The Zero Net CO2 Industrial Plant: A Holistic Approach

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ABSTRACT

Most developed countries are committed, or about to commit, to massive reductions of their greenhouse gas (GHG) emissions, including CO_2 emissions. Honoring these commitments requires, or will eventually require, the industrial sector to reduce its carbon emissions. Industrialists need strategies to ensure that they can become low-CO_2 in a cost-effective way, without having to relocate to countries with less stringent carbon regulation (carbon leakage). To meet this challenge, they will have to develop innovative approaches, relying on attractive business models. Building Zero Net CO_2 (ZNC) industrial plants could be one of the most ambitious of theses approaches, and perhaps the one that most industrialized nations will ultimately have to deploy.

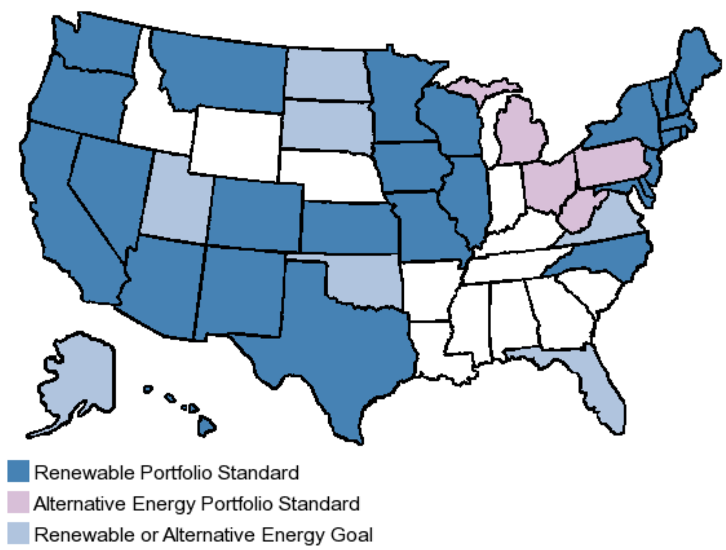
This article reintroduces the concept of a ZNC industrial plant, and gives some insights about the various levers which can be used to design such a plant. Some examples of existing ZNC industrial plants are given.

Introduction

Most developed countries are committed, or about to commit, to massive reductions of greenhouse gas (GHG) emissions. The European Union already made a unilateral commitment to cut its emissions by at least 20% from 1990 levels by 2020 - 30% if an equitable international agreement is reached, and 80% by 2050 (EU 2007). This commitment is being implemented through a package of binding legislations. Some European countries committed to even more ambitious reductions. For instance, the United Kingdom aims to reduce its emissions by 34% by 2020, as compared to 1990 (UK 2008). Across the ocean, the US government proposes to achieve 80% of clean energy by 2035 (Obama 2011), but many US states did not wait for a federal move to have their own GHG regulations in place (see Figure 1). As of November 2008, eighteen states have imposed mandatory GHG emissions reporting requirements. For instance, California passed bill AB32, which requires the state to have in 2020 the same emission level as in 1990, which corresponds to a 29% decrease from the forecasted 2020 level (AB32 2006). Another example is the Regional Greenhouse Gas Initiative, whose participants are ten Northeastern and Mid Atlantic States that have implemented a market-based mandatory cap-and-trade program (RGGI 2007).

In developed countries, besides the transportation sector, the main sources of CO_2 emissions from energy consumption are the industrial sector (27%), the residential sector (21%) and the commercial sector (18%) (percentages given for the US) (EIA 2010). Numerous actions have been engaged to reduce emissions from the residential and commercial sectors. Stringent standards for thermal insulation are becoming mandatory (Directive 2002/91/EC of the European Parliament, California Title 24, etc.) ; numerous rebate, incentive and tax credit programs have been put in place to help individuals improve the efficiency of their houses, to install solar panels, etc. The R&D effort to reduce home and building emissions is also considerable, focusing on software tools to design zero CO_2 buildings or houses, energy efficient appliance, or smart buildings. The maturity of the technologies and methods to decrease emissions in these sectors allowed governments to impose ambitious and holistic legislative measures. Examples include California CALGREEN code (CALGREEN 2011), the US's first statewide green standards building code, or UK's 2016 zero carbon homes policy (UK 2009). In the industrial sector, the European cap and trade system is probably one of the most effective instruments to cut CO_2 emissions. Its impact cannot be denied, however caps cannot be reduced too quickly or set too low for risk of inducing an unbearable burden for companies and/or carbon leakage (relocation to countries with less stringent carbon regulation). Moreover the European cap and trade system concerns only the biggest industrial plants and does not tackle in particular Small and Medium Enterprises that contribute to about 60% of the European Union's GDP (Euractive.com 2007).

