Extreme Energy Efficiency on the Path to Climate Stability: A Tale of Two Municipalities

Tina M. Kaarsberg, U.S. Department of Energy
David Van Holde, King County, Washington Government

ABSTRACT

In this paper, we develop technology and policy pathways for two very different municipalities to achieve the goal of cutting building energy use in half (extreme energy efficiency or (EEE) by 2030. We estimate the potential benefits and costs of these pathways including energy savings and carbon emissions reductions. The pathways being developed are consistent with the announced goals of the municipalities, states or regions in which they reside, and groups of buildings that reside in them. One of the municipalities we study is King County Washington, which recently announced aggressive greenhouse gas mitigation goals, including 80 percent reduction in releases by 2050. King County will also implement Washington State's renewable portfolio standard (RPS) – requiring 15 percent new renewable electricity by 2020. The other municipality is Washington, DC, which is home to several initiatives including the Energy Efficiency Partnership of Greater Washington, the Greening of the Capitol Initiative, and the federal building goal in the 2007 energy law of reaching zero fossil energy by 2030. DC also has an RPS. As in previous analyses, we show how the 2030 goal can be reached by aggressive penetration of key commercial or near-commercial energy-efficient technologies such as passive solar design, advanced envelope technologies, advanced natural ventilation, solid-state lighting, onsite photovoltaics and combined heat and power (CHP). We do not explicitly model the policy changes that could cause such accelerated technology penetration and general efficiency increases but suggest how such policies may be implemented by drawing on historical and current examples.

Introduction and Overview

With undeniable and increasingly dire predictions for climate change, there are more and more calls for dramatic greenhouse gas (GHG) emissions reductions. Since fall 2006, a group of architects' organizations has called for all new buildings to use zero fossil energy by 2030 and their goals have now been included in federal legislation and endorsed by more hundreds of municipal leaders (A2030, 2006). In January 2007, the U.S. Climate Action Partnership was formed and called for US emissions targets between 70–90 percent of today's levels within fifteen years (USCAP 2007). In summer 2007, interpretation of the Nobel Peace prize-winning Intergovernmental Panel on Climate Change showed that an 80 percent reduction in GHG emissions by 2050 would be needed in order to keep GHG concentrations below a dangerous level. Finally, in December 2007, the President signed into law a bill that included a goal for new federal buildings to also use zero fossil energy by 2030. In light of these goals, extremely large building efficiency increases—such as doubling US efficiency by 2030—that just a few years ago seemed extreme—must now be considered in policy planning. Since energy use accounts for most US GHG emissions, energy efficiency is a key GHG reduction strategy.

