policies achieved over 4 Mt CO_2-eq. GHG emissions reductions in the 1990s. The EIA, a fiscal investment credit, achieved its share at a cost of EUR 9 per t CO_2-eq. • **Sweden:** Exemption from fuel and carbon taxes underlies the success of DHC development.

Utility supply obligations

What is it?

Utility supply obligations (USOs) (also known as energy portfolio standards) are a market-based mechanism using certificate trading to guarantee a market for CHP electricity. They place an obligation

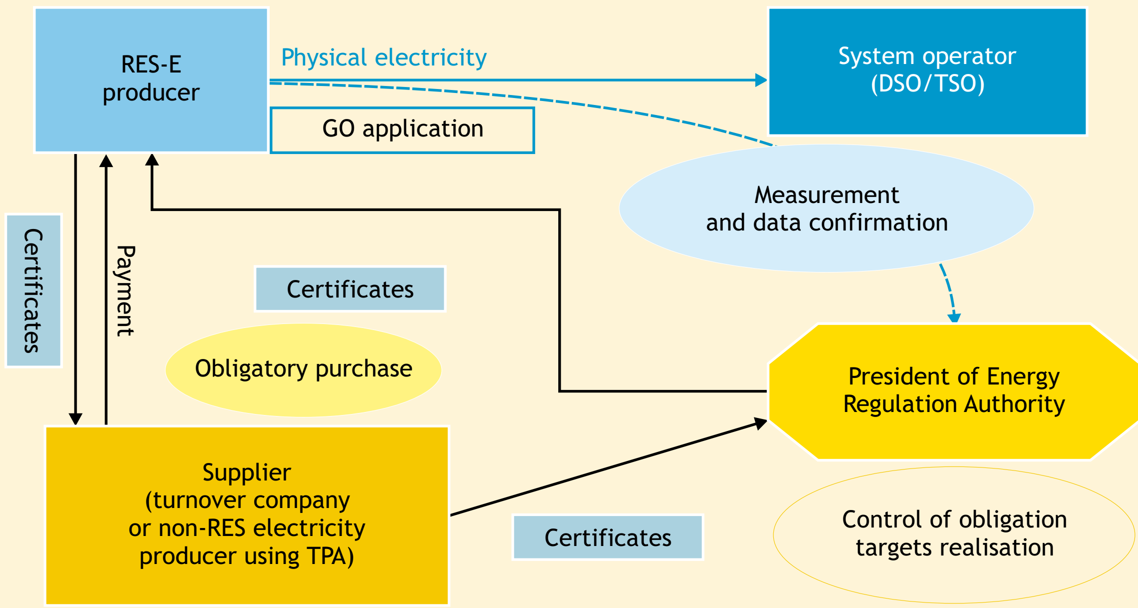
* Annexes can be found at www.iea.org/files/CHPbrochure09annex.pdf.

on electricity suppliers to source a certain percentage of their electricity from CHP. The share of supply to be met by CHP can increase year-on-year, in step with policy targets.

Electricity suppliers can meet the obligation in two ways:

- owning a CHP facility;
- buying CHP electricity from a CHP facility bilaterally or on the market.

Figure 3.2 • Transactions in a USO



Source: Adapted from Lipinski (2004).

The energy market regulator provides CHP plant operators with certificates for each unit of electricity or CO_2. Electricity suppliers can then purchase the required number of certificates from the CHP plant operators. The sale of certificates provides additional revenue to support CHP plants.

Supply of, and demand for, certificates will determine their value, but the regulator can create enough predictability to incentivise investment in CHP by creating a ceiling and floor on prices:

- If suppliers fail to submit the required number of certificates, they must purchase the outstanding certificates from the regulator at the penalty buy-out price (the ceiling).
- Some European USOs also allow CHP plants to sell certificates back to the regulator for a guaranteed minimum price (the floor).

How can USOs help CHP?