Figure 1: US States Having Renewable Portfolio Standard or Renewable Goal



Source: Pew Center on Global Climate Change, 2011

Reduction of CO_2 Emissions in Industry

Numerous factors are hindering the decrease of CO_2 emissions in the industrial sector, in particular:

- Industrialists are reluctant to modify their installations, lest it would negatively affect production,
- Even within a single industrial sector (e.g. the food industry), plants and processes are very diverse. Therefore it often difficult to in extenso duplicate proven solutions,
- Industrial companies need technical assistance and resources to aid in the design and execution of projects to reduce their emissions.

Nevertheless the main impediment to implementation of carbon reduction measures is financial-related. Indeed, industrialists usually consider only one lever to reduce their emissions: energy efficiency. Their first improvements come from cheap "low-hanging fruits", and therefore generally have a good payback. Further energy efficiency improvements require substantial investments, and longer payback periods. The cost-effectiveness of such projects becomes fragile and no stakeholder (industrialist, local utility, etc.) can identify a profitable business model in the project.

New approaches must be developed to lead the industrial sector to achieve substantial reduction of CO_2 emissions and mitigate its impact on climate change. Above all, these approaches must rely on attractive business models for stakeholders in order to be deployed. Building Zero Net CO_2 (ZNC) plants is likely among the most ambitious approaches, and perhaps the one that most industrialized nations will ultimately have to deploy.

Zero Net CO_2 Industrial Plant

There is still no universal definition of ZNC industrial plant. However, by analogy with the building and residential sectors, it can be considered that a plant is ZNC when its direct and indirect CO_2 emissions are null on average over the year. Such a plant may have no direct or indirect emission, for instance if it is fully powered by "green electricity" and on-site renewable energy. The plant may also produce CO_2 but compensate it, by for example:

- Producing renewable electricity and selling it to the grid. In a number of areas, grid operators/utilities are required to accept/purchase (net metering) all available green electricity, and therefore have to ask for a decrease of fossil fuel-powered plant generation, cutting overall CO_2 emissions,
- Financing projects leading to reductions of GHG emissions elsewhere: other plants or other sectors, anywhere in the world.

A ZNC plant can be achieved by retrofitting an existing plant or, more easily, by building a new one. In most cases, this requires essentially designing the plant’s power system through a threefold approach, which consists of:

- Enlarging the number of levers to reduce emissions. At least seven levers have to be considered: 1) energy efficiency, 2) on-site renewable energy, 3) energy storage, 4) demand response, 5) fuel switching, 6) carbon offsets, and 7) green electricity or green certificates. The approach requires to allow for all levers and to assess their individual and collective effects on CO_2 emissions, costs and benefits. The more levers within a project or plant, the easier it is to develop attractive business models for stakeholders.
- Conducting an analysis in order to identify the combination of levers leading to the highest ratio of CO_2 reduction over capital cost and cost-in-use, whenever possible with the shortest payback. This analysis must be holistic, i.e. consider the industrial plant as a whole and allowing for its evolution over time, so as to identify the optimal combination of levers. It is of paramount importance to understand and take advantage of synergies between levers. Such synergies can be energy-related, for instance by combining a heat recovery system with a heat pump or a thermal energy storage system. The synergies can be financial, for instance by counting on energy efficiency savings to finance green electricity purchases. The optimal combination of levers builds upon the plant’s processes, costs and CO_2 content of grid electricity, local climate conditions, local renewable energy potential, and a host of other factors.

- Establishing a win-win partnership between the industrialist and companies able to bring competences to define or contribute to the plant's energy and emission management through the selected levers. The approach is particularly cross-cutting, and very few organizations have the ability to fully develop it. The most relevant partners have to be identified, for example a utility, which can bring competences in energy efficiency or energy storage, and find interest in selling green electricity, operating a biomass boiler on-site, etc.