Background

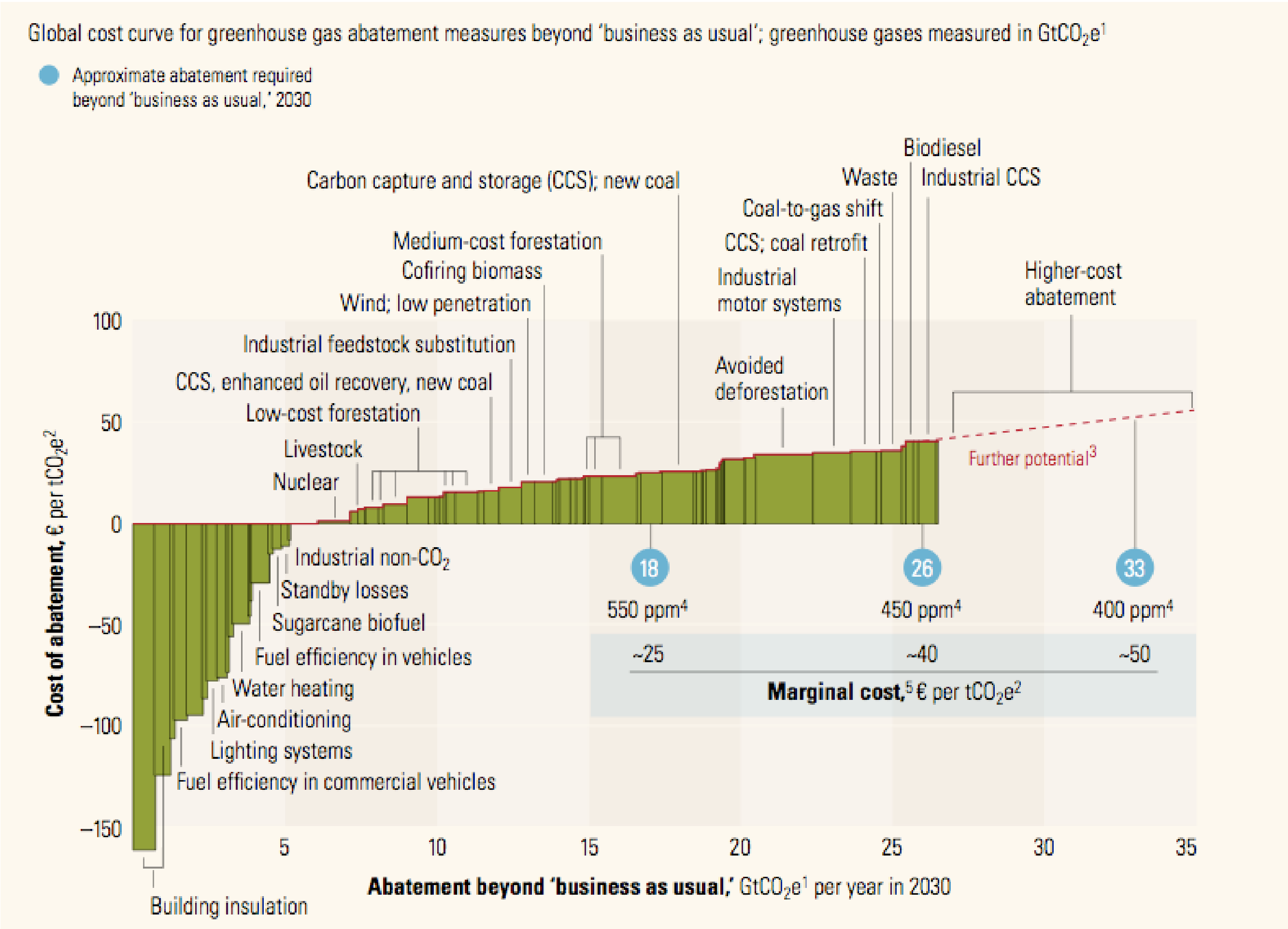
Last year we did a 'thought experiment' (Kaarsberg et al, 2007) to estimate the economic and environmental impact of doubling U.S. energy efficiency by 2030. Since the zero fossil energy goal applies strictly to new buildings, our 2030 efficiency doubling goal turned out to be consistent with it. It also is roughly consistent with an 'energy efficiency only' approach to achieving the aforementioned GHG reduction targets. This very rough analysis—our so-called 'Extreme Energy Efficiency' (EEE) case—led to CO_2 emissions decline of nearly 2 Gigatonnes (GT)—or about 30 percent below today's emissions and half the business as usual (BAU) reference case.

In the 2007 EEE paper, the first 'technology' we modeled was building strategies suggested by the Architecture 2030 **C**hallenge (A2030, 2006): an immediate 50 percent reduction in fossil energy use for new and renovated buildings going down to zero fossil energy use by 2030. What makes the non-renewable part of this 'technology' unique is that energy use reductions are achieved almost entirely through design—for example with passive solar orientation, natural cooling, ventilation and daylighting—strategies that do not necessarily increase capital costs over conventional systems. The onsite renewable power and the imported renewable energy are evaluated separately in our analysis. By 2030, 'Architecture 2030' 'technologies' reduce energy consumption by 17.6 Q compared to the reference case.

The second technological approach we used was onsite/distributed renewable generation. To be conservative, we modeled one of the more costly options, photovoltaics (PV). Using PV, we achieved 4.4 Q of avoided energy use nationally. The third technological approach is far greater use of onsite combined heat and power (CHP), which can be 60-90 percent efficient by making productive use of thermal energy lost in electricity production. Many types of CHP configurations can be deployed in buildings (Kaarsberg et al. 1998), (Onsite 2000). For example, in commercial and institutional buildings the market potential for this sector was estimated to be 35 GWe by 2020 (Resource Dynamics, 2002). Even residential CHP potential is significant (Kaarsberg et al., 2000). In our national scenario, CHP accounts for 5.7 Q of savings in buildings compared to the reference case.