Independent CHP plant operators may find it difficult to find buyers for the electricity they produce. This can be the result of:

- **Market procedures**: In competitive electricity markets, small independent generators often do not have the expertise or resources to participate in electricity trading, so they rely on demand from a local supplier or consumer.
- **Size**: Electricity suppliers generally prefer sourcing electricity from a small number of large power plants. Small CHP plants may therefore not find a buyer for their output, although using multiple smaller generators can increase diversity and security of supply.

- **Long-term contracting**: In regulated markets, suppliers often buy electricity through long-term contracts with a small number of power plants. Consequently, independent power producers can only enter the system when one of these expires.
- **Costs**: Electricity from new efficient CHP plants can be more expensive than electricity from the existing generation system.

USOs can assist in addressing these issues by:

- creating demand for CHP electricity through obligation on electricity suppliers;
- allocating tradable certificates for CHP electricity.

Table 3.2 briefly explains the aims of USOs, their effectiveness, and gives examples of jurisdictions that have implemented them successfully.

Table 3.2 • Utility supply obligations for CHP

	Utility supply obligations
Policy goals	USOs create a demand for CHP electricity through a purchase obligation on electricity suppliers. The two main objectives are: • Making CHP plants competitive in the electricity market; and • Guaranteeing a market for CHP electricity.
Success factors – What makes it work?	• Set and adjust the obligation share realistically – enough to create scarcity and sustain demand, but with reference to the potential for developing CHP. • Create a penalty buy-out price to place a ceiling on certificate prices, and a guaranteed minimum price creating a floor price. • Establish a transparent and easy-to-use accounting system for compliance.
Where has it been used?	**Europe** • Renewables: 11 of EU-15 • CHP: Belgium, Poland • Energy efficiency: Italy **North America** • Renewable Portfolio Standards (RSPs): 36 US States, eight of which include CHP • Clean energy/CHP: Pennsylvania, Connecticut
Best practice examples	• **Belgium** – Wallonia has implemented a USO that supports CHP plants with certificates based on CO_2 savings, rather than on electricity output (see case study in Annex 1*). • **United States** – eight US States had included CHP in their RSPs by May 2008: Colorado, Connecticut, Hawaii, Nevada, North Carolina, North Dakota, Pennsylvania and Washington (US EPA, 2008). Connecticut's Renewable Energy Portfolio Standard includes a special category extending the obligation from renewables to CHP. It was one of the first State RSPs to recognise the CO_2 saving potential of efficient CHP plants (DSIRE, 2009).

Local infrastructure and heat planning

What is it?

Local infrastructure and heat planning create a rational framework for providing heat and cooling efficiently by identifying and linking demand and supply, and supporting the best energy sources available. DHC infrastructure can create the necessary linkages, while CHP is a versatile energy supply source that can meet demand efficiently.

* Annexes can be found at www.iea.org/files/CHPbrochure09annex.pdf.

Heat planning typically combines facilitating measures with regulation. Municipal governments in Denmark, for example, first assessed heat demand and supply options, then introduced restrictions on electric heating and power generation without heat recovery. At the same time governments supported R&D in emerging renewable CHP technologies to stimulate a transition to a low-carbon heat and electricity system.

Building regulations for CHP

Building regulations replicate some elements of heat planning at a building-scale – they aim to further the uptake of systems that optimise the energy supply. Building standards usually set requirements for the energy performance of buildings, which can be met using energy efficiency measures, on-site renewable generation or CHP. Developers can choose the most suitable and cost-effective option, allowing for flexibility to reflect local circumstances.

How can local energy and heat planning help CHP?

Local heat/energy planning at a municipal or building level can help to trigger CHP/DHC development in a number of situations by:

- **Co-ordinating heat, cooling and energy supply**: Heat planning facilitates CHP development by creating stable heat and cooling loads through DHC networks. Local governments have the spatial planning tools to facilitate this process and to address the regulatory challenges of construction, installation and energy sales.
- **Helping to overcome the high upfront costs of heating and cooling networks:** DHC networks are a valuable long-term asset for optimising energy supply and creating a bridge to low-carbon systems, but the upfront investment is often not feasible under private-sector criteria. Local governments can support DHC network investment through loans and guarantees, or by investing themselves, as with other long-term infrastructure.
- **Setting standards for building environmental performance that may not be achieved through market or other incentives:** The accelerated use of small-scale CHP and other low energy solutions in buildings will often require a critical mass of customer demand to bring down product costs. Building regulation standards, applying to thousands or millions of new buildings, can create this demand in a relatively short period.