For very energy-intensive plants, such as steel- glass-, cement-, pulp-and-paper- or petro-chemical-plants, reaching ZNC status with the aforementioned levers and in the framework of attractive business models is difficult. Another way to decarbonize significantly energy-intensive industries is to rely on Carbon Capture and Sequestration (CCS). According to the Intergovernmental Panel on Climate Change (IPCC), there are about 2,700 industrial sites worldwide (IPCC 2005) (not including power plants) where the CCS approach can (has to) be followed. These sites represent about 3,000 million metric tons of CO_2 per year, but for some facilities CO_2 emissions are too diluted in plant exhausts, implying very high capture costs. There are already some relevant examples in this path, for instance in the Great Plains Synfuels Plant in North Dakota (coal to methane plant): CO_2 is captured, compressed and piped (205-mile long pipe) to the Weyburn oil field in Canada where it is injected to enhance oil production. It is estimated that 50% of the injected CO_2 will be permanently sequestered in the oil that remains in the ground, the remainder coming to the surface with the produced oil. The cost for CO_2 capture, transport and injection is over-compensated by the revenues brought by the recovered oil. The project is expected to inject 18 million tons of CO_2 and to produce at least 122 million barrels of incremental oil from a field that has already produced 335 million barrels since its discovery in 1955 (Riding 2005).

For many plants that are not among the 2,700 most energy-intensive ones, it could be possible to achieve Zero or near Zero Net CO_2 emission. The subsequent part of the article provides some insights about the seven aforementioned levers, and shows how they can significantly contribute to meet this objective. Detailed descriptions of the levers can be found in many reference documents (EPRI 2010; Hamilton et al. 2010; Jain, Jamison, & Thomas 2006; McKane et al. 2008; Salas 2009; UNIDO 2010; US COTA 1993).

Some Insights about Seven Levers to Achieve ZNC Plants

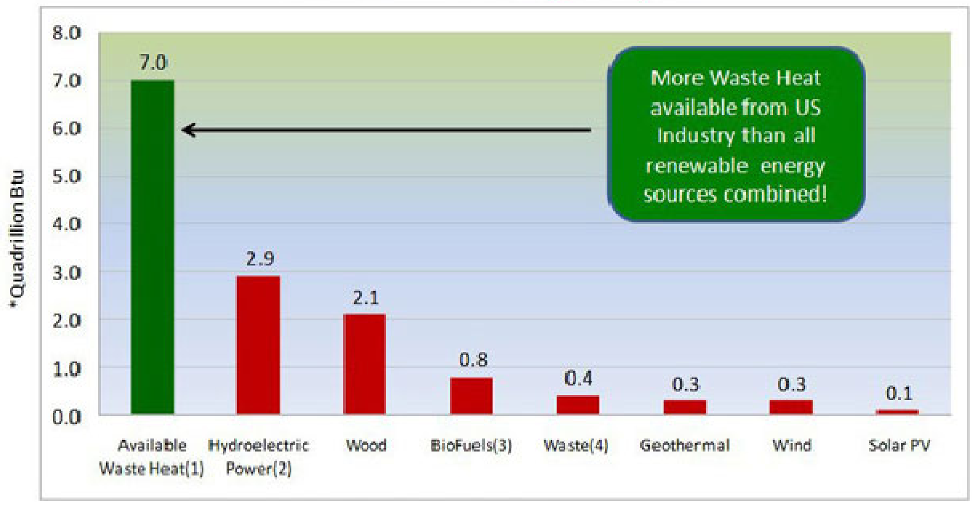
Energy Efficiency

Increasing energy efficiency is one of the quickest, most effective, and most cost-effective ways to reduce CO_2 emissions in industry. It also contributes to preserving irreplaceable fossil fuels, and to enhance energy independence of many nations. For instance, it is considered, that EU-25 and the USA could save at least about 20% (Mc Kinsey 2009) of their energy consumption through cost-effective energy efficiency actions. EU-25 has announced a plan to reduce the energy use in manufacturing industries by 27% by the year 2020.

Energy efficiency of industrial plants can be improved by many ways, often referred to as Best Available Techniques. "Techniques" include both the technologies and the way in which the installation is designed, built, maintained, operated and decommissioned. "Available" means that the techniques are developed on a scale which allows implementation in the considered industrial sector, under economically and technically viable conditions. Those techniques are very well known and detailed in reference documents (European Commission 2009), among them: reducing leaks in compressors, measuring currents and flows with advanced metering systems, proper motor sizing, reducing heat losses by insulation, cutting mass flow of flue gas from combustion system by reducing the excess of air, etc.