A paper published in the McKinsey Quarterly last fall (Einskvist, 2007) created a cost curve (See Figure 1) for a wide swath of GHG reducing technologies. The energy efficiency analysis community was quick to note that in the new study, the majority of the negative cost technologies are energy efficiency technologies (e.g. low cost building efficiency improvements, such as insulation and lighting retrofits). In what follows we draw upon these and other cost curve analyses in estimating technology penetration and economic impacts.

Figure 1: Cost Curve for GHG Reducing Technologies Source (Einskvist, 2007)



Approach

To see how an Extreme Energy Efficiency (EEE) goal—halving building energy use by 2030—might be implemented for different municipalities, we project region specific technology paths for each municipality. We also discuss energy savings and carbon emissions reductions for these paths. The pathways being developed are consistent with the announced goals of the municipalities, states or regions in which they are located, and groups of building types found in these municipalities.

Base Case

In order to determine technology specific goals for 2030 from implementing the EEE strategy, our first task is to develop a 'base case' (BAU) for our two municipalities in 2030 including commercial and residential buildings' projected end use consumption disaggregated by fuel type. In our previous work we used the AEO 2007 Reference case forecast (EIA 2007), and we do so again here. EIA does not, however, provide forecast information down to the municipal level, so we used the regional forecast (Region 5 –South Atlantic, for Washington DC and

Region 9 –Pacific, for King County) scaled by the difference factors in the municipalities' 2004 (DC) and 2005(KC) energy data.

EEE Case

Once we have a business as usual (BAU) 2030 baseline, we have a target for our EEE energy efficiency technologies. It was clear from the outset that our municipalities' EEE case would be different than the national EEE case for buildings developed previously. To begin with, both municipalities had the aforementioned energy policy goals to comply with first (e.g. Washington RPS and 80 percent GHG emissions reduction by 2050 for King Co, and Federal Zero Energy buildings for DC). As seen in Figures 1b and 2b below, the two municipalities also have very different fuel mixes in their electricity supply; King County's being mainly hydro with an RPS, while DC's supply is coal heavy. The additional actions developed to achieve the goal are selected to reduce building energy uses—electric or non-electric—with the greatest primary energy and carbon savings that can be achieved at a reasonable cost. As at a starting point, however, we looked at high penetration of those EEE technologies lowest on the cost curve.

From the technology/policy futures developed for both municipalities, it appears that most of the goals for energy efficiency called for in this paper are attainable with commercially available and cost-effective measures. While the McKinsey Report cost curve shown above (Figure 1.) shows very general cost of savings, and so might be challenged on practicality, the National Action Plan for Energy Efficiency performed sector and measure-specific modeling with currently cost-effective measures in 2007, and found savings that reach 30 percent in many cases (Table 1.) (NAPEE 2007). The approach used includes both O&M and capital measures, which should be expected to become the norm in a future where energy efficiency expectations are greatly raised from current common practice.

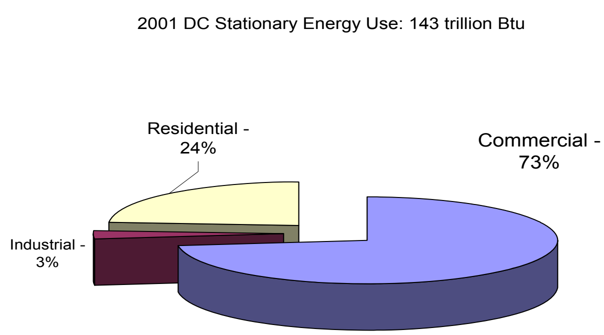
In the case of new construction, we assume even greater savings based on abundant evidence. ASHRAE 90.1 represents a widely applied efficiency baseline expectation in 2005; it is the baseline used by many utilities for calculating incentives for efficiency improvements. One typical example of new high performance buildings is the Clackamas County Public Service building that is 40 percent more efficient than ASHRAE 90.1 (Johnson, 2004). Such performance is the norm for large new showcase buildings. Performance contracting (provided in this case by Johnson Controls) and triple-bottom-leases require careful financial management of projects. The preceding cases are provided as examples for our rationale that measures resulting in greater than 30 percent reductions in building energy can be assumed to be incorporated in buildings before 2030, justified by reduced life-cycle-costs. Our proposed EEE scenarios' method assumes these are incorporated routinely, without explicitly identifying measures or incremental costs associated with such improvements.