Table 3.3 describes the different types of local heat/energy planning, their relevance and effectiveness, and gives examples of jurisdictions that have implemented them successfully.

Climate change mitigation (emissions trading)

There is a growing range of policy measures designed to address the challenge of climate change. This section focuses on cap-and-trade Emissions Trading Schemes (ETS) which are becoming an increasingly popular measure. These schemes follow the example of carbon taxation, which has been successful in supporting CHP and DHC development in countries like Sweden.

What is the issue?

The main challenge facing CHP in ETS design is that, with CHP, on-site emissions increase, while overall global emissions decrease (power plant emissions displaced by CHP exceed the additional on-site emissions when a boiler is replaced by CHP).

Unless ETS design reflects this issue, CHP will normally be penalised through having to buy more allowances than would be needed with a heat-only boiler and grid-supplied electricity.

Two other important issues for CHP are:

- Determining the sector to which CHP belongs. If CHP is categorised in a sector whose allowances are capped stringently, this will disincentivise CHP.

- Defining the boundaries for inclusion of CHP. For example, conversion of individual residential boilers (not included currently in ETS schemes because they are too small) to a large urban CHP/DHC scheme (which would be included) would disincentivise the emissions reducing investment.

Table 3.3 • Planning policy supporting CHP and DHC

	Local and individual planning policy	
	Heat planning and municipal initiatives	**Building regulations**
Policy goals	• To reduce urban or regional carbon emissions. • To improve the efficiency of energy use at the community level by co-ordinating heat and cooling supply and demand. • To facilitate the transition to energy systems using low- or zero- carbon fuels. • To reduce heating costs for consumers and bring down fuel poverty. • To establish long-term energy supply assets through supporting investment in DHC infrastructure.	• To increase the energy efficiency of new buildings. • To increase the use of low-carbon renewable energy and CHP in individual buildings.
Success factors – What makes it work?	Planning at the municipal level requires co-ordination and co-operation among policy makers, energy suppliers and customers to establish clear goals and agreement on the means of achieving it. Evaluating heat and cooling demands and available sources is essential for establishing an efficient supply system.	Success requires co-ordination and co-operation between planners and building developers, and agreement on ambitious but achievable goals.
Where has it been used?	**Europe** – including Denmark, Finland, Germany, Italy, Russia, Sweden **North America** – Puerto Rico **Asia** – South Korea, China	**Europe** – the United Kingdom, Germany, Austria
Best practice examples	• Denmark – Heat planning (see case study in Annex 1*). • South Korea – Integrated Energy Supply Act (see case study in Annex 1*).	• United Kingdom – Merton Rule (see case study in Annex 1*). • Germany – the EEWärmeG (Renewable Heat Law), effective in 2009, obliges building developers to use renewable technologies or CHP for heating in new buildings.

How can emissions trading help CHP?

The principle behind ETS is that allowances to emit GHGs are limited and thus a market price for their emissions is derived.

By giving carbon emissions a price, technologies that reduce emissions (*e.g.* CHP) should benefit in theory – partly through increases in electricity prices. It is, therefore, important to ensure that evolving ETS design takes account of the unique CHP position in the energy delivery chain and, if desired, incentivises its development. At the very least, ETS programmes should not penalise CHP.

Table 3.4 briefly sets out the key issues relating to treatment of CHP in emissions trading, its relevance and effectiveness, and gives examples of jurisdictions that have implemented emissions trading successfully.

* Annexes can be found at www.iea.org/files/CHPbrochure09annex.pdf.

