B O N N E V I L L E   P O W E R   A D M I N I S T R A T I O N

Energy Efficiency Technology Road Map

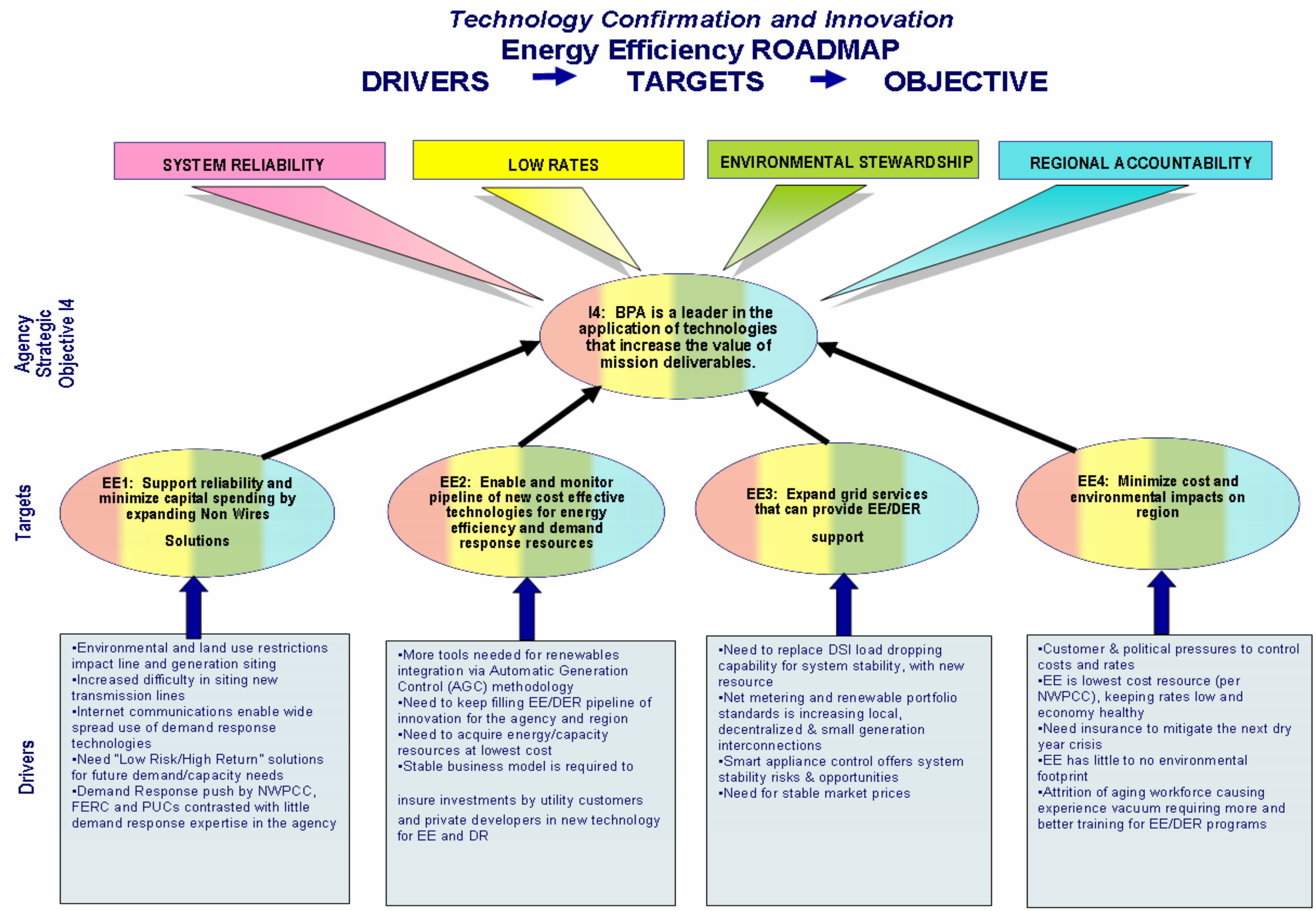
"It is common for technology to be introduced to reduce cost, *while its greatest value turns out to be the added value capabilities that it brings.*"

July 2006

TABLE OF CONTENTS

Cover quote: Technology Roadmap for Intelligent Buildings, P#34 <http://strategis.ic.gc.ca/epic/internet/intrm-crt.nsf/vwapj/TRM_English.pdf/$FILE/TRM_English.pdf> (accessed 25 May 2006)

Drivers and Targets – Energy Efficiency Technology Road Map



Executive Summary

I. Introduction

In 2005, the Bonneville Power Administration laid out a strategy to reinvigorate and focus its research, development and demonstration activities. It created an Office of Technology Innovation and appointed its first Chief Technology Innovation Officer. The new officer determined that the most effective way to explicitly identify and convey BPA's Research & Development (R&D) needs was to create an agency R&D agenda through a set of technology roadmaps for key areas of BPA's operations.

Technology Road Mapping is a strategic and operational approach used extensively in business to help organizations chart technology issues that are important to their future success. As with a geographical map, a technology roadmap charts direction, giving a starting point and where to go – as well as critical choices in between.

This document is the technology roadmap for the Energy Efficiency business unit and covers energy efficiency and distributed resources. Similar documents are available for transmission, environment, physical security, grid-connected renewables and hydro resources. BPA's ongoing fish and wildlife efforts are substantial and are not included in technology innovation or the road mapping processes.

In recent years, the Pacific Northwest's (PNW) energy requirements have shifted from winter peaking to summer and winter peaking. During this time, BPA's electricity generation and transmission capacity has become increasingly limited.

The Northwest Power and Conservation Council (Council) set a target for BPA to capture 40 average megawatts (aMW) of conservation for 2006 and 157 aMW for the period 2007 to 2009. Using the same proportioning methodology, BPA has a target for demand response of about 200 megawatts (MW) (hourly) by 2009 and 800 MW (hourly) by 2020[1]. BPA has committed to achieving its share of the conservation target, but has not yet committed to demand response targets set in the Council's fifth Northwest Power Plan published in May 2005.

Unless the R&D pipeline is fed, the region will not meet its targets for energy efficiency and demand response. Without new technologies, the region will not be able to benefit from next generation efficiency savings and the implementation of demand response. New technologies are needed that provide large energy savings, are cost effective and are easy for consumers to use.

"Historically BPA has been the regional center for energy efficiency R&D, providing funding and direction. BPA as a federal agency is situated to take the long view."[2]

[1] BPA's targets are approximately 40% of the regional targets
[2] Mike Hoffman's phone conversation with Tom Eckman, NWPCC, May 2006

II. Purpose

BPA is placing a renewed emphasis on RD&D and has developed this roadmap to ensure BPA achieves the maximum benefit from limited but growing dollars available for RD&D. The purpose of this roadmap is to provide direction for BPA's RD&D efforts. It provides a snapshot in time that identifies emerging high-priority energy efficiency and distributed resource technologies or practices. It also identifies associated new research and demonstration projects that may help advance these technologies and provide insight into where BPA's investments can make a difference.
This Roadmap covers Fiscal Years 2006 and 2007. It will be updated during FY 2007 for application in FY 2008 and beyond.

III. Scope

This document covers the residential and commercial sectors and a very limited exploration of the industrial sector. It includes both energy efficiency and distributed resources (particularly focused on demand response) technologies and practices. While BPA supports some research applicable to efficiency generally, this roadmap specifically focuses on new energy efficiency and demand response technologies and practices with potential significant impact in the Pacific Northwest. This report is not intended to ignore otherwise important R&D efforts underway by BPA or others in the region. Nor is it intended to guide decisions by the Northwest Energy Efficiency Alliance or Regional Technical Forum. It is intended to provide additional guidance about BPA's energy efficiency and demand response R&D interests both internally and externally for others interested in supporting advances in these technology areas.

IV. Methodology

BPA convened a group of Northwest experts[3] to brainstorm emerging technologies that have the potential for a large efficiency or demand response impact within the region. A specific focus was on technologies for which RD&D had the potential to advance commercialization. After originally identifying 14 technologies, the group prioritized the technologies considering the technology risk, potential value to the region and commercial risk. Over the winter of 2005/2006, BPA contacted individuals at major energy-related RD&D organizations[4] around the country to learn their primary areas of focus. The calls were both to ensure the group had not missed any promising emerging technology and to ascertain what RD&D for priority technologies are planned or currently underway.

Next, BPA reviewed the American Council for an Energy Efficient Economy (ACEEE) report, "Emerging Energy-Savings Technologies and Practices for the Buildings Sector as of 2004." This was the most comprehensive assessment of emerging energy efficiency technologies and practices available, and its recommendations mirrored BPA conclusions. For each of the eight priority technologies, the team addressed the following questions:

- Will the technology provide energy savings or capacity savings?

---

[3] Tom Eckman, NWPPC, Jeff Harris, NEEA, Ken Keating, Jack Callahan, Terry Oliver, Karen Meadows, Adam Hadley, Mike Hoffman BPA
[4] List of organizations and contacts in Appendix L.

- What research projects have other RD&D organizations undertaken or are planning with these technologies? In addition to avoiding duplicating research, the idea was to identify potential partners for collaborative research.
- What were the key research or demonstration issues?
- Was additional BPA RD&D activity likely to have an impact (or is sufficient research already being done)?
- What actions could BPA undertake to advance the state of the technology?