Table 1. National Action Plan for Energy Efficiency (NAPEE) Results [NAPEE, 2007]

	Upgrade Measures	Electricity Savings (%)	Gas Savings (%)	Energy Savings (%)	Peak Demand Savings (%)	Energy Cost ($)	Energy Savings ($)	EPA Energy Rating
Office	Baseline	n/a	n/a	n/a	n/a	$598,049	n/a	59
(250,000 ft ^{2})	O&M Only	16%	25%	20%	8%	$490,035	$108,014	74
	Lighting Only	10%	-3%	4%	8%	$559,788	$38,261	65
	HVAC Only	21%	-5%	9%	27%	$515,895	$82,154	72
	All Measures	41%	17%	30%	36%	$392,768	$205,281	88
Hotel	Baseline	n/a	n/a	n/a	n/a	$351,957	n/a	44
(180,000 ft ^{2})	O&M Only	10%	10%	10%	6%	$316,249	$35,708	59
	Lighting Only	21%	-12%	3%	19%	$317,787	$34,170	61
	HVAC Only	23%	-1%	9%	23%	$300,991	$50,966	68
	All Measures	45%	4%	22%	42%	$243,256	$108,701	90
Supermarket	Baseline	n/a	n/a	n/a	n/a	$342,750	n/a	66
(45,000 ft ^{2})	O&M Only	4%	40%	9%	3%	$322,211	$20,538	71
	Lighting Only	7%	-30%	2%	11%	$327,279	$15,471	71
	HVAC Only	1%	0%	1%	4%	$340,042	$2,707	67
	All Measures	16%	10%	15%	21%	$288,215	$54,535	83
Retail	Baseline	n/a	n/a	n/a	n/a	$55,261	n/a	41
(30,000 ft ^{2})	O&M Only	14%	32%	24%	10%	$44,479	$10,782	57
	Lighting Only	28%	-27%	5%	25%	$46,861	$8,399	57
	HVAC Only	4%	0%	2%	12%	$53,770	$1,491	43
	All Measures	42%	14%	30%	41%	$35,729	$19,532	75

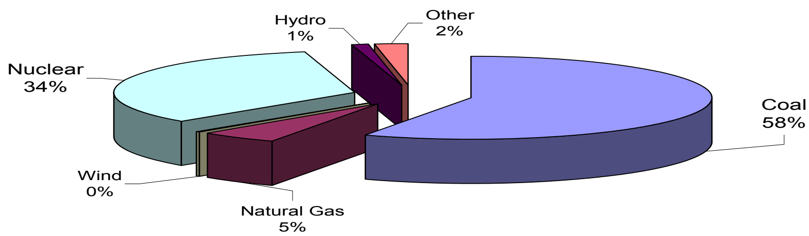
District of Columbia - DC has a fairly transient population of approximately 600,000 with about 300,000 housing units, 100 million square feet of commercial office space and a lot of federal buildings. The average size of commercial/institutional buildings in DC is above average, presenting some unique challenges (e.g. lighting) and opportunities (e.g. district heating and cooling).

Figure 1a. DC Stationary Energy Use by Sector



The relatively small energy use by residences compared with commercial buildings, (Figure **1a**), suggests we focus on commercial building energy savings to start with.

Figure 1b. DC 2005 Electric Fuel Mix (Source: PJM 2005)



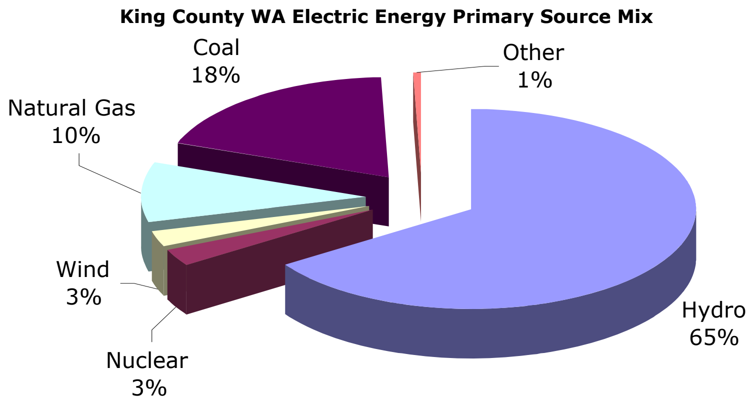
Thermal and Electric Fuel Mix

District of Columbia - Nearly all of DC's direct coal consumption comes from the Capital coal plant that heats the Capitol's District Energy system. DC's indirect coal use—through its consumption of electricity from coal plants, is above average at 58 percent compared to 48 percent nationally[1]. Electrical energy supplies to DC (Fig. **1b**) in 2005 are dominated by coal and nuclear (34 percent). Natural gas (almost entirely from recently constructed CCGTs) provides 5 percent, while wind power is less than 1 percent. Waste energy (2 percent) comprises most of the remaining 'other' category. Nearly all DC buildings have natural gas space heating.