Techniques aimed at recovering waste heat energy are among the most relevant ones, since the potential resource is quite large. For instance, according to the United States Department of Energy, there is more waste heat available in the United States than all other sources of renewable energy combined (see Figure 2).

Figure 2: Waste Heat Potential in the US



Source: Energy Information Administration (EIA 2007)

Many countries or states have put in place regulations that require utilities to achieve a certain amount of energy efficiency improvements in their territories. If the right amount of energy savings cannot be shown at the end of the year (or period), the utility has to pay penalties. In 2008 alone, US utilities offered more than $3.1 billion in rebates and incentives for energy efficiency (EERE 2009). For instance, Southern California Edison offers cash incentives for industrial energy efficiency improvements that can go up to 50% of the total project cost, based on the electricity saved.

On-Site Renewable Energy

Many expect that renewable energy sources - solar, wind, biomass, geothermal and hydro - can play a key role in the decrease of CO_2 emissions. Currently, use of these energy sources on the commercial market is still hampered, mainly by non-competitive costs and the intermittence of their power generation. However, many countries or states have implementation goals for the use of renewables (see Figure 1), and have set up incentive systems to support these goals. The result is a significant rolling out of renewable-based technologies, leading to steady cost reductions. In particular, several learning curves show that renewable electricity should be cost-competitive with fossil electricity within the next 10 to 15 years.

Without waiting for this turning point, incentive systems in conjunction with high local renewable resources can already lead to very attractive investments for industrialists. For instance, industrialists may have interest in using photovoltaic panels in areas with high sunshine and/or where a green certificate system (see below paragraph on Green Certificates) has been implemented, biomass or biogas heater if their plant produces bio-wastes, wind turbine in windy areas where there is a feed-in tariff, etc. In some areas, the upfront cost of feasibility studies and the capital cost of installation may also be subsidized, by utility rebate, tax credits, etc. For example, from 2001 to 2011 the state of New Jersey has given out $375 million of rebates and incentives for renewable energy projects (New Jersey Clean Energy 2011).

Energy Storage

Several types of energy storage can be used on industrial sites, for instance batteries, thermal storage, flywheels. The services provided are also diverse and include: demand charge management, time-of-use energy cost management, on-site renewable support, power quality/continuity, reactive power compensation, participation in demand response programs, energy arbitrage. These services can lead to different revenue streams, such as reduced costs or payment from the grid operator, and reduce CO_2 emissions.

In the example of demand charge management, the revenue stream comes from the decrease in the utility demand charge. In the US, the demand charge for industrial customers ranges from $10 to $20 per kW. EPRI (EPRI 2010) has estimated the economic value of demand charge management with a storage system of 1 MW of power and 2 MWh of capacity, having a 15 year lifetime. The average present value was evaluated at $459 per installed kW, and rises to $2,297 per installed kW above the 95th percentile (corresponding to the 5% of the highest present values for demand charge management). For comparison, indications about current costs of several battery technologies adequate for demand charge management are provided in Table 1. Reduction of plant peak demand allows grid operators to diminish their reliance on peak power sources. Those sources, generally used a limited number of hours per year, can be hydraulic, but are often fossil-fuel based (gas, oil). Consequently, decrease in peak demand generally leads to a decrease in the grid CO_2 emissions.

All other applications of energy storage can also be associated to a revenue stream and can generally lead to CO_2 reductions in the electricity grid. Cost-effective use of energy storage is probably already feasible in some niche markets, or if used synergistically with other levers, e.g. on-site renewable, demand response or waste heat recovery (energy efficiency).

Table 1: Information on Battery Technologies for Peak Load Reductions

Technology Option	Maturity	Capacity (MWh)	Power (MW)	Duration (hrs)	% Efficiency (total cycles)	Total Cost ($/kW)	Cost ($/kW-h)
Advanced Lead-Acid	Demo-Commercial	0.1-10	0.2-1	4-10	75-90 (4500)	2800-4600	700-460
Sodium-Sulfur	Commercial	7.2	1	7.2	75 (4500)	3200-4000	445-555
Zn/Br Flow	Demo	0.625	0.125	5	60-63 (>10000)	2420	485-440
		2.5	0.5	5		2200	
Vanadium Flow	Demo	0.6-4	0.2-1.2	3.5-3.3	65-70 (>10000)	4380-3020	1250-910
Li-ion	Demo	0.1-0.8	0.05-0.2	2-4	80-93 (4500)	3000-4400	950-1900

Source: Electric Power Research Institute 2010. (EPRI 2010)

Demand Response

Demand Response is a consumer's ability to reduce electricity consumption at their location when wholesale prices are high or the reliability of the electric grid is threatened. Common examples of demand response include: raising the temperature of the thermostat in summer so the air conditioner does not run as frequently, slowing down or stopping production at an industrial operation or dimming/shutting off lights, and basically any explicit action taken to reduce load in response to short-term high prices or a signal from the electricity provider or system operator.