Priority Screening Criteria were used to select the top eight actions as shown in Section VI, BPA R&D Actions for Energy Efficiency – Table 1. These criteria are:

- Not currently standard practice.
- Performance-related features are readily identifiable and related to RD&D gaps.
- Significant non-energy benefits for utility or consumer provide an avenue for overcoming market barriers.
- Large potential savings (>30 percent) over existing technology or practice.

These criteria were applied to the original 14 technologies targeted by the group. The criteria led to actions that focus on technologies not in the market and that can be influenced by BPA R&D efforts, provide end users with non-energy or convenience benefits and would save large amounts of energy over current systems or practices.

Finally, BPA developed a rough estimate of the conservation and/or demand response potential in the Northwest, shown in Table 1, under the column Region Potential 2005 -2025.

V. Results – BPA R&D Actions:

Table 1 lists the technology, the section of the report the technology is in, actions BPA will take – from R&D to simply tracking the technology, what other organizations are doing, the potential MW savings for the technology according to the Council and a preliminary estimate of FTE and costs. Based on BPA's assessment of the criteria described above, the eight highest priority energy efficiency and demand response technologies and practices were selected and are shown in the following table. For a detailed explanation of why the particular technology was selected, read the Opportunity Overview section of each detailed Technology Report. To understand the drivers of each technology, see the technology road map diagrams for each of the detailed Technology Reports.

BPA R&D Actions for Energy Efficiency – Table 1

Technology or Practice (document location)	BPA Approach[5]	Recommended BPA RD&D Actions	RD&D by Others	Regional Potential [6] 2005 - 2025	FTE Preliminary Estimate	Budget Order of magnitude estimate

[5] BPA approach designates whether BPA intends to sponsor PNW research, participate in demonstration projects, co-sponsor collaborative research, or simply track progress of research by others, pending some breakthrough that would bring

Technology or Practice (document location)	BPA Approach[5]	Recommended BPA RD&D Actions	RD&D by Others	Regional Potential [6] 2005 - 2025	FTE Preliminary Estimate	Budget Order of magnitude estimate
Demand Response (Section 2.1)	R DPNW DPNW DPNW	White paper on demand response experiences and research needs Demonstrate effective demand reduction from Energy Management Systems: Demonstrate commercial building upgrade of Energy Management System (EMS) software to perform direct load control Demonstrate commercial (large and small chain stores, chain restaurant and convenience store) EMS system that delivers direct load control capability	CEC, NYSERDA, PNNL, PLMA, IEA, ALCA, LBL	228MW	.1 .2 .5 .5	$? $50-100k $200-500k $200-500k
Smart Appliances (Section 2.2)	C T C	Participate in Demand Response Research Center advisory committee. Track communicating thermostat standards Join Homeplug Alliance	Whirlpool, PNNL, GridWise, IBM, Samsung, Intel, CEC	90 MW (in addition to DR values above)	.1 .1 .1	$10k $10k $5k
Heat Pump Water Heater (Section 2.3)	D	Coordinate regional effort for CEE "Golden Carrot"	ORNL, VEIC, NRDC, EPA, NEEA	78 MW	1	$1million+
Heat pump without strip heat (Section 2.4)	R RPNW D	Test of new Low Temperature Heat Pump versus standard heat pump for efficiency performance Assuming positive outcome in Laboratory test, monitor and analyze performance of 20 LTHPs versus 20 standard HPs Coordinate planning for CEE or Regional "Golden Carrot"	ORNL	50 MW	.2 1 1	$100k $200-500k $1million+
Integrated Building Design (Section 2.5)	DPNW C	Demonstrate automated diagnostics for building retrofits Sponsor education on "energy	LBL, ORNL, DOE, ASHRE, CEC	100 MW	.2 0	$100-200k $20k

the technology higher on our priorities. Key: DPNW = demonstrations within the PNW, D = demonstrations potentially outside the PNW; C = collaborate with others, CPNW = collaborate specifically with PNW organizations, T =track, and R = research, RPNW = conduct research within the PNW or with PNW organizations.

[6] (est. from 5th Power Plan) < http://www.nwcouncil.org/energy/powerplan/default.htm> (accessed 19 May 2006)

Technology or Practice (document location)	BPA Approach[5]	Recommended BPA RD&D Actions	RD&D by Others	Regional Potential [6] 2005 - 2025	FTE Preliminary Estimate	Budget Order of magnitude estimate
		object" use in design				
Low Energy Cooling (Section 2.6)	T, C	Specific technology interests: • evaporative cooling	CEC, NEEA	100MW	.2	$?
High Efficiency Lighting (Section 2.7)	T	Specific technology interests: • LED task lighting, • wireless control and • dimmable ballast	DOE, NEEA, Phillips, Cree	260 MW	.1	$10k
Industrial process (Section 2.8)	C T	Forest Products - sponsor PNW nano tech conference Track Paper machine laser sensor research with NEEA - LBL	LBL, ORNL, NEEA, DOE	10 MW	0 .1	$20k $?
Totals		FTE & Cost spread over FY 2007-2008			5.4 (2.7/year)	$3-4 million

VI. How this Road Map Will Be used: Next Steps

BPA can use the Road Map in the following ways:

1) As a guide to spend technology innovations funds for FY 2007 and FY 2008.

2) For additional funding requests outside of the EE budget, from BPA’s Technology Innovation group to fund the projects suggested.

3) To solicit RFP’s for the proposed actions.

4) With other Road Maps to develop an agency action plan for Technology Innovation.

5) As a living document by implementing the following actions:

- Start dialogues with the organizations associated with each technology in Table 1 on the topics to be pursued for research in each technology
- Start regular reviews of the options for collaborative funding between BPA and national laboratories.

Technology Reports:

2.1 Demand Response (DR)
(Demand Exchange, Distributed Generation, Energy Storage, Direct Load Control)

2.1.1 Technology Overview:

Demand Response (DR) uses a wide range of technologies, which offer a wide range of options for both peaking and energy capacities across the electrical system. Demand response technology has three forms: voluntary demand reduction, direct load control and distributed generation.

Voluntary demand response is a method of offering consumers incentives to voluntarily reduce their electric loads at system peaks. BPA has used this approach with the Demand Exchange™ (DEMX) system. DEMX is a Web-based system that allows BPA to make offers for demand reductions at facilities that have contracts in place. The facility can accept, reject or make a counter offer. The system saved BPA $1.9 million in the 2001-2002 power crisis in demonstration mode.[7]

Direct Load Control (DLC) involves a utility-controlled appliance at a customer site. The bulk of DLC is in the residential sector, as air-conditioning load control and winter heat control. Commercial DLC programs also target air conditioning and occasionally lighting. Commercial and residential utility programs are primarily in the Northeast, Southeast, Midwest and California.

Distributed generation (DG) is normally used to start back-up generators when peaking resources are needed. Generators are often converted to run on natural gas to lower the fuel costs and reduce the environmental impact of burning diesel fuel. Portland General Electric currently has 30+ MW of DG in the Portland area and uses it for capacity and reserves.

BPA is participating in a demonstration project using all three technologies as part of the GridWise effort on the Olympic Peninsula.[8] Pacific Northwest National Laboratory's (PNNL) Grid Friendly Appliance Controller (GFA) is being tested for the GridWise effort as a new system reliability tool. It is embedded in appliances and heating, ventilation and air-conditioning (HVAC) systems to help prevent system blackouts by dropping appliance loads in underfrequency conditions; in other words, when there has been a major disturbance in the power system. GridWise demonstrations also show that energy management (efficiency) systems can deliver reliability benefits.[9]

Communications pathways to enable DR have multiplied, become faster and dropped in price. They have the ability to reach most electric utility end users. DR control communications currently include cellular phone service, one and two-way paging and VHF radio, as well as broadband, DSL and cable Internet connections. The benefit of two-way communications to DR devices is the real-time display of

[7] BPA Demand Exchange Pilot Program Annual Report, Dec. 2001, P# 10
[8] GridWise press release <http://www.pnl.gov/news/2006/gridwise/gridwise_demo_flier-final.pdf> (accessed 13 May 2006)
[9] Ibid.

exactly how much curtailable load is online. Such real-time control allows PacifiCorp to use DR resources for supplemental and spinning reserves, in addition to a capacity resource. This increases PacifiCorp's ability to sell power, rather than use spinning reserves at generation facilities.

2.1.2 Opportunity Overview:

Demand response (DR) is a method of using technology and incentives to change electricity use by end-use customers that can result in reductions of energy generation at times of peak use and at times of high wholesale market prices.

Demand response offers benefits to both utilities and consumers. These benefits include increased electric system reliability and reduced price volatility. Over the last five years, DR programs have been used increasingly by major independent system operators (ISO), regional transmission operators (RTO)[10] and individual utilities around the country, particularly in the East and California. In the Northwest, demand response could also help meet river operations requirements to protect fish in a dry year and lessen market pressure from California. BPA could improve its ability to protect the environment, minimize market prices and maintain system reliability. In addition, reducing use of gas peaking turbines reduces CO^2 emissions,[11] another benefit to the environment. Also, BPA's non-wires solutions efforts have shown that DR technologies can defer the need to construct transmission or distribution assets.[12]

BPA is already using one aspect of demand response on a limited basis, the Demand Exchange™ system. BPA successfully demonstrated the Demand Exchange™ system during the 2000-2001 West Coast energy crisis when it saved $1.9 million[13] by purchasing DR instead of power on the open market.[14] If another very low water year triggered another energy crisis, expanding the Demand Exchange™ system could limit the effects of the crisis.

