Efficient and Decentralised Generation of Energy

An Evolution from Financial to Physical using Green CCHP

Distributed energy solutions such as combined cooling heating and power (CCHP) are efficient solutions that displace energy from the grid. They deliver clean electrical and thermal energy directly to the point of use (**Physical**) as opposed to financing supply to the grid (**Financial**). CCHP can be both cheaper and greener than the grid.

Financial	Major corporate energy users have successfully used financial measures such as power purchase agreements (PPAs) and offsets to reduce their carbon footprint. This may not however result in match between clean energy supply from intermittent renewables compared to the 24/7 demand load profiles of datacentres.
Physical	Corporate energy users are increasingly taking advantage of energy and cost efficiencies to procure energy for their corporate facilities from on-site clean energy generation. The system energy and cost efficiency of CCHP can substantially exceed that of the grid or renewables alone. This can represent a saving.

The corporate PPA market has grown substantially in the past decade. Corporate drivers include:

- ✓ economic: price certainty against fluctuating wholesale prices
- ✓ environmental: climate and sustainability commitments

In addition to these benefits, physical and efficient distributed energy solutions such as CCHP offer:

- ✓ avoided system costs with off-grid / private wire solutions
- ✓ supplementing existing low carbon power supply with greater flexibility

Additionality Both PPAs and distributed energy solutions such as CCHP can demonstrate additionality by either adding new power to the grid, in the case of a PPA, or by delivering energy directly to the point of use. In the case of distributed energy, this provides additional advantages (see below) including reduced demands on the grid, avoiding the need for utilities to build new power plants.

Investment While some corporates may be uncomfortable committing capital to distributed energy with the associated complexity of constructing, owning and operating energy systems that are not within their core business functions, SDCL is delivering CCHP as a service under a PPA.

Efficiency As a society, we are wasting up to two thirds of the energy we are using in generation, transmission and distribution losses. CCHP can dramatically reduce this inefficiency by using heat as well as electrical generation and by eliminating transmission and distribution losses through generation on site, at the point of use. By reducing demand from the grid, CCHP is one of the largest and most cost-effective sources of clean energy and greenhouse gas emission reductions.

Green Gas There is an increasing availability of cost-effective green gas supply solutions for CCHP (Green CCHP). Carbon neutrality can be achieved through green gas supply or offsets. Cost-effective green gas supply solutions are increasingly available for instance through utility contracts or purchasing fully traceable and certified green gas certificates, e.g. offtake from a bio-methane/renewable natural gas plant.

Key Advantages of Green CCHP

Green CCHP can deliver highly efficient, low carbon and secure supply of energy directly to data centres and other buildings and critical infrastructure assets. Green CCHP is:

- ✓ **Prime power**: It is a prime power source that can use the grid and uninterruptible power supply solutions such as diesel and batteries as backup.
- ✓ **Cost efficient**: It is typically lower cost than the grid, availing of attractive spark spread conditions and the increasing availability of green gas options.
- ✓ **Energy efficient**: the combined electrical and thermal efficiency of Green CCHP (> 65-80%) can be double the efficiency levels of the grid (< 40%) and a baseload energy solution that is substantially more efficient than wind, solar and other intermittent renewables.
- ✓ **Resilient**: a reliable and secure defence against black-outs from electrical grid interruptions and 24/7 baseload operations with availability of 95-99.999%.
- ✓ **Flexible**: a long-term solution that can be contracted through a PPA (with a 10 to 15 year plus term) that reduces risk from design, build, operation and maintenance and to levels of output that can provide grid services as well as prime power for on-site consumption.
- ✓ **Environmental**: It is lower carbon and can meet the highest environmental standards such as emissions control in challenging urban environments such as New York and London.

Cost efficiency

Green CCHP offers substantial energy cost savings compared to the grid and any other clean energy solution in a number of key markets, taking into account all environmental and emissions controls.

The economic advantages of CCHP are often underpinned by the gross margin associated with the value of electricity generated compared to the fuel costs (the "spark spread"). Where the spark spread is sufficient to cover all operation, maintenance, capital and financial costs, there is a business case for CCHP and it may compete favourably with supply from the grid. These conditions are particularly prevalent in the North East United States and European markets such as the UK & Ireland.

Spark spread: The $/MWh difference in price between electricity and natural gas is between 3 to 5x in several key markets.

Cost savings: Annual cost savings of 10-25% p.a. are available in the several key markets, taking into account the cost of green gas procurement and typical capex and opex.

PPA: SDCL offers a long-term PPA solution under which it provides up to 100% of the cost of the design, build finance, ownership, operation and maintenance of CHP solutions.

It structures a long-term service fee or tolling arrangement for energy produced and subject to specified levels of availability and other key performance indicators.