King County - King County's population is approximately 1.83 million, concentrated around the Puget Sound coast, in the Seattle metropolitan area. The county has 742,237 housing units, of which 443,405 (60 percent) are single family and 298,832 (40 percent) are multifamily. 83 percent of 2005 King Co. energy consumption is in the commercial and residential sectors, split almost evenly between these (Fig **2a)**. Industrial energy use is only 17 percent.

[1] DC also is home to two large oil fired plants: Benning Road (550 MW) and Buzzard Point (256 MW) but they are rarely used now and are scheduled to shut down completely by 2012 (see http://www.pepcoholdings.com/about/news/archives/2007/article.aspx?cid=788)

Fig. 2a 2005 King County Energy Sectors

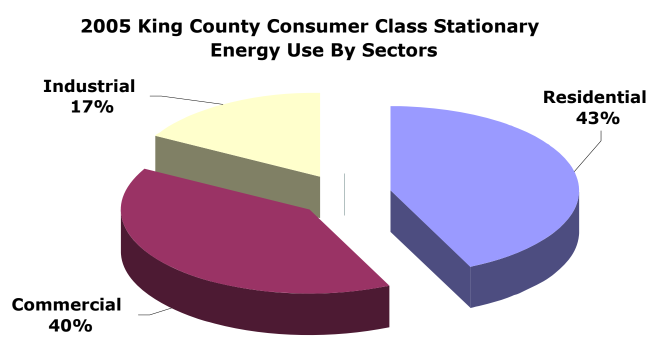


Thermal and Electric Fuel Mix

King County - Thermal fuels provide slightly more (52 percent) energy to King County stationary applications than does electricity (48 percent). The county needs more heating than air conditioning in its northerly marine climate. Thermal fuels in King County are dominated by natural gas at 82 percent, with fuel oil supplying 15 percent of heat and liquid petroleum gas (LPG) providing 3 percent, although in the BAU case LPG is projected to grow 23 percent over the 2005-2030 time of the study.

Electrical energy supplies to King County (Fig. **2b**) in 2005 are dominated (66 percent) by large hydropower sources ("non-renewable"). Coal supplies the second largest share (18 percent). Natural gas (typically recently constructed CCGTs) provides 10 percent, while wind and nuclear power each provides 3 percent. This wind is not included in a 15 percent renewable resource addition required by the Washington RPS in 2020.

Figure 2b. King Country Electricity Primary Sources



Energy Goals

King County—In developing the EEE pathway for King County, the following energy and carbon goals needed to be taken into account:

- Washington State RPS of 15 percent new renewable electricity by 2020.
- GHG emissions goals for Washington State to return to 1990 emissions levels by 2020; establish a pathway that achieves a 25 percent reduction below 1990 levels by 2035, and reduce emissions 50 percent below 1990 levels by 2050
- King County and Seattle governments' shared goal to reduce GHG emissions 80 percent below 1990 levels by 2050.

District of Columbia-- In developing the EEE pathway for Washington DC, the following energy and carbon goals and programs needed to be taken into account:

- Federal Government Building goal of zero fossil energy by 2030
- DC Building Code Standards for Public Buildings and non-residential building requiring LEED[2] certification in 2008 and 2012
- DC Green Building Act Standards[3]
- DC RPS of 11 percent renewable electricity by 2022 and other PJM RPSs (e.g. PA 18 percent by 2020, NJ 22.5 percent by 2021, MA 9.5 by 2022)
- Goals of the '30 percent solution' for residential buildings[4]

2030 EEE Scenarios

Washington DC- In the 2030 BAU case, DC building energy use rises to 225 trillion Btus. The EEE goal is to reduce this to 113 trillion Btus or ~20 percent below the 2001 DC building energy use of 138 trillion Btus. We also assume implementation of the Greening of the Capitol initiative will reduce GHG emissions of the Capitol complex by 50 percent in 10 years. In our EEE case for DC, the building sector accounted for energy savings of nearly 112 trillion Btu (or 50 percent) compared to the DC reference case (225 trillion Btus). Commercial (including government buildings) accounted for most of these reductions at 90 trillion Btu.