The Council has set targets[15] for DR of 500 MW for the region in 2009 and 2000 MW in 2020, reinforcing the importance of both environmental and market drivers for BPA. Also the Energy Policy Act of 2005 (EPA) made recommendations for achieving DR benefits on a national scale.[16]

---

[10] A Critical Examination of ISO Sponsored demand response Programs, Aug. 2005 by Center for Advancement of Energy Markets (CAEM) pg # 1. Regional Transmission Operators using this technology are located in New England, New York, Pennsylvania Jersey & Maryland, ERCOT – Texas, California and Midwest – MISO.

[11] OPUC Advanced Metering Workshop, Slide # 34, <http://www.oregon.gov/PUC/electric_gas/010605/malemezian.pdf > (accessed 13 May 2006)

[12] BPA Non Wires Solutions site link <http://www.transmission.bpa.gov/PlanProj/Non-Wires_Round_Table/NonWireDocs/NonWiresQuestionsAnswers.pdf >

13 BPA Demand Exchange Pilot Program Annual Report, Dec. 2001, P# 10

[14] This early use of DR was a BPA demonstration project in which BPA customers bid on lower energy prices by changing their time of use of the electricity. This project was of limited scope with limited customers, many of which were plants that have since ceased operation, so few agreements are still in effect.

[15] May 2005 5th Power Plan, P# 31< http://www.nwcouncil.org/energy/powerplan/default.htm> (accessed 19 May 2006)

[16] EPA 2005, P# 75,<http://energycommerce.house.gov/108/0205_Energy/05policy_act/Title%2012%20-%20Electricity.PDF > (accessed 6 May 2006)

2.1.3 R&D Challenges

DR faces many challenges remain in the market. Consumer acceptance is a large challenge, because customers must agree to use equipment in their homes or businesses to supply energy or capacity to the system through their thermostats, appliances or generators. The challenge is to work with end users and communicate the need and benefits of this technology to retail utility customers, not BPA customers. Making DR customer friendly is the biggest issue in successful implementation of DR programs.

A recent Department of Energy (DOE) report, "Benefits of Demand Response in Electricity Markets and Recommendations for Achieving Them,"[17] details the challenges to implementing DR successfully. These include the need to foster price responsive DR, the need to improve incentive-based DR, better analysis of the value of DR for policymakers, the need to adopt enabling technologies for DR (such as communications and smart meters) and integrating DR into utility Integrated Resource Planning (IRP)[18].

Most regions have based DR on rate structures that do not currently exist in BPA's utility customers rates. An example is California's Critical Peak Price (CPP), which assumes the presence of smart meters to automate the accounting for CPP price events. BPA's utility customers will need to adopt the smart meter technology or create a different automated accounting process at the end-use level. Another hurdle is that many of BPA's utility customers give an incentive to end users for higher electricity use.[19] Still another hurdle with politically influential customers may be a perception that implementing DR would force "market-based" rates on them.

Given that opinions on the value of DR vary, BPA's internal challenge will be to prioritize the following uses for DR with a cross-agency team.

- Reducing winter peak (in constrained areas)
- Providing energy in dry years
- Stabilizing market prices at peaks (winter or summer)
- Economic use (sale to California in market crisis – likely an exchange rather than sale)

2.1.4 Sector Actors

A. FERC: Federal Energy Regulatory Agency's (FERC) 2005-2008 Strategic Plan states that FERC will "Promote development of policies that accommodate effective demand response programs."

B. Council: Northwest Power and conservation Council set regional targets of 500MW of demand response by 2009 and 2000 MW by 2020.

C. CEC: California Energy Commission made the following policy recommendations to increase the level of demand response:

---

[17] http://www.doedemandresponsereporttocongress.com/ (accessed 17 May 2006)
[18] Ibid P # xiv
[19] Jackson Hole News article <http://www.jacksonholenet.com/news/jackson_hole_news_article.php?ArticleNum=1426> (accessed 13 May 2006)

Policy 1- Support continued installation of Automated Metering Infrastructure (AMI) systems with functionality to support dynamic rates for all California utilities.

Policy 2- Develop performance-based incentive system to encourage the CEC's DR goal attainment by 2008

Policy 3- Support use of Critical Peak Pricing rates (CPP) as the default rate for residential customers with opportunity to opt out to time-of-use or current rates after trial period

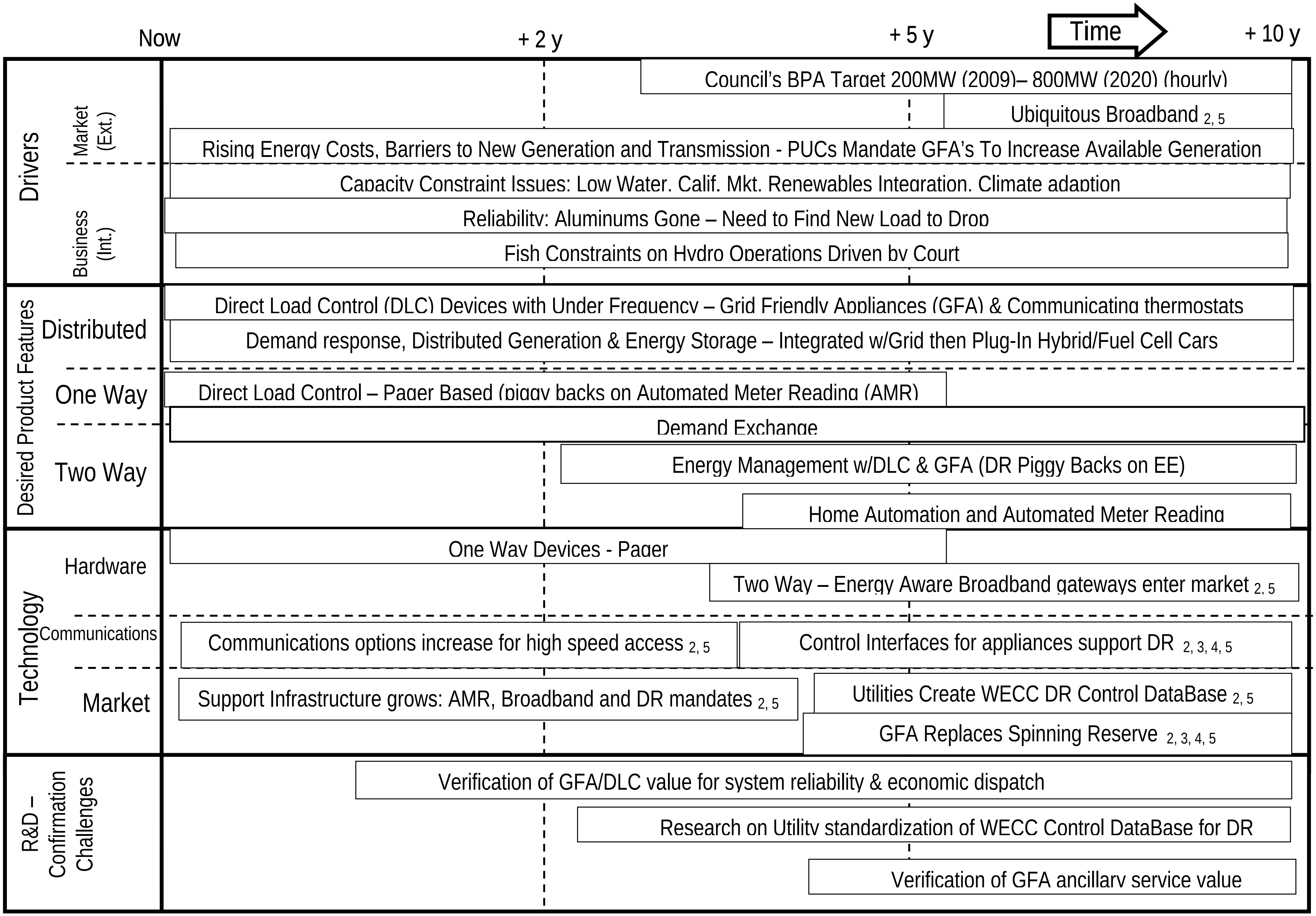
D. DRRC: Demand Response Research Center says California needs a real-time demand-side infrastructure to respond to supply-side problems. This DR infrastructure must be compatible with the state's independent system operator and electric utility companies while serving the loads and needs of California's electricity customers. The DRRC will plan and conduct multi-disciplinary research to advance DR in California.

E. ACEEE: American Council for an Energy Efficient Economy sponsored publication of "Exploring the Relationship Between Demand Response and Energy Efficiency: A Review of Experience and Discussion of Key Issues." It reviews leading studies of DR programs and analysis and discusses conflicts and synergies between energy efficiency and DR. It contains a summary of expert opinion on integrated approaches to customer energy services.