Table 3.4 • Emissions trading schemes and CHP

	Climate change mitigation (emissions trading)
Policy goals	To bring about cost-effective carbon emissions reductions by incentivising (or at least not penalising) CHP plants.
Success factors – What makes it work?	The key requirement for those determining allocation plans is to ensure that the main challenge for CHP is addressed through specific allocation design features. For example, providing bonus allowances to CHP plants to recognise the additional useful heat energy that is being used by other energy consumers. Double-benchmarking is one methodology to allocate allowances more equitably to CHP plants (see case study in Annex 1*).
Where has it been used?	Experience is predominantly in the EU where the ETS has been in operation since 2005. Since that time, several member states have introduced innovative allowance allocation methods for overcoming the main design challenge for CHP.
Best practice examples	There are several examples under the US Regional Greenhouse Gas Initiative (RGGI) and the EU ETS that are described in the IEA CHP and Emissions Trading Report (and see EU ETS case study below).

Interconnection measures

What is it?

The three main types of measures are as follows:

Interconnection standards provide clear rules for obtaining physical connection to the distribution/transmission network depending on connection voltage levels. They outline the procedures for the application process in a clear and transparent way. They also set out the technical requirements for connection.

Measures **enabling grid access** that relate to the participation of CHP plants in the grid network. They can, for example, be developed to give CHP generators priority access to the electricity system. These measures include:

- Net metering: this allows for the flow of electricity both to and from a customer's facility through a single, bidirectional meter, and can enable the plant to secure an electricity sales price equivalent to the purchase price.
- Priority dispatch: this ensures that generators will have priority in exporting into the grid system.
- Licensing exemption: this allows CHP operators to generate without a generator license, helping to keep costs down.

Figure 3.3 • Two generator sets installed at an industrial manufacturing site in Trentino, Italy

Source: Solar Turbines Incorporated

* Annexes can be found at www.iea.org/files/CHPbrochure09annex.pdf.

Incentivising network operators enables them to benefit where they may lose revenue by connecting CHP plants to their systems. Incentives may include:

- Decoupling of the link between kWh throughput and profit.
- Allowing, or incentivising, network operators to develop CHP plants.
- Allowing network operators flexibility in charging for system use.

How can interconnection measures help CHP?

Grid connection enables a CHP plant to sell any surplus electricity to the grid, and to import when the site needs exceed the CHP output. A key factor determining the market viability of CHP is therefore its ability to safely, reliably and economically interconnect with the utility grid system (IEA, 2008b).

However, grid connection has traditionally been one of the main challenges to encouraging increased uptake of industrial and commercial CHP. See Figure 3.4 for an example of a CHP industrial site. In some cases the process of interconnection to the network has been unclear and at times inconsistent. The implementation of measures that facilitate interconnection of CHP systems on the other hand can provide developers with clear guidelines or incentives for connecting to the grid.

Figure 3.4 • CHP on Esti Láktép in Hungary

Source: Dalkia

The implementation of such interconnection measures can be done at a national level or regional level. The rules or standards are mostly proposed and enforced by electricity sector regulators after discussion and agreement with grid operators, CHP interests and other parties.

Table 3.5 briefly explains these three types of measures, their relevance and effectiveness, and gives examples of jurisdictions that have implemented them successfully.

Table 3.5 • Electricity network interconnection measures for CHP

	Interconnection measures		
	Interconnection standards	**Enabling grid access**	**Incentivising network operators**
Policy goals	To streamline and facilitate the interconnection procedures for CHP and other decentralised energy generation projects.	To improve the commercial conditions for CHP.	These incentives encourage network operators to treat CHP favourably when considering grid connection applications and after the establishment of projects.
Success factors – What makes it work?	• Regulators working closely with all the main stakeholders. • Development of standards that address all elements of the interconnection process. • Making the connection process and related fees commensurate with the generator size. • Monitoring the effectiveness of measures (US EPA, 2007).		
Where has it been used?	• In the United States, the Energy Policy Act (2005) urges all States to implement interconnection standards for CHP, which many have done. • The United Kingdom, the Netherlands and Germany have all implemented a "fit and inform" process for grid connection of micro-CHP. This means that there is no cost for connection.		
Best practice examples	**The Netherlands**: the Dutch Net Code in the 1990s simplified connection rules, ensuring transparency and fairness in the connection process. The government set out the requirements and the utilities developed the code. As such it was the utilities' initiative, and, therefore, was more effective. **The United States**: Many states and non-regulated utilities have developed, or are developing, standards that take into account the application process and the technical requirements for connection. The standards set out a standard framework for network connection and export of electricity (see case study below).		