The business case for CCHP in markets with high electricity prices and constrained supply also includes resilience and security of supply. Locations at risk of grid interruptions from natural disasters and other extreme events are also a key focus for CCHP, which can be used as a line of defence against business interruption and associated financial losses.

Emission reduction and controls

In addition to major carbon emission reduction benefits, Green CCHP can employ Best Available Control Technology (BACT) for the control and reduction, versus the electrical grid, of:

- ✓ NOx (50% plus reduction versus grid)
    - Dry Low NOx Combustors
    - Catalytic Combustion
    - Water or Steam Injection
    - SCR with Ammonia or Urea
- ✓ CO2 (20% plus reduction versus grid)
    - Oxidation Catalyst
- ✓ SO2 (90% plus reduction versus grid)
    - Control with low sulfur and ultra-low sulfur fuel selection
- ✓ VOC / UHC
    - Oxidation catalyst
- ✓ PM
    - Controlled with fuel selection

Addressing traditional hurdles to PPAs with CCHP

Hedging While PPAs offer companies stable power prices and a hedge against electricity price volatility, many companies are not comfortable with committing to 15 or 20 year contractual arrangements if they are concerned that power prices will fall in the years ahead. However, CCHP PPAs can help mitigate this concern by allowing companies to keep control of, or hedge, their natural gas fuel price exposure, while offering a fixed price for electricity and heat produced. Given the correlation between natural gas and electricity prices, this can help mitigate or control risk.

Accounting Long-term PPAs also can present accounting issues or gain treatment as "debt equivalents" by credit-rating agencies. CCHP PPAs can be structured as service contract, delivering off-balance sheet treatment for companies.

Size Companies may have too small an electrical load at any one site to make a renewable energy PPA arrangement attractive to a developer on the one hand or to deliver a cost-effective baseload energy solution on the other hand. CCHP PPAs can be delivered to a bespoke design and specification to match load profile. SDCL has delivered CCHP PPAs for as small a load as 1.4MW, while at the same time having to flexibility to be designing system solutions for to up to 100MW of flexible generation.

APPENDIX A

CCHP can deliver substantial reductions in greenhouse gases and other emissions.

Table 1: Illustration of good quality CCHP compared to the grid (US Average)

CHP Results

CHP
EPA COMBINED HEAT AND POWER PARTNERSHIP

The results generated by the CHP Emissions Calculator are intended for educational and outreach purposes only; it is not designed for use in developing emission inventories or preparing air permit applications.

Annual Emissions Analysis

	CHP System	Displaced Electricity Production	Displaced Thermal Production	Emissions/Fuel Reduction	Percent Reduction
NOx (tons/year)	74.09	68.20	79.87	73.98	50%
SO2 (tons/year)	7.80	116.76	1.25	110.20	93%
CO2 (metric tons/year)	125,549	73,301	86,223	33,976	21%
Carbon (metric tons/year)	34,241	19,991	23,515	9,266	21%
Fuel Consumption (MMBtu/year)	2,325,946	938,724	1,597,393	210,171	8%
Acres of Forest Equivalent				9,266	
Number of Cars Removed				5,791	

Displaced Electricity Generation Profile: eGRID State Average All Sources 2014

Region Selected: US Average

This CHP project will reduce emissions of Carbon Dioxide (CO2) by 33,976 metric tons per year
This is equal to 9,266 metric tons of carbon equivalent (MTCE) per year

This reduction is equal to removing the carbon that would be absorbed by 9,266 acres of forest

or

This reduction is equal to removing the carbon emissions from 5,791 cars

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Existing Generation Sources				Heat Rate
Name	NOx lb/MWh	SO2 lb/MWh	CO2 lb/MWh	Btu/kWh
EGrid Annual Average	0.93	1.63	1,123	9,630
EGrid Annual Fossil	1.28	2.40	1,665	13,916
EGrid Annual Coal	1.885	3.95	2,167	10,470
EGrid Annual Oil	2.686	3.69	1,568	9,299
EGrid Annual Natural Gas	0.34	0.046	913	7,675
Coal Boiler 3.8 lb/MWh NOx	3.800	5.000	1,967	9,500
Coal Boiler 1.5 lb/MWh NOx	1.500	2.500	1,967	9,500
Coal Boiler with SCR 0.8 lb/MWh NOx	0.800	1.000	1,967	9,500
Gas Boiler 0.77 lb/MWh NOx	0.770	0.006	1,286	11,000
Gas Turbine Peaker 25 ppm	1.103	0.007	1,403	12,000
Gas combined-cycle 9 ppm	0.265	0.005	935	8,000
Gas combined-cycle 3 ppm	0.077	0.004	818	7,000

Sources: United States Environmental Protection Agency, Combined Heat and Power Partnership

N.B. The emissions comparisons above are versus the grid, rather than a “typical” or “average” thermal plant on the US grid today. The grid included approximately 1/3rd non-thermal generation such as nuclear, non-hydro renewable and hydro. This should therefore provide a conservative comparison to typical or average thermal plant generating on the US grid today. Further, while best in class combined cycle gas turbines can now operate at above 50% efficiency, good quality CCHP can achieve combined electrical and thermal efficiencies of over 85%.