F. NEDRI: The New England Demand Response Initiative was created to develop a comprehensive, coordinated set of demand-response programs for New England power markets. NEDRI's goal was to outline workable market rules, public policies and regulatory criteria to incorporate customer-based, demand-response resources into New England's electricity markets and power systems.

2.1.5 Demand Response Roadmap

The following diagram is intended to briefly: 1) illustrate the most relevant drivers of DR technology from internal and external perspectives; 2) list desired (future) product features from cost, operational and technical perspectives; 3) list the types of technology and suggest when future products may be come available; and 4) indicate the R&D challenges to development of those technologies. The timeframe illustrates current understanding of how this technology may develop over the next 10 years.



2.1.5 Demand Response Roadmap

Legend: Technologies supporting or overlapping with DR $_1$, Smart Appliance $_2$, Heat Pump Hot Water Heater $_3$, Heat Pump without Strip Heat $_4$, Integrated Building Design $_5$

2.1.6 Suggested Role for BPA….

Phase I –Demonstration and evaluation, encourage research and information sharing
June 2006 to June 2007

- Produce report of lessons learned from using DR techniques, paying special attention to the implications of dealing with utility customers, contracting and field installation logistics. The report will cover the following BPA experiences:
  - Trading floor scheduling with Demand Exchange (DEMX)
  - Transmission dispatching of loan reductions using DEMX
  - Non-wires demonstration projects
    -- Ashland two-way broadband
    -- Olympic Peninsula load control
    -- Umatilla irrigation control demonstration

- Actively work with the Council's Demand Response Working Group (DRWG) to define demand response as it applies to the Northwest.

- Collaborate with the Demand Response Research Center in California as it is developing methodology for quantifying the value of demand response.

- Use the methodology for quantifying the value of DR to add a DR value variable(s) to the Energy 2020 software as requested by the Council. The value variable will be used during Phase II to show the value of DR and energy efficiency in minimizing regional costs of the power system (including transmission and distribution line deferrals).

- Compile DR technology options for various economic sectors and climate zones. Build a budget that shows current costs and projected future costs for large-scale implementation across economic sectors and climate zones.

- Actively pursue commercial (nonresidential) DR demonstration projects. Projects using energy management systems for both energy efficiency and DR would be tested in commercial operations. Likely locations are the southern Oregon coast (non-wires rollout) and the Puget Sound area (improve transfer capability).

- Continue work with Pacific Northwest National Laboratories on GridWise concepts, including the integrated energy operations center, Grid-Friendly Appliance (GFA) controller and consumer responsiveness to cost and comfort control. This work is expected to show the value of integrating several DR resources: DLC, DG and GFA devices for deferral of line construction.

- Continue to support the work of the Northwest Energy Technology Collaborative (NWETC) in bringing new technologies to market, with a special focus on DR.

- Work with Oregon State University engineering students on senior projects directed at control of individual appliances across the Internet using the power line carrier or wireless technologies.

Phase II – Regional buy-in to large-scale implementation
June 2007 - 2009

- Conduct southern Oregon coast demonstration project to determine the cost savings potential and practical implications of using non-wires solutions to defer transmission line construction and to test customer utility partnering options. Evaluate the project based on cost, installation time, customer acceptance and marketability.

- Participate with the Council's regional effort, the Demand Response Working Group (DRWG), BPA customers, investor-owned utilities and environmental organizations to develop consensus on the financial rationale and value to the region of DR program implementation, including the value of non-wires solutions for transmission and distribution applications. This process, to be led by the Council, should also include the issues of rates, smart metering and critical peak pricing.

- Participate with regional players in the DRWG to create a plan for encouraging third-party aggregators to invest in DR technology. The Council would also lead this process.

BPA's DR goal is to reduce costs, defer transmission investments and safeguard the region's resources.

2.2 Smart Appliances

2.2.1 Technology Overview

Smart Appliances offer a new resource to manage and shed load to maintain system stability. Formerly, BPA relied on aluminum plant electricity customers to shed load in emergencies, but this is no longer possible since most regional aluminum plants have closed.

Another benefit to utilities would be the potential to use Grid Friendly Appliance (GFA) devices to reduce load in emergencies instead having to set aside part of their electricity generation capability as spinning reserves.[20] Therefore, utilities would then be able to sell rather than set aside this power generation capability.

By remotely controlling appliances (over the Internet), the end user could save money by choosing off-peak energy use, with the assumption of time–of-use (TOU) rates. The efficiency and convenience of Internet control has been demonstrated in both the California Automated Demand Response System Demonstration[21] and in BPA's two-way broadband load control demonstration in Ashland, Ore. In California, the demand reduction at peak averaged 7.4 kilowatts per hour for homes controlled with two-way broadband systems.[22] In Ashland, where end users had remote control over water heaters and HVAC systems, they were able to turn systems off while away and turn them back on before returning so that they could return to a hot shower and air conditioned comfort.[23]

The cost of chips is steadily falling, making it cheaper to add intelligence to appliances, and therefore making Smart Appliances more affordable. At the same time, more end users have the capacity to use this technology because of growing broadband Internet connectivity in their homes. As of April 2006,[24] 42 percent of the U.S. population had this ability.

2.2.2 Opportunity Overview

Smart appliances are home appliances that have technology built into them that, in some cases, can communicate with and allow control by utilities for load management. In other cases, the technology allows for independent action. Built-in sensors can turn the appliance off intermittently when the electrical grid is under stress. Smart Appliances are one form of demand-response technology discussed in Section 2.1 of the EE Technology Road Map.

This technology has value in two ways: First, smart appliances can be used to shave electrical energy peaks and prevent or delay the need for new generation, new transmission lines or new distribution lines. Second, smart appliances could be used to prevent expensive blackouts by under-frequency load shedding. The impact of Smart Appliances can be substantial, because home appliances represent

[20] A percentage of power generation that utilities may not sell and are required to hold in reserve
[21] DRRC Statewide Pricing Pilot – Report Slides, Slide # 19 <http://drrc.lbl.gov/pubs/intDRseminar_messenger.pdf> (accessed 25 May 2006)
[22] Ibid Slide # 26
[23] According to Jenny Roehm, BPA point of contact for Ashland's pilot.
[24] Pew Trust, <http://www.pewinternet.org/PPF/r/182/report_display.asp> (accessed 17 May 2006)

35 percent of residential energy use.[25] Major appliances that are candidates for smart appliance technology include clothes washers and dryers, refrigerators and freezers, dishwashers, stoves, microwave ovens and room air conditioners.

The concept of smart appliances is new and is being tested in a regional demonstration project through Pacific Northwest National Laboratory (PNNL) using its GFA controller. The PNNL test is using residential clothes dryers to test under-frequency load shedding. Three organizations – BPA, PGE and PacifiCorp – are participating in demonstrations on the Olympic Peninsula, in Portland and in Yakima, respectively.

2.2.3 Challenges

Smart Appliances could be the foundation of a residential reliability/demand-response system. Most utilities have yet to consider end-use devices for reliability and demand response and have not pursued developing programs to reimburse end users or manufacturers for these capabilities. The technology must win the support of utilities and consumers, and it must develop the infrastructure to allow widespread use that will convince manufacturers to build these capabilities into their products.

There are both physical and process infrastructure issues to overcome. Before consumers can use the technology to respond to utility requests for DR, a system for centralized control of large numbers of appliances must be developed. While in-home control of appliances is now in the marketplace, it is essentially limited to controlling entertainment devices. In addition, automated metering must be developed to facilitate direct-load control rates or incentives.

The current utility rate model of requiring higher consumption to increase profits must be modified if utilities are to promote Smart Appliances. Education is needed for both utilities and consumers. Some consumers may perceive the external control of their electricity is a form of “Big Brother” in the home, and this fear must be overcome.

Regulatory support from state public utility commissions (PUCs) is important for utility integration of these devices. Investor-owned utilities need rate recovery assurance before they will try to tap the Smart Appliances resource. In addition, both public and private utilities are cautious about any impact on customer comfort.

A long-term commitment by utilities to both use and pay for reliability and demand response is needed before appliance manufacturers will consider building these capabilities into their products.

2.2.4 Sector Actors

A. PNNL: Pacific Northwest National Laboratory, supported by DOE, is running the Pacific Northwest GridWise™ Demonstration Project, a regional initiative to test and speed adoption of new Smart Grid technologies that can make the power grid more resilient and efficient. In the portion of the demonstration focused on the smart appliance technology, a computer chip developed by PNNL is being installed in 150 Sears Kenmore dryers produced by Whirlpool Corporation. At the end of the study, researchers will evaluate customers' reactions to the chip

[25] EPA Energy Efficient Appliances, <http://www.energystar.gov/ia/new_homes/features/EstarAppliances1-17-01.pdf> (accessed 17 May 2006)

and their responses to the real-time pricing information. This will provide insight into consumer acceptance and will help government and industry determine whether and how best to make the technologies more widely available to consumers.

B. Whirlpool supplies the washing machines used in the Pacific Northwest GridWise™ Demonstration projects. Whirlpool developed the Application Programming Interface (API) that allows a signal to shut off the dryers' heating elements temporarily in response to an electrical system emergency need.