Capacity building (outreach and research and development (R&D))

What is it?

Capacity building can be undertaken in two ways:

- **Outreach and education** raises the awareness of CHP, making known to potential users the benefits of CHP and the types of sites particularly suited to CHP. This can be implemented through training programmes, active campaigning or the creation of a central CHP office or champion.
- **R&D** supports the development of CHP technologies and applications towards market commercialisation. R&D funding can also be applied towards the training of potential users to facilitate CHP technology uptake.

How can capacity building help CHP?

Incentive policies for CHP can be most effective if the potential users are aware that the CHP opportunity exists and if emerging technologies are mature enough to be applied on a commercial basis.

Table 3.6 explains the different forms of capacity building, its relevance and effectiveness, and gives examples of jurisdictions that have implemented it successfully.

Table 3.6 • Outreach and R&D programmes for CHP and DHC

Capacity building (outreach and R&D)	
Policy goals	• To ensure that policy makers can incentivise the best and most efficient projects. • To ensure that energy users are fully aware of the CHP opportunity. • To accelerate the commercialisation of emerging CHP technologies.
Success factors – What makes it work?	Where capacity building has been most successful, it tends to have: • involved all the key stakeholder groups in programme design; • been accompanied by effective incentive policies; • been targeted at the most suitable energy user groups.
Where has it been used?	**Europe**: including Germany and the Netherlands **Asia**: including Japan
Best practice examples	**KWK Modellstadt Berlin:** The main goal of this scheme is to make Berlin a role model city for cogeneration. By producing free publications such as "CHP: double use of resources" and newsletters, the initiative has been informing the inhabitants of Berlin – the potential users – of the benefits and potential of CHP (Berliner Energieagentur, 2009). **Japanese PEFC Roadmap:** Brings together government research institutes, technology manufacturers and energy companies to cooperate towards the successful introduction of fuel cell CHP systems into the market (see case study below). **Dutch CHP Agency (*Projektbureau Warmte-Kracht*):** The Dutch CHP Agency brought together government, industry and energy companies to work together to identify opportunities, advise on policy and implement new projects. The Agency was set up to overcome the various regulatory and other barriers that hindered the development of CHP, and played a central role in the CHP boom in the Netherlands in the 1980s and 1990s. **US EPA CHP Partnership:** This partnership has successfully engaged potential CHP users and the wider public since 2001 through workshops, publications and awards, such as the Energy Star® CHP award. By 2007, it has contributed to installing 335 CHP projects with a total capacity of 4 450 MWe (US EPA, 2008).

Figure 3.5 • IC engine system installations at Edinburgh University

Source: GE Energy

Section 4 • Next step action items for policy makers

CHP – whether applied in industry, in buildings or integrated with DHC networks – offers policy makers a very significant opportunity to achieve a number of energy and environmental goals at relatively low cost compared to alternatives. CHP also provides a growing opportunity to incorporate renewable bio-based fuels that bring about an even greater environmental gain.

Moreover, the majority of CHP applications offer a proven, reliable and cost-effective means to meet electricity, heating and cooling demand in a highly efficient way. Therefore policy incentives for CHP are normally only needed where barriers (market, regulatory, institutional, etc.) cause projects to be uneconomic.

This report provides a summary of some global best practice CHP policies that have successfully delivered new CHP investment and thus helped achieve wider policy goals. Policy makers can be confident that they will find among these some effective policy tools that can help them meet their goals more quickly.

Some critical success factors

The report also highlights some of the critical factors that can most effectively bring about successful policy development and implementation:

A CHP/DHC "champion"

This can be an individual or a dedicated CHP department or agency that is charged with driving and coordinating policy development. Several examples in this report have arisen through such champions.