---

[2] LEED is the US Green Building Council's Leadership in Energy and Environmental Design standard. A 2006 assessment of 500 LEED certified buildings showed that every $4.00 in green building investment brings $28.00 in long term benefits.

[3] The DC Green Building Act was signed into law on December 5, 2006. On Oct 1, 2007, Mayor Fenty announced that the Department of Consumer and Regulatory Affairs (DCRA) would begin implementing the GBA and approved an update of the building codes to comply with 2006 IECC. Starting in 2012, the Act requires all commercial development of 50,000 square feet or more to qualify for LEED certification.

[4] In February 2008, DC Mayor Fenty joined mayors from across the country including Seattle WA in calling for the adoption of more energy-efficient building standards. The reforms, known as the 30% Solution, would make new residential construction 30%more energy efficient. It can include higher-efficiency window requirements; increased flexibility and higher efficiency for insulation, improved building envelope sealing, higher efficiency and function HVAC sizing and lighting efficiency improvements

Table 2. EEE Technology Approaches for DC Building Energy Savings

Technology Approach	2030 Primary Energy Savings (or fuel switching) Compared to Reference (trillion Btu)
RPS fuel switching	6.2
Non-renewable Electricity Efficiency: increase in base commercial buildings efficiency and Advanced lighting and daylighting (as per Green Buildings Act) + Photovoltaics for + CHP (including cooling and district energy)	58
Natural Gas Efficiency: increase in base commercial buildings efficiency + superinsulation as per Green Building Act Requirements and passive solar design (reach zero-heating buildings by 2030)	39
Residential Building Code requirement of 30% higher efficiency for new construction	8.3
Total	**112**

King County - The building sector accounted for energy savings of approximately 88 trillion Btu (or 40 percent of non-renewable energy supply) compared to the KC reference case (221 trillion Btus) and CO2 emissions reductions of 14.6 million MtC or 46 percent as compared to the BAU case for 2030. Of this total, residential buildings accounted for 41 trillion Btus (47 percent of buildings) and commercial for 47 trillion Btus. Notably, in the King County model, renewable energy contributes significantly (10 percent of total energy into these sectors by 2030 – 22 trillion Btus), as a result of the 2007 RPS. Renewables are considered on the "same side of the balance sheet" as conservation/ efficiency, as they also reduce CO_2 release. This is why conservation / efficiency goals could be set lower at 40 percent and still achieve total CO_2 release reductions of 46 percent by 2030 – slightly ahead of the goal of 40%, or halfway to 80% reductions by 2050. The EEE fuel mix includes significant decreases in all types, as compared to 2005.

Table 3. EEE Technology Approaches for KC Building Energy Savings

Technology Approach	2030 Primary Energy Savings Compared to Reference (trillion Btu)
RPS driven fuel switching to renewables: 15% of electric generation by 2020; assumed 1% per year increase 2020-2030	22
Non-renewable Electricity Efficiency: 30% increase in base buildings efficiency + Advanced lighting and daylighting + Photovoltaics + Combined Cooling Heat and Power	59
Natural Gas Efficiency: 30% increase in base buildings efficiency + superinsulation and passive solar design (reach zero-heating buildings by 2030)	26
Fuel Oil Efficiency & fuel switch: 30% increase in base buildings efficiency + switch to biofuels**	2.3
LPG Efficiency & fuel switch: 30% increase in base buildings efficiency + switch to biofuels**	0.75
Total	**110**

** Increasing growth of a variety of volatile liquid biofuels is assumed appropriate to replace home heating / generator liquid fuels where location / other restraints do not allow for piped gas, electricity or other options [Hancock 2008]

Policy Examples

The municipal building codes and state standards modeled for DC and KC are examples of the traditional 'stick' policies. In the past, however, 'carrot' approaches have had mixed success. Even when state and federal subsidies make energy efficiency and renewable systems cost effective, their adoption rates remained low. This may be changing however as knowledge about barriers to cost-effective energy efficiency has increased. For example, in fall 2007, Berkeley CA announced a plan to finance energy efficiency and solar energy by allowing cost to be paid by customers' city tax bills as a long-term assessment.[5] The City provides the funding for the project from a bond or loan fund that it repays through assessments on participating property owners' tax bills for 20 years. If the building owner sells prior to the end of the 20-year repayment period, the next owner takes over the assessment as part of their property tax bill.