There are a number of demand response programs that industrial customers can participate in. These programs are managed by utilities or by aggregators, i.e. independent third parties who have contracted both with utilities and a pool of customers. They vary by country or state, by amount of consumption, by type of demand response (automated or not), by amount of notice prior to the demand response event, etc. In 2008 alone, US utilities offered approximately $500 million for demand response programs The coincidental peak load reduction capacity was about 40 GW (Cappers, Goldman & Kathan 2009).

The PG&E Peak Choice program is a good example of an effective demand response program. For a customer accepting a 30-min notice before reducing its electricity demand by 1MW anytime of the week, PG&E offers an annual incentive that can go from $45,000 to $80,000 depending of the number of hours of demand response events. This corresponds to revenues of $45 to $80 per kW of load reduction capacity per year (PG&E 2011).

Fuel Switching

Fuel switching consists in displacing a high-carbon fuel with a lower-carbon fuel. This can mean 1) replacing fossil fuel used on-site by a renewable fuel, e.g. biomass or thermal solar for heating needs instead of gas, or 2) replacing a fossil fuel-based technology by an electro-technology, e.g. replacing a gas-based metal heating process by an induction-based process.

The first case can be considered as a case of on-site renewable energy, already described above. In the second case, the legitimacy of the fuel switching to electricity is highly dependent upon the origin of the utilized electricity. If the electricity comes from the grid and has a high CO_2 content per kWh, the total (indirect) emissions can increase due to the switching. However, even with non-zero CO_2 content in the mix, the use of electro-technologies (to replace fossil-fuel based technologies) can be justified due to their usual higher efficiency.

The cost-effectiveness of a fuel switching to electricity is dependent of regional gas and electricity prices. Depending upon the baseline process, significant energy cost savings can be achieved. A report by the Electric Power Research Institute (EPRI 2007) mentions that one fuel-switching application in industrial heating, where induction heating replaced a salt bath and a gas-fired furnace, achieved 50% reduction in energy costs, 40% increase in productivity, and 20% reduction in rejects. Another fuel-switching application, where in-line induction hardening system replaced an aluminizing process, achieved 20% reduction in energy costs, and 25% increase in productivity.

Carbon Offset

Carbon offsetting consists in compensating greenhouse gas emissions by making reduction elsewhere; it is measured in tons of carbon dioxide-equivalent. Companies may decide to use carbon offsets:

- In the framework of a voluntary trade market where different kinds of providers sell various types of offset certificates (regarding reforestation programs, etc.). In 2008, around US$730 million of carbon reductions were traded on the voluntary markets. Due to the economic crisis, markets declined to US$387 million in 2009, with the average price of an emission reduction being $6.5/tCO2e (Hamilton et al. 2010; EcoBusinessLinks 2011). Surveys show that Company Social Responsibility and marketing are the main motivations for voluntary offset purchase.
- To comply with a Cap System. In such a system, companies received emissions credits(1) (certificates) corresponding to a maximal limit of CO_2 emissions, fixed according to their activity sector, size, etc. If a company emits more than its imposed limit, it has to pay a penalty (currently 100 €/ton in Europe) and/or offset its excess emissions. Several offset trading systems are currently in place: the International Emission Trading system involving countries having ratified the Kyoto Protocol (Annex I countries), the European Union Trading Scheme (EU ETS) involving 25 European countries, the Regional Greenhouse Gas Initiative (RGGI) gathering ten US Northeastern and Mid-Atlantic states, the Western Climate Initiative (WCI) joining seven US states and Four Canadian provinces, etc. Each system defines offset possibilities (see Table 2), either by purchasing emission credits or funding projects aimed at reducing CO_2 emissions.

Several markets have been set up to organize CO_2 (and more generally GHG) offset trading: Climate Exchange (United Kingdom), Chicago Climate Exchange (United States of America), Bluenext (France), etc. The average price of emission credits has varied a lot since the start of the trading systems, it is currently about €13/tCO2e in Europe, where credit trading reached about €66 billion in 2009 (Conseil 2010).