A CHP/DHC strategic framework

This can consist of a long-term target for CHP development, agreed across government departments and supported by a clear definition of the actions and initiatives that are needed to bring it about. The case studies in Annex 2* highlight the importance of a strategic approach to developing policy for CHP. The case studies are as follows:

1. The US CHP Roadmap;
2. The EU CHP Directive;
3. The Danish Integrated Approach to Energy Planning;
4. The Frankfurt (Germany) Municipal CHP Strategy;
5. The South Korean Integrated Energy Supply Programme.

These case studies illustrate the effectiveness of strategic, co-ordinated policy approaches to CHP development. These examples often consist of longer-term targeted programmes, involving a number of government agencies and consisting of several different CHP policy incentives, like those highlighted in Figure 4.1.

Appropriate implementation levels

Some of the most effective CHP policies can be best implemented at the sub-national level: regional, state, local or municipal. Cities can be especially effective in driving CHP/DHC, as these combine a dense and steady energy demand with distinct pollution and waste challenges (IEA, 2008c).

Many cities have implemented CHP/DHC initiatives to increase the efficiency of energy supply using building efficiency standards, urban heat planning that incentivises CHP/DHC and the establishment of "low-carbon zones" at the local level. For example, Copenhagen, Frankfurt and Mannheim have made the transition to "CHP/DHC Cities," while London, New York and Shanghai have introduced low-carbon policy initiatives more recently.

* Annexes can be found at www.iea.org/files/CHPbrochure09annex.pdf.

Qualifying definitions for CHP

Policy makers have created definitions in order to calculate national CHP capacity/generation and to ensure that incentives are properly targeted at schemes that meet defined criteria, usually based on the system's overall energy efficiency and primary energy savings. At present, there is a lack of international agreement on "good" or "high-quality" CHP. This is one reason why different countries continue to measure national CHP shares in different ways. Nonetheless, the two examples below indicate that solutions can be found, and may be useful models for other jurisdictions.

EU Cogeneration Directive (2004/8/EC), Article 11 (EU, 2004)

"*High efficiency cogeneration is in this Directive defined by the energy savings obtained by combined production instead of separate production of heat and electricity. Energy savings of more than 10% qualify for the term 'high-efficiency cogeneration'. To maximise the energy savings and to avoid energy savings being lost, the greatest attention must be paid to the functioning conditions of cogeneration units.*" (DG TREN, 2009)

UK Government CHP Quality Assurance Scheme (DEFRA, 2000)

"*CHPQA provides a methodology for assessing the quality of CHP Schemes in terms of their energy efficiency and environmental performance. This methodology is based on Threshold Criteria, which must be met or exceeded in order for the whole of the Scheme to qualify as 'Good Quality'. Threshold Criteria are set for Quality Index and Power Efficiency, and both can be determined from just three sets of data: fuel used, power generated and heat supplied.*"

Identifying next steps: a pathway

To help develop a process for choosing and implementing effective CHP policies, a recommended decision pathway is as follows:

1. Can CHP/DHC help achieve policy objectives? It is important to understand whether the greater use of these technologies can help achieve specific policy objectives. These objectives include reducing CO_2 emissions, reducing fuel imports and/or increasing energy efficiency. Such an assessment may best be done at a cross-departmental level. If it is concluded that CHP and/or DHC offers a potentially effective way forward, cross-departmental links need to be maintained and consideration given to the benefits of a longer-term strategic approach.

Best practice examples: the Netherlands and Denmark (see Annex 2) and IEA national CHP profiles (IEA, 2008b)*

2. Is there potential for further development? It is important to understand what the current market is for these technologies and what the potential for growth is on a sector-by-sector basis. Such an analysis will be most helpful if it seeks to identify the most cost-effective, new investments based on reasonable economic criteria.

Best practice example: EU CHP directive (see Annex 1)*

3. Identify market and other barriers. If it is concluded that there is further economic potential, then it is important to understand – again at a cross-departmental level – what is holding back investment. As this report has indicated, there are a wide range of potential barriers that can constrain CHP/DHC development. If some barriers can be removed, that is the best place to start. Incentives may be necessary to introduce newer technologies, including biogas CHP or fuel cell/micro CHP.