C. Intel Capital's digital home system appliances are served by a central computing hub that picks up satellite signals, then dispenses them to the various electronic appliances scattered throughout the household.

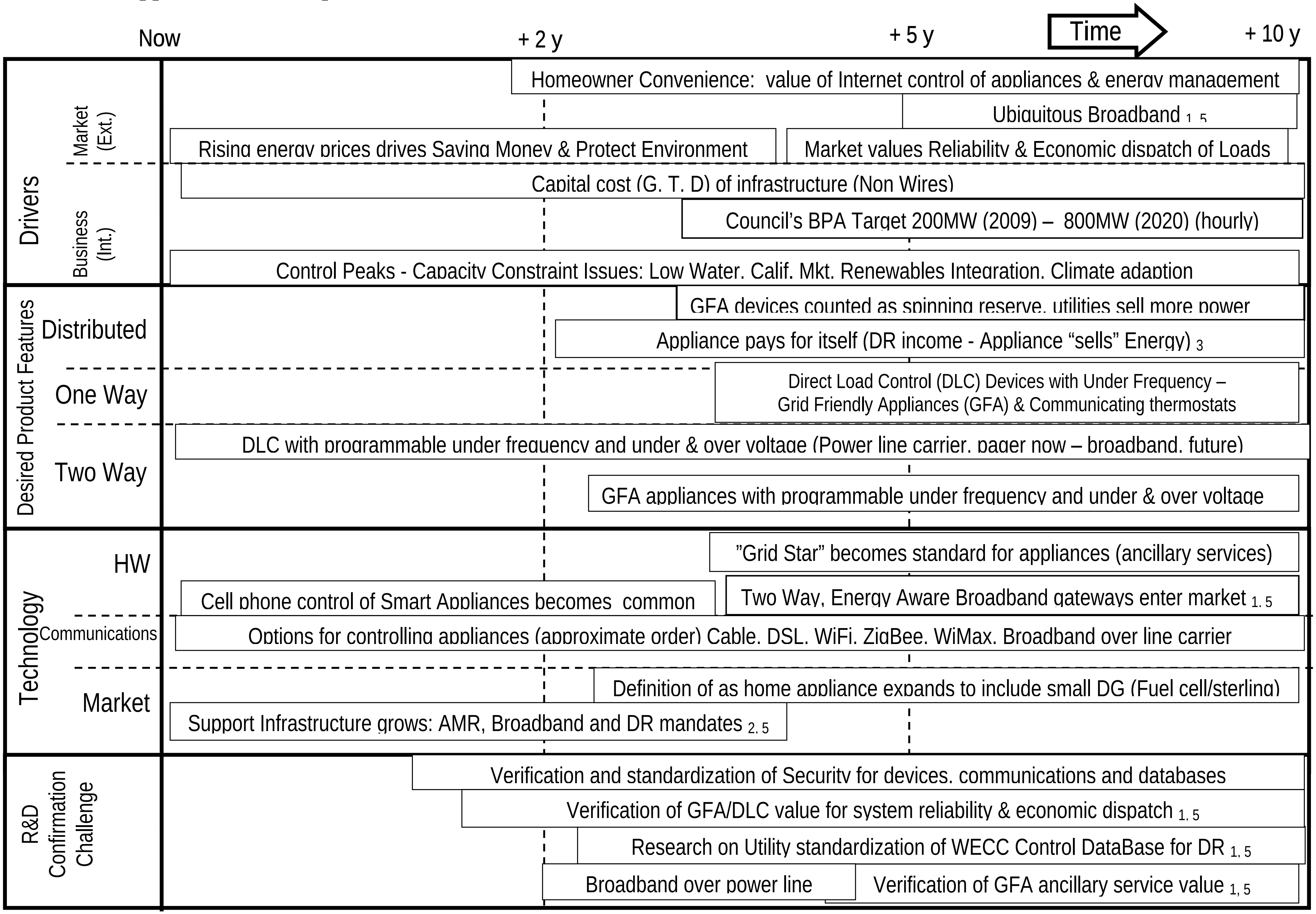
D. Invensys supplies the two-way broadband residential appliance control system BPA used in the Ashland, Ore., demonstration and by PNNL for the PNW GridWise demonstration.

E. Home Plug Alliance's mission is to enable and promote rapid availability, adoption and implementation of standards-based home power line networks and products that are cost effective and interoperable.

2.2.5 Roadmap

The following diagram is intended to briefly: 1) illustrate the most relevant drivers of smart appliance technology from internal and external perspectives; 2) list desired (future) product features from cost, operational and technical perspectives; 3) list the types of technology and suggest when future products may be come available; and 4) indicate the R&D challenges to the development of these technologies. The timeframe illustrates current understanding of how this technology may develop over the next 10 years.

2.2.5 Smart Appliances Roadmap



Legend: Technologies supporting or overlapping with DR 1, Smart Appliance 2, Heat Pump Hot Water Heater 3, Heat Pump without Strip Heat 4, Integrated Building Design 5 HW =Hardware, SW = Software

2.2.6 Suggested Role for BPA:

Phase 1: Fall 2006 through 2007
Educate critical appliance manufacturers producing high-load appliances and evaluate regional communication infrastructure.

- Present Olympic Peninsula GFA project information to Association of Home Appliance Manufacturers (AHAM) at the next annual technical meeting and work to educate members about the value of reliability through GFA controllers and demand response for consumers and utilities.

- Present Olympic Peninsula information and AHMA's level of interest to National Association of Utility Regulatory Commissioners (NARUC) to raise the level of national visibility of the value of smart appliances.

- Educate consumer appliance manufacturers, through the Home Plug Alliance, who are building this communication standard into their products. Inform them of the value of reliability and demand response to utilities and consumers. Track Home Plug Alliance standard implementation in white goods and entertainment industries. The AHAM, Home Plug Alliance and NARUC actions are meant to educate consumer goods manufacturers and regulators about the value of reliability and demand response, with the assumption that it will speed implementation of the technology.

- Using BPA's geographic information system (GIS), map BPA territory to show where capabilities for communicating with smart appliances are located, Include the following: cable, pager (both one and two way), cellular coverage, Digital Subscriber Line (DSL),[26] broadband over power lines (BPL)[27], WiFi[28], and WiMax[29] as it evolves. (This is a key component for BPA's potential to implement the Council's DR targets.)

Phase 2: 2008-2010

Implement demonstration projects to support development of a demand-response market for smart appliances.

- Demonstrate new methods of using appliance controls (HVAC, white goods and commercial lighting) via the various communications options.
- Use smart appliances in a demonstration of a demand-response market for reliability and demand response in coordination with the Council, IOUs, public utilities and PNNL.

The second phase would demonstrate the functionality of smart appliances with a demand-response market to highlight the market transformation potential for quickly implementing smart appliances as a resource across a wide area.

---

[26] <http://www.sharpened.net/glossary/definition.php?dsl> (accessed 21 May 2006)
[27] <http://compnetworking.about.com/od/broadband/g/bldef_bpl.htm> (accessed 21 May 2006)
[28] <http://wi-fiplanet.webopedia.com/term/w/wi_fi.html> (accessed 21 May 2006)
[29] <http://isp.webopedia.com/TERM/8/802_16.html> (accessed 21 May 2006)

2.3 Heat Pump Water Heater

2.3.1 Technology Overview

In the Pacific Northwest, 200 MW of conservation savings are possible from heat pump water heaters over the next 20 years, according to the Council.[30] Currently systems are being built in Australia and Japan,[31] but there are no HPWH manufacturers in the United States.

The Council estimates that 64 percent of all housing units in the Northwest currently use electric resistance water heaters. The Council projects that over three million existing electric water heaters will be replaced in the region and an additional four million new units will be added between now and 2025.[32] These units could be replaced with HPWHs, which have a life expectancy of 15.9 years,[33] comparable to a standard water heater.

Some 392,700 standard model water heaters were sold in the region between July 2004 and June 2005 (both replacement & new units).[34] If BPA's customers account for 40 percent of the region's load,[35] then BPA's potential conservation from HPWHs is 80 MW or 157,000 water heater purchases in BPA's territory each year. Using BPA's Energy Efficiency cost target for conservation of $1.5 million per aMW, BPA could spend up to $336 per HPWH to buy the conservation and meet the cost-target goal. If BPA could capture just 10-percent market acceptance of HPWH change outs each year, and assuming 2000 kWh of energy reduction, it would reduce BPA's load by 3.5 aMW (15,600 HPWH @ 2,000 kWh/yr). It is reasonable to expect market penetration to increase beyond 10 percent over time, with energy savings increasing proportionately.

If the current $300 federal tax credit for water heaters with an efficiency performance of 2 is extended beyond 2007[36] and a BPA/utility incentive of $300 were used to buy down a $1,000 HPWH, this would put the remaining cost of $400 within $100 of the current technology. The

---

[30] 5th Power Plan, May 2005, Conservation section, page 3-4.