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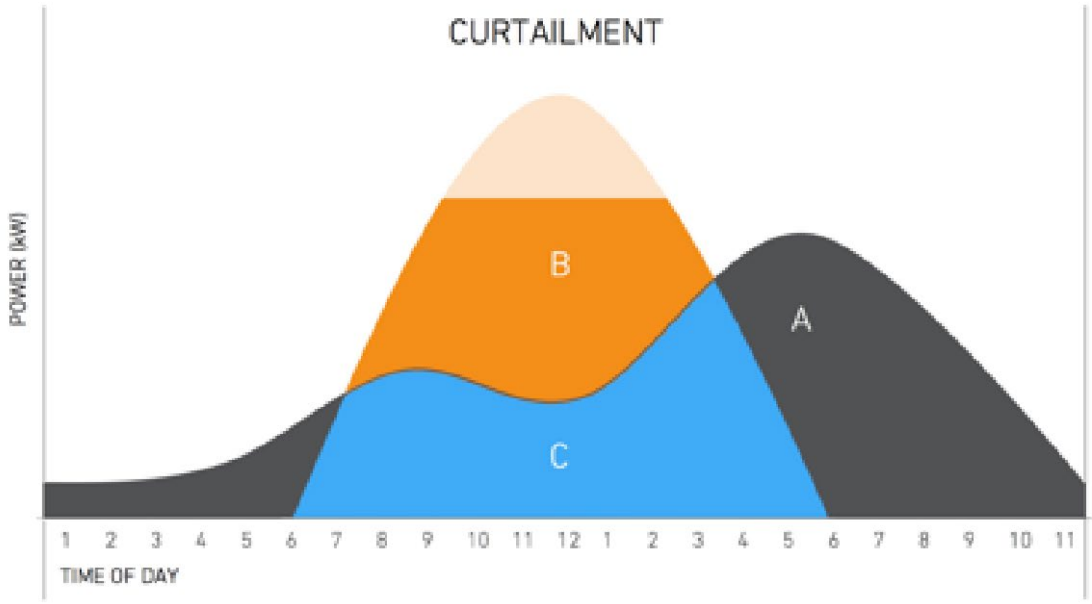
APPENDIX B

Green CCHP can help achieve a "carbon free" as opposed to a "carbon offset" outcome. Carbon offset can be achieved by buying clean energy to offset corporate use. Carbon free can only be achieved by matching supply to demand over time. Green CCHP has the potential to achieve this.

Chart A: Simplified illustration of "Carbon Free" versus "Carbon Offset"



Source: The Energy Collective

Carbon Offset: In Chart A above, a fictitious company's electrical load profile over a day is depicted as the combined grey and blue areas (A+C). The chart also depicts a solar generation deal (Power Purchase Agreement or "PPA") that the company struck for energy supply. Total generation is depicted as the combined orange + blue areas (B+C). In this case, Clean Generation has been dimensioned to match the electrical load. That is to say: A+C = B+C. The areas under both the load and generation curves are equal. That balance is often referred to as 100 Percent Carbon Offset. It is a milestone, such as that preannounced for 2017 by Google.

Limitations of Offset: However, there is excess generation at times, because the load and generation are not matched. The blue area reflects "Clean Operations", corporate electrical load that is supplied by "Clean Generation". The orange, however, reflects excess Clean Generation that must be utilized elsewhere in the grid at the time it is generated. Most notably, the grey reflects "Dirty Operations"; corporate electrical load that requires traditional generation sources (coal or gas) for supply. The company therefore still needs significant amounts of traditional generation to meet its needs. It is operating at only c. 50% Carbon Free, despite buying Clean Generation for 100 Percent Carbon Offset. In advanced solar markets like California, utilities don't always have a place to use all the solar generation. Excess is periodically produced, and sometimes production from solar facilities gets curtailed because the grid is saturated. Curtailed energy is depicted as the light orange area above. As the frequency of curtailment rises with growing solar on the gird, carbon offset becomes less valuable.

Achieving Carbon Free: Solutions to achieve a carbon free outcome require load management, diversification of clean energy and storage. Carbon free may also achieved via **Green CCHP**.