Best practice examples: US interconnection standards (Annex 1), CHP Directive (Annex 2*)*

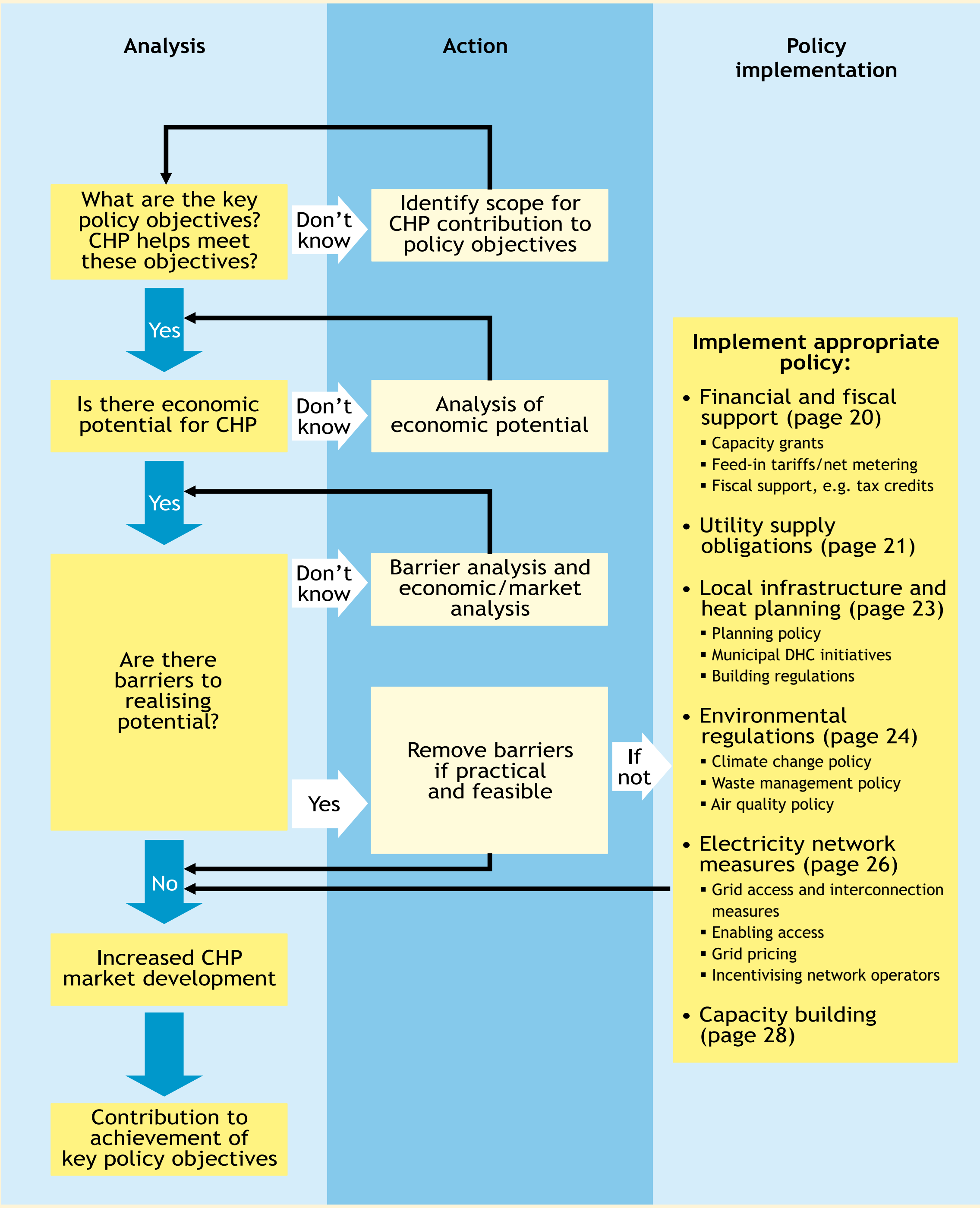
4. Identify and introduce the most suitable best practice policies. Depending on the government's policy goals, a choice can be made as to the most suitable best practice policy tools that can be implemented to bring about market growth and, thus, to make a contribution to the achievement of broader policy goals.