Purchase of Green Electricity or Green Certificates

Many electricity suppliers are now offering a "green tariff". This tariff is higher than the regular tariff, but it implies that the suppliers totally or partially match each sold kWh by purchase of one kWh of renewable electricity. The client may then consider that the electricity he uses is partially or fully green. Subscribing to a green tariff is an easy way for companies to reduce their indirect CO_2 emissions.

Companies may also purchase Renewable Energy Certificates (REC), also named green certificates. In countries or states that have a REC program, a green energy provider (such as a wind farm) is credited with one REC for every MWh of electricity it sells. This REC can then be can be traded or bartered on the open market, and the final owner can claim to have purchased

(1) Names of these emission credits vary with the system, e. g. European Union Allowance and Assigned Amount Units in the European and Kyoto Protocol cap and trade systems, respectively.

renewable energy. What defines "renewable" varies depending upon the certificate trading system. Such national trading schemes are in use in e.g. Poland, Sweden, the UK, Italy, Belgium, and several US states.

As a Conclusion: Some Examples of Zero or Near Zero Net CO_2 Plants

There are already relevant examples of Zero or Near Net Zero CO_2 plants. Some of them are pointed out along with the levers used to cut CO_2 emissions in Table 3. It seems that the energy systems of these plants have been designed in the framework of win-win partnerships between plant owners and energy-related companies. In some cases, local electricity providers have been involved through very attractive business models.

These examples show that ZNC plants are achievable, but a large effort of demonstration projects is still necessary to convince other industrialists of the relevance of the concept, to facilitate the identification of the right stakeholders' business models, and to demonstrate that cutting CO_2 emissions and improving the competitiveness of the industry can be compatible.

Table 2: Examples of Offset Mechanisms

	International Emission Trading (Kyoto Protocol)				**European Union Trading Scheme**
Name of the mechanism	Trading of Assigned Amount Units	Clean Development Mechanisms	Joint Implementation	CO_2 sink enhancement	Trading of European Union Allowance
Involved organizations	Public organizations and companies from countries listed in the Kyoto Protocol's Annex I				European companies with a net heat excess of 20 MW
Principle of the mechanism	Purchasing credits	Getting credits through projects carried out in non-Annex I countries (i.e. developing countries)	Getting credits through projects carried out in countries with economy in transition (European Eastern countries and Russia)	Getting credits through project aimed at increasing carbon capture through land use, land use change and forestry (e. g. planting trees)	Purchasing credits
Name of the trading unit	Assigned Amount Unit (AAU)	Certified Emission Reduction (CER)*	Emission Reduction Unit (ERU)*	Removal Units (RMU)	European Union Allowance (EUA)

* CRE and ERU are also accepted by the European cap and trade system

Table 3: Examples of Zero or Near Zero Net CO_2 (ZNC) Plants

	L'Oréal	Volvo Truck	Frito-Lay (Group PEPSICO).	Renault
Location	Aulnay-sous-Bois, France	Ghent, Belgium	Casa Grande, Arizona USA	Tangier, Morocco
Activity	Cosmetic producer	Truck producer (40,000 trucks/year)	Potato chips producer	Car producer (170,000 cars/year)
Status	Near ZNC (60% CO_2 reduction)	ZNC	ZNC by end of 2011	ZNC
Renewables on site	Yes	Yes	Yes	Yes
Selling green electricity	No	Yes	Yes	No
Fuel switching	No	Yes	Yes	No
Purchase of green electricity	No	Yes	No	Yes
Energy efficiency measures	Yes	Yes	Yes	Yes
Carbon offsets	No	No	No	No
Energy storage	No	No	No	No

References

[AB32] California Assembly Bill 32: **Global Warming Solutions Act**. Passed in 2006.

[CALGREEN] **California Green Building Standard Code, California Code of Regulations Title 24, Part 11**. Effective since January 2011.

Cappers, P., C. Goldman, and D. Kathan. 2009. **Demand Response in U.S. Electricity Markets: Empirical Evidence**. http://eetd.lbl.gov/ea/emp/reports/lbnl-2124e.pdf. Lawrence Berkeley National Laboratory, ref. LBNL-2124E.