[31] Australia Dux. "Dux Heat Pump Water Systems."<http://www.dux.com.au/solutions.php?cat=heatpump>. (accessed May 11, 2006 - Japan EcoCute. "Chubu Electric Power develops high output heat pump unit employing CO2 coolant for regions with severe winters - Allowing production of EcoCute water heaters with 460-liter hot water tanks designed for cold regions - ." <http://www.chuden.co.jp/english/corporate/press2005/0425_1.html>. (25 April 2005) (accessed May 11, 2006). [no sales number available]

[32] Northwest Energy Efficiency Alliance. "Assessment Of The Residential Water Heater Market In The Northwest." NEEA study. 5 December, 2005: 1-1.

[33] Northwest Energy Efficiency Alliance. "Assessment Of The Residential Water Heater Market In The Northwest." NEEA study. 5 December, 2005:3-3 page 3-3.

[34] Northwest Energy Efficiency Alliance. "Assessment Of The Residential Water Heater Market In The Northwest." NEEA study. 5 December, 2005:3-3 table 3-3.

[35] BPA's assumed percentage of regional load by NWPCC.

[36] Energy Policy Act 2005. < http://www.energy.ca.gov/efficiency/2005_federal_tax_credits.html>.

NEEA study showed that 26 percent of survey respondents would be willing to pay an additional $119 for a water heater that would save them $125 a year in energy costs.[37]

2.3.2 Opportunity Overview

A heat pump water heater (HPWH) is an appliance, usually in the same form as a standard electric water heater that uses a heat pump thermodynamic cycle to remove energy from a low temperature heat source – the ambient room air around the water heater. It then transfers it to a high temperature heat sink – the water stored in the hot water heater tank.

Heat pump water heaters (HPWH) can cut hot water heater energy use by 50 percent[38]. They could save even more energy if the cool air they produce is used to supplement air conditioning.

According to a Natural Resources Defense Council (NRDC) report of November 2005, the HPWH technology is ready for the market, because research and development have addressed concerns raised over the last decade in field testing.[39] Past efforts to promote the technology have been handicapped by the lack of a market research plan to coincide with the R&D programs, according to Oakridge National Laboratories (ONRL).[40] However, a California Energy Commission report of April 2004[41] lists research and development concerns that may still need to be addressed.

Leaders from key regional organizations with a strong interest in EE support could use a "golden carrot" process to bring HPWH to Market.[42]

2.3.3 R&D Challenges

In contrast to the optimistic NRDC report referenced above, an April 2004[43] California Energy Commission (CEC) report on HPWH design refinements listed both technical and market issues that needed resolution.

---

[37] Northwest Energy Efficiency Alliance. “Assessment Of The Residential Water Heater Market In The Northwest.” NEEA study. 5 December, 2005: 8-11.

[38] Jan Harris and Chris Neme. Vermont Energy Investment Corporation “Residential Heat Pump Water Heaters: Energy Efficiency Potential and Industry Status.” November 2005: 1. “Savings potential is real and substantial. Various field tests of heat pump water heaters have demonstrated that annual savings of approximately 50% are realistic (note: this is less than the difference in energy factor would imply, but still substantial)”.

[39] Ibid.

[40] “Heat Pump Water Heater Technology: Experiences of Residential Consumers and Utilities.” (ORNL/TM-2004/81) June 2004: vi. “The HPWH is an excellent example of a technology that would have benefited from the implementation of a market research program run in parallel with the technology R&D program.”

[41] TIAX LLC. “Design Refinement and Demonstration Of A Market-Optimized Heat-Pump Water Heater”. Consultant Report. 500-04-018. April 2004

[42] Phone conversations- Jan 2006, between Mike Hoffman, BPA and Tom Eckman - NWPCC; Jeff Harris – NEEA; and Marc Ledbetter – PNNL

The technical issues in the CEC report include adding a condensate recovery system to HPWH, using CO² as a refrigerant (considered the next big leap in efficiency for HPWH and Heat Pumps), cost reductions in manufacturing, reliability improvements and noise reduction. The market issues of reliability, brand recognition, distribution of units and parts, service infrastructure, and market education need to be addressed in the "golden carrot" approach to overcome a two-decade-long lack of market acceptance. An additional key issue is consumer acceptance of integrated units (compressor and tank in one unit).[44] Northwest Energy Efficiency Alliance (NEEA) and Vermont Energy Investment Corp. (VEIC) recommend integrated, not split units.[45]

In a May 11, 2006, phone call between Mike Hoffman of BPA and Chris Scruton of CEC, Scruton said that although there are still technical issues to resolve, the NRDC report is correct in that the technology is ready for a large scale rollout by a major manufacturer. This assumes that the issues in the CEC report would be dealt with in design review before production.[46]

2.3.4 Sector Actors

A. CEC has sponsored a study on improvements needed to bring HPWH to market.

B. Northwest Energy Efficiency Alliance (NEEA) has sponsored a study of the hot water heating market in the Northwest, including information on what percentage of consumers would pay, how much, for a more efficient water heater.

C. Natural Resources Defense Council (NRDC) has sponsored a Vermont Energy Investment Report on HPWH readiness for commercialization.

D. Oakridge National Laboratories (ORNL) is the technical center for testing HPWH equipment for DOE and CEC. ORNL sponsors the "In Hot Water" newsletter about HPWH technologies.

E. Dux-Australia is a major supplier of HPWH.

F. EcoCute is the Japanese manufacturer of a CO² HPWH that is very efficient but expensive ($5,000).

G. Hallowell Intl. is a heat pump manufacturer that is also developing a HPWH.

2.3.5 Heat Pump Water Heater Roadmap

---

[43] TIAX LLC. "Design Refinement and Demonstration Of A Market-Optimized Heat-Pump Water Heater". Consultant Report. 500-04-018. April 2004: 76.

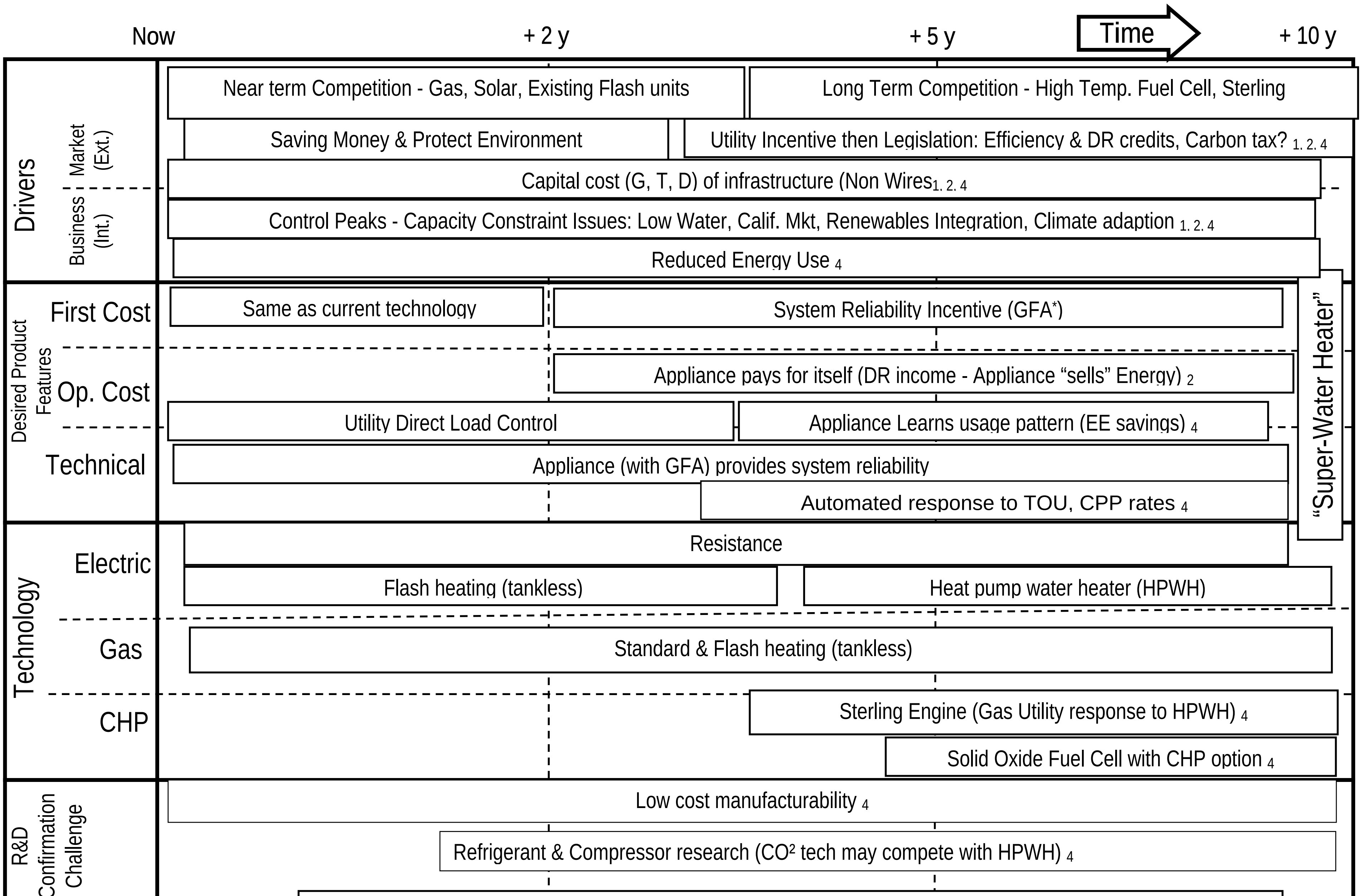
[44] Mike Hoffman's phone conversations with Jeff Harris of NEEA and Chris Neme of VEIC. Feb. 2006.