In the Clinton Climate Initiative's Energy Efficiency Building Retrofit Program, four of the largest energy service companies (ESCOs) in the world have agreed to do audits of municipal and large private buildings in participating cities and identify retrofit projects. Five major global banks have committed $1 billion each to finance cities and private building owners to perform these retrofits at no net cost, with paybacks for the loans plus interest coming from the energy savings over several years. According to CCI these building retrofits can reduce energy use by 20 to 50 percent in existing buildings, which comprise the bulk of the building stock in cities.

Conclusion

The scenarios leading to cutting energy use in half by 2030 are well within reach. The two cases we looked at demonstrated clearly that the 'national' base case is missing a lot of the action. After all, in the United States, as in most developed countries, about 80 percent of the population lives in cities. The municipalities studied in this paper and hundreds of others in the U.S. are leading the way. The municipal results support the earlier national estimates in that they show this 'extreme' level of efficiency improvements saves energy and dramatically reduces CO_2 and appears both technologically and financially feasible, and in fact a boon to the economy.

To achieve these goals, however, a far greater effort in policy implementation is needed. For the electrical savings alone in King County, an estimated 99 average megawatts of savings will need to be captured each year for 20 years. This is approximately *3 times* the current rate of conservation capture. A large efficiency workforce and creative financing mechanisms will be needed to implement electrical efficiency / conservation programs at the level recommended to meet the 2050 goals.

References

[A2030] Architecture *2030 Challenge*, 2006. Details at http://www.architecture2030.org/

[EIA] Department of Energy. 2007 Annual *Energy Outlook*, Energy Information Administration, U.S. Department of Energy. February 2007. Washington, D.C.

[5] The Sustainable Energy Financing District is being developed as part of the City's implementation of Measure G – last year's Berkeley city ballot measure setting greenhouse gas reduction targets for Berkeley and directing the Mayor to lead the development of a plan to meet those targets. See http://www.ci.berkeley.ca.us/mayor.

[Enkvist] P.A., Naucler, T., Rosander, J; 'A cost curve for greenhouse gas reduction', *The McKinsey Quarterly* 2007 Number 1, 2007.

[Hancock] Hancock, J. G.; 'Booze Clues', *Motor Trend.com,* April 2008, pp. 37.

[Johnson] Johnson Controls, Case Study: Clackamas County, *Design-Build-Operate Brings Taxpayer Savings and Environmental Stewardship to Clackamas County Public Services Building,* 2004, www.johnsoncontrol.com

[Kaarsberg, et al 2007] Kaarsberg, Tina M, Ehr Ping Huang Fu, and Joseph M Roop 2007. *Extreme Energy Efficiency in the US: Industrial, Economic and Environmental Impacts.* ID# 61, in the proceedings of the ACEEE Summer Study on Energy Efficiency in Industry, July 25, 2007, White Plains, NY.

[Kaarsberg, et al. 2000] Kaarsberg, Fiskum, Deppe, Rosenfeld, A, and J. Romm, 2000. *Combined Heat and Power for Saving Energy and Carbon in Residential Buildings*, Paper 535, Panel 10: ACEEE 2000.

[Kaarsberg et al. 1998] Kaarsberg, T; Koomey J.; Romm; J., Rosenfeld; A. and Teagan, W.P., 1998. *Combined heat and power for saving energy and carbon in commercial buildings.* ID # 482 for 1998 ACEEE Summer Study on Energy Efficiency in Buildings, Pacific Grove, CA.

[Onsite] Onsite Sycom Energy Corporation. 2000. *The Market and Technical Potential for Combined Heat and Power in the Commercial Industrial Sector*; prepared for the Energy Information Administration, by ONSITE SYCOM (now with EEA, Inc) January 2000.

[NAPEE] National Action Plan for Energy Efficiency; "Sector Collaborative Accomplishments and Next Steps," (Draft report), December 2007.

[Resource Dynamics]. *Market Assessment of Integrated Energy Systems (IES) for Buildings*, prepared for DOE/ORNL (August 2002).

[USCAP]. U.S. Climate Action Partnership, *A Call for Action* January 22, 2007. Washington DC. see http://www.us-cap.org/ClimateReport.pdf