[Conseil] Conseil économique pour le développement durable. 2010**. Prix du quota de CO2 et taxe carbone : quelques éléments de cadrage**. http://www.developpement-durable.gouv.fr/IMG/pdf/012.pdf

EcobusinessLinks. **Carbon Emission Offset**. 2011. http://www.ecobusinesslinks.com/carbon_offset_wind_credits_carbon_reduction.htm

[EERE **2009] Energy Efficiency and Renewable Energy Newsletter.** 2009 http://www1.eere.energy.gov/femp/pdfs/46311.pdf

[EIA 2007] Energy Information Administration 2007. **Annual energy review 2006.**

[EIA 2010] Energy Information Administration 2010. **Annual energy review 2009**.

EPRI. 2007. **Efficient Electric Technologies for Industrial Heating Emerging Activities**. Electric Power Research Institute, Palo Alto., ref. 1014000.

EPRI. 2010. **Electric Energy Storage Technology Options – A White Paper Primer on Applications, Cost & Benefits**, Electric Power Research Institute, Palo Alto., ref. 1020676.

[EU 2007] **European Commission Climate Energy Package**, passed in 2007.

Euractive.com. 2007. *SME Growth*. http://www.euractiv.com/en/innovation/sme-growth/article-155451?display=normal

European Commission. 2009. **Reference Document on Best Available Techniques for Energy Efficiency.** http://www.energimyndigheten.se/Global/F%C3%B6retag/ENE_BREF_Adopted_02-2009.pdf

Hamilton, K., M. Sjardin, M. Peters-Stanley and T. Marcello. 2010. **Building Bridges - State of the Voluntary Carbon Markets**. http://www.forest-trends.org/publication_details.php?publicationID=2433; Ecosystem Market Place, New Energy Finance, Bloomberg

[IPCC 2005] Intergovernmental Panel on Climate Change 2005. **Special Report: Carbon Dioxide Capture and Sequestration**. http://www.ipcc.ch/pdf/special-reports/srccs/srccs_summaryforpolicymakers.pdf

Jain, R.J., K. Jamison, and D.E. Thomas. 2006. **Identifying Opportunities and Impacts of Fuel Switching in the Industrial Sector**, US Department of Energy, Energy Efficiency and Renewable Energy.

McKane, A., M.A. Piette, D. Faulkner, G. Ghatikar, A. Radspieler Jr., B. Adesola, S. Murtishaw and S. Kiliccote. 2008. **Opportunities, Barriers and Actions for Industrial Demand Response in California**. LBNL-1335E.

McKinsey. 2009. **Unlocking Energy Efficiency in the US Economy**. http://www.mckinsey.com/en/Client_Service/Electric_Power_and_Natural_Gas/Latest_thinking/~/media/McKinsey/dotcom/client_service/EPNG/PDFs/Unlocking%20energy%20efficiency/US_energy_efficiency_full_report.ashx

New Jersey Clean Energy, 2011. **Project Activity Report.** http://www.njcleanenergy.com/renewable-energy/project-activity-reports/project-activity-reports

[PG&E] Pacific Gas & Electric. Test Drive PeakChoice™ Committed website. Updated in 2011. http://www.pge.com/mybusiness/energysavingsrebates/demandresponse/peakchoice/testdrivecommitted/

President Obama. 2011. **State of the Union Address.**

[RGGI] Regional Greenhouse Gas Initiative. 2007. **Overview of RGGI CO_2 Budget Trading Program**. http://rggi.org/docs/program_summary_10_07.pdf

Riding, J. 2005. "**Weyburn Enhanced Oil Recovery Project**", C02 Capture and Storage, International Energy Agency Greenhouse Gas R&D Programme. http://www.co2captureandstorage.info/project-specific.php4?project_id=70

Salas, C. 2009. "**Green Tags and Carbon Trading**". Proceedings of ACEEE Summer Study on Energy Efficiency in Industry.

[UNIDO 2010] United Nations Industrial Development Organization 2010. **Renewable Energy in Industrial Applications, An Assessment of the 2050 Potential.**

[UK 2008] UK Department of Energy and Climate Change website. Climate Change Act 2008. http://www.decc.gov.uk/en/content/cms/what_we_do/lc_uk/lc_uk.aspx

[UK 2009] UK Department for Communities and Local Government. 2009. **Zero Carbon Homes Impact Assessment.**

[US COTA 1993] U.S. Congress Office of Technology Assessment. 1993. **Industrial Energy Efficiency OTA-E-560** (Washington, DC: U.S. Government Printing Office).