[45] Ibid.

[46] Mike Hoffman's phone conversation with Chris Scruton (916 653-0948, cscruton@energy.ca.stete.ca.state.us.) Scruton feels that all of the issues are resolvable in large scale manufacture and/or as part of a golden carrot process. (11 May 2006)

The following diagram is intended to briefly: 1) illustrate the most relevant drivers of Heat Pump Water Heater technology from internal and external perspectives; 2) list desired (future) product features from cost, operational and technical perspectives; 3) list the types of technology and when future products may become available; and 4) indicate the R&D challenges to development of these technologies. The timeframe illustrates current understanding of how this technology may develop over the next 10 years.

2.3.5 Heat Pump Water Heater Roadmap



Legend: Technologies supporting or overlapping with DR 1, Smart Appliance 2, Heat Pump Hot Water Heater 3, Heat Pump without Strip Heat 4, Integrated Building Design 5
* GFA – Grid Friendly Appliance (under frequency device)

2.3.6 Suggested Role for BPA:

Support jump starting a national effort via a "golden carrot" competition, coordinated through the Council for Energy Efficiency (CEE) to bring HPWH to market. The following is a skeleton outline for the process:

Coordinate with Energy Star partners and interested utilities before approaching CEE for support of a golden carrot process. Identify an organization to lead this effort.

Draft an approach and plan to present to CEE using assistance from the Council, NEEA, PNNL and DOE, along with Energy Star Partners (water heaters).[47] Include definition of success, budget, timeline, and number of sponsors and dollars needed to interest manufacturers (three-to-six months). According to PNNL, CEE and members are not likely to put up money in advance, but the military may. It will take high level salesmanship to encourage utilities and manufacturers to make a major commitment to HWHP. Utilities will have to be confident that the units work, and the manufacturers will need to be confident that the utilities will commit serious money for multiple years. Both will need to be confident that consumers will want the units.

BPA, regional advocates and Energy Star Partners present a draft plan to CEE members and take comments and revise targets as needed. CEE/members confirm manufacturer interest and plan (six-to-12 months).

Business proposition for manufacturers: CEE to pay ($50 million) for the design, manufacture and sale of (100,000) HPWH units ($500/unit, requiring 25 utilities at $2 million each to participate). Stage gates for the effort would need to be decided by CEE members. Manufacturer recruitment, design and manufacture would be logical milestones for evaluating the effort. Additionally, energy efficiency organizations should have a parallel effort to extend the EPA 2005 tax credit of $300 and work with states and PUCs to provide utility rebates and/or state energy tax credits.

The plan for a CEE golden carrot should include the following:

1) Design and successfully test HPWH (one-to-two years) with verification of energy and demand reduction based on the following specification:

- Drop-in replacement for current size electric water heaters, identical electric and plumbing hook ups;
- Condensate-free model; otherwise can use floor, clothes washer or other drain for improved performance;
- Robust compressor and common refrigerant, small and widely available;
- Design eliminates any need for a water pump;
- Fits anywhere conventional water heater fits (garage, basements, utility rooms, even closets);
- Minimal maintenance limited to periodic cleaning of evaporator air filter;
- Quiet operation;

[47] Energy Star. <http://energystarpartners.net/index.cfm?fuseaction=water_heaters.display>. (accessed May 11, 2006).

- Efficient - Energy Factor = 2.0+ which is more than double today's most efficient electric resistance water heater;
- Potential for a two-year simple payback depending on utility rates and rebates;
- Optional kit for directing exhaust air into a duct, either for discharge to outside or to cool the home;
- Default the unit to resistance heating should the pump fail; also use resistance heating when water temperature falls below a defined point to speed recovery of hot water after heavy use.

2) Manufacture and sale of 100,000+ units with warranty into a limited market test area, within X months. Market research and education campaign in parallel with design and manufacture.

3) If successful, the manufacturer gets a two-year or longer right to the Energy Star HWHP designation (concept discussed “Energy Star Labeling Potential for Water Heaters”[48]), which must be negotiated with DOE/EPA – likely with the Energy Star Partners as the lead negotiator.

4) Champion Northwest utility financing to stock heat pump water heaters both in stores and on service vehicles as well as parts to bring this product to market. Create an automated incentive rebate via registered dealers with phone or online access to approval for immediate replacement water heater.

BPA’s potential accomplishment with HPWHs is to help grow national consensus on the practicality of HPWHs and move the involved organizations to implement the technology through market transformation.

[48] Energy Star. “Energy Star Labeling Potential for Water Heaters.” (4 April 2003). <http://energystarpartners.net/ia/Water_heaters/Documents/ENERGYSTAR_WHResearch_April2003.pdf>. (accessed May 11, 2006).

2.4 Heat Pumps without Strip Heat

2.4.1 Technology Overview

Low-temperature heat pumps have the potential to solve numerous problems for utilities and consumers:

- Lower heating costs for end users during freezing temperatures
- Much lower capital and maintenance costs than for complex high -efficiency ground source heat pumps, which also use less energy than standard heat pumps[49]
- Increased comfort for the end users because LTHP's put out hot air instead of the lukewarm air from standard heat pumps (HP)
- Lower winter peaks by avoiding strip heat use when heat pump compressors alone are already taxing the electrical grid. This frees up system generating capacity in cold weather and improves reserve margins
- Improved utility system efficiency if end users upgrade from forced air or standard heat pump systems to LTHPs

Two BPA customer utilities have tested LTHP units, United Electric in Heyburn, Idaho, and Chelan PUD in Washington State. BPA's Energy Efficiency group has been monitoring the performance of this type of unit as well, and testing has shown negligible strip heat use[50].

2.4.2 Opportunity Overview

LTHPs, also know as Cold Climate Heat Pumps (CCHP), use two stages of compressors instead of one to eliminate use of strip heat (electric resistance backup) when the temperature falls below freezing, down to -15 degrees Fahrenheit.[51] Standard heat pumps are efficient down to freezing temperatures, but below that, strip heat is used and efficiency falls. The strip heat can cause peaks on the electrical system. Because temperatures in BPA's territory generally do not fall below -15 degrees Fahrenheit, this technology is well suited to both save energy and reduce the magnitude of strip-heat-induced winter peaks.

[49] Kimberly Craig, "**Cold Climate Heat Pump shows promise, but manufacturing delayed** ", Chelan County PUD. (April 1, 2005). <http://www.chelanpud.org/newsreleases/2005/ColdClimateHeatPump_040105.htm>. (accessed May 16, 2006).

50 Without Strip Heat: In-Situ Monitoring of a Multi-Stage Air Source Heat Pump in the Pacific Northwest
Adam Hadley, Jack Callahan, and Richard Stroh, Bonneville Power Administration, (2006). "In fact, the data from this study show the homes maintained reasonable average temperatures, even in cold winter conditions, without the use of strip heat."

[51] Charles Linn, Architectural Record, P # 4,5 Can a New Kind of Heat Pump Change the World? <http://archrecord.construction.com/resources/conteduc/archives/0603edit-5.asp>

LTHPs could cut the cost of electricity for the residential end user in half[52] compared to using a standard heat pump. LTHPs function more effectively than standard heat pumps because they were designed for heating, rather than cooling. Standard heat pumps are designed primarily to act as air-conditioning units. LTHP units produce high-temperature air flow from ducts at low outside temperatures, making end users more comfortable[53].

In the Northwest, widespread implementation of LTHPs could reduce winter peaks for all utilities, giving the region more flexibility and capacity for system operations, especially in dry years.

LTHPs could also be used for air conditioning. They are also more efficient than standard air conditioners or standard heat pumps used for air conditioning (estimated Seasonal Energy Efficiency Rating ((SEER)) of 16 versus standard Energy-Star HP SEER of 13.[54]) With the Northwest becoming a dual peaking system (summer peaks close to winter peaks in magnitude), LTHPs could also reduce the summer peaks.

Currently, only one technology, a dual-stage compressor system invented by Dave Shaw,[55] meets the E-Source definition of an LTHP. E-Source is the only utility consulting firm that has reported on this technology[56]. A range of products by Asian manufacturers are close to, but do not meet the E-Source LTHP definition.[57] These Asian manufacturers are attempting to adjust their current technologies to meet the E-Source LTHP definition[58].

Shaw originally licensed the LTHP technology to Nyle, the first manufacturer of this technology[59]. That license apparently expired, and Shaw is now working with Hallowell to commercialize the technology.[60] Nyle, however, says it has created its own version of the technology that does not infringe on Shaw's patent[61].

---

[52] Chelan County PUD, Kimberlee Craig, <http://www.chelanpud.org/newsreleases/2005/ColdClimateHeatPump_040105.htm>

[53] E-Source Report – Volume1 Technical, performance and Economic Analysis, LTHP: 23. (Ron Abrahamson, PKM Electric Coop in Warren Minn., when speaking with E-Source – He has been delighted with the product, relying solely on the CCHP to meet all his space heating needs over the past winter. Duct temperatures were a respectable 100 degrees f at 0 degrees outside temperature.)