* Annexes can be found at www.iea.org/files/CHPbrochure09annex.pdf.

Best practice examples: Frankfurt, the Netherlands, Denmark and Finland (see Annex 2 and IEA national CHP profiles (IEA, 2008b))*

Figure 4.1 illustrates this decision pathway.

Figure 4.1 • CHP policy decision pathway



Source: IEA analysis.

* Annexes can be found at www.iea.org/files/CHPbrochure09annex.pdf.

These steps will apply differently to different countries, depending on the share of CHP/DHC already achieved and the overall national experience with CHP. For example:

- **Little CHP/DHC experience** – such countries may not have undertaken any steps and will need to start by gaining a full understanding of how CHP can align with broader policy objectives.
- **Some CHP/DHC experience** – such countries may already have an understanding of how CHP can help meet objectives but have until now only adopted piecemeal approaches to CHP. There are also likely to be still significant barriers and an incomplete understanding of the full potential for CHP.
- **CHP success stories** – such countries will typically have a share of CHP in electricity generation exceeding 25% and are already enjoying the benefits of this growth. However, there may be minor barriers remaining, but also new opportunities, for example, for expanding renewable CHP development.

What next?

Whatever the stage of CHP/DHC development in a country or jurisdiction, there is proven experience elsewhere that is directly relevant and that can be applied to help achieve important policy goals.

There is almost certainly at least one example – and probably several examples – of co-ordinated strategies and individual world-class policies in this report that apply today – and so enable a country to secure many of the benefits already gained by growing numbers of countries and cities around the world.

The International CHP/DHC Collaborative

The International CHP/DHC Collaborative was launched in March 2007 to help evaluate global lessons learned and guide the G8 leaders and other policy makers as they attempt to assess the potential of CHP as an energy technology solution.

The Collaborative includes the following activities:

- collecting global data on current CHP installations;
- assessing growth potentials for key markets;
- developing country profiles with data and relevant policies;
- documenting best practice policies for CHP and DHC;
- convening an international CHP/DHC network, to share experiences and ideas.

Participants in the Collaborative include the Partners, mentioned in the acknowledgments, as well as the Collaborators, a group of government, industry and non-governmental organisations that provide expertise and support. The Collaborative Network, the larger group that is informed about meetings, publications and outreach, has over 400 participants.

For more information, please visit www.iea.org/G8/CHP/chp.asp.

Abbreviations and acronyms

APS:	Alternative Policy Scenario
CCGT:	Combined Cycle Gas Turbine
CHP:	Combined Heat and Power
CHPQA:	Combined Heat and Power Quality Assurance
DHC:	District Heating and Cooling
EEG:	Erneuerbare-Energien-Gesetz (Renewable Energy Law)
EEWärmeG:	Erneurebare-Energien-Wärme-Gesetz (Renewable Heat Law)
EIA:	Energieinvesteringsaftrek (Energy Investment Allowance)
ETS:	Emissions Trading Scheme
FiT:	Feed-in Tariff
GHG:	Greenhouse Gas
RGGI:	Regional Greenhouse Gas Initiative
RPS:	Renewable Portfolio Standard
USO:	Utility Supply Obligation

Units Used

CO2-eq.:	CO_2-equivalent
GWe:	Giga watts of electricity
GWh:	Giga watt hours
Kg:	Kilogram
Km:	Kilometer
Kt:	Kiloton
KWh:	kilo watt hours
M2:	Squared meter
MW:	Mega watts
MWe:	Mega watts of electricity
MWh:	Mega watt hours (of electricity)
Mt:	Million tonnes
Mtoe:	Million tonnes of oil equivalent
Toe:	tonnes of oil equivalent
TWh:	Tera watt hours

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