54 E-Source report, Can the Low-Temperature Heat Pump Defrost the Status Quo in the Space Heating Sector? Volume 2: Marketing Issues P # 5

[55] Charles Linn, "Can a New Kind of Heat Pump Change the World?", FAIA. < http://archrecord.construction.com/resources/conteduc/archives/0603edit-1.asp> P # 1. (accessed May 16, 2006).

[56] Jay Stein, "Will Utilities Warm up to Low-Temperature Heat Pumps?". E-Source. <http://www.esource.com/public/pdf/WP-2-LTHP_LowTempHeatPump.pdf>: 3. (accessed May 16, 2006).

[57] LTHP E-Source Report. "Technical, performance and Economic Analysis".. Volume 1, P # 10.

[58] Ibid P # 2

[59] Charles Linn, "Can a New Kind of Heat Pump Change the World?", FAIA. < http://archrecord.construction.com/resources/conteduc/archives/0603edit-1.asp> P # 1. (accessed May 16, 2006).
[60] Ibid

[61] Ibid P # 6

2.4.3 R&D Challenges

The technical issues that the LTHP faces include:

- Refrigerant charging; i.e., under-charged units because of field charging. Standard heat pump systems come charged, but LTHPs are charged with refrigerant in the field for safety reasons. Trucks cannot carry LTHP-charged systems due to extreme temperatures in limited locations (desert). In the future, systems will be modified to allow units to be shipped charged.

- Defrosting of the heat exchanger. The new generation Hallowell LTHP has been designed to significantly retard excess frost accumulation during relatively high humidity and is more appropriately sized to minimize frost and optimize BTU output during heating.

- Control and cycling strategy. The Hallowell LTHP has improved staging and comfort capabilities using a new control logic and an indoor thermostat. Additional features have been added to the control logic to minimize and protect the system cycling in any condition which could penalize performance and system longevity. The new system is installed as a matched system which includes the outside condensing unit (LTHP) and the indoor high-efficiency variable speed air handler unit and thermostat, which will allow greater ease of installation, better control and indoor comfort. This should mean greater performance in both heating and cooling.

Market issues include the following: LTHP is not seen as a mainstream product, there is currently no competitor, the unit is not supplied by a “name” HVAC company, and installer and service channels need to understand the differences from standard heat pumps if the LTHP is to become mainstream.

2.4.4 Sector Actors

A. Hallowell Intl.: Hallowell’s low-temperature heat pump (Hallowell LTHP) is the only air source heat pump designed specifically for heating in any climate, even when outdoor temperatures drop below zero. The Hallowell LTHP is the only heat pump that offers high efficiency and reliable heating in cold climates. It not only delivers heating but also exceptionally high efficiency cooling.

B. Nyle: Originally the manufacturer of the LTHP, Nyle is now building a competing device after losing marketing rights from the inventor.

C. Chelan PUD is a BPA customer that has reported successful use of the LTHP to reduce strip heat use and reduce energy usage.

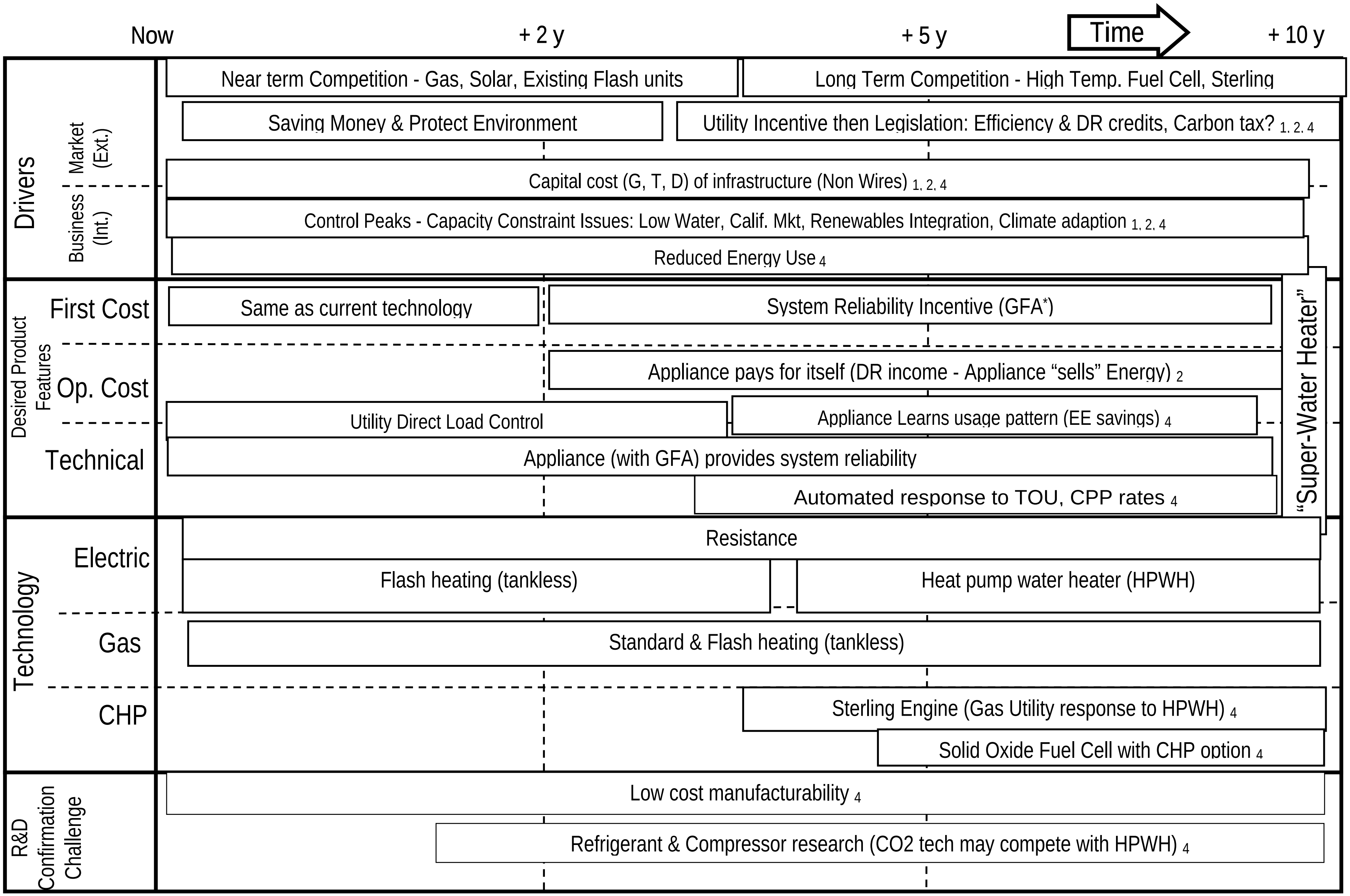
D. E-Source is a utility industry consultant that reported on LTHP systems from both technical and marketing perspectives.

E. CEA Technologies Inc. is a Canadian energy research organization that has tested LTHP.

2.4.5 Heat Pump without Strip Heat Roadmap

The following diagram is intended to briefly: 1) illustrate the most relevant drivers of heat pump without strip heat technology from internal and external perspectives; 2) list desired (future) product features from cost, operational and technical perspectives; 3) list the types of technology and when future products may be come available; and 4) indicate the R&D challenges to the development of those technologies. The timeframe reflects current understanding of how this technology may develop over the next 10 years.

2.4.5 Heat Pump w/o Strip Heat Roadmap



Legend: Technologies supporting or overlapping with DR 1, Smart Appliance 2, Heat Pump Hot Water Heater 3, Heat Pump without Strip Heat 4, Integrated Building Design 5
* GFA – Grid Friendly Appliance (under frequency device)

2.4.6 Suggested Role for BPA:

Phase 1 June 2006 – 2008 (two winters)

Continue testing heat pumps with two-stage compressors such as the Hallowell pump and verify energy savings and peak demand reductions, as well as customer acceptance. There is the potential to radically reduce energy use (50 percent energy savings) compared to standard heat pumps and reduce peak load impacts with this technology. Install 10 of the soon-to-be-released (June 2006) Hallowell units in the region and verify their performance both in the Olympic Peninsula and the southern Oregon coast. Verification of both peak energy use and energy efficiency would be a confirmation project for BPA's Energy Efficiency staff at this time, because of the staff's current experience with LTHP. Timeframe: 2006 to 2008 (two winters).

Phase 2 – 2009 and beyond

Move on to testing a system that combines heat pump, water heater, dehumidifier and air conditioner unit that will be available five years into the future.

Assuming successful testing of Hallowell or other units, approach regional utilities to create a plan that can be proposed to CEE for "golden carrot" process nationally. Without utility intervention, it is not likely that the HVAC industry will implement LTHP technology on a commercial scale. Utilities must show support for the technology[62] by demonstrating and monitoring units in the field, marketing and promoting the product, offering financial incentives and providing manufacturers with seed funding.

Conduct research to confirm the potential for manufactured home use. The concept is of a combined unit that puts a heat pump, heat pump water heater, dehumidification and air-conditioning into manufactured homes. The concept could be developed in cooperation with the Pacific Northwest National Laboratory, which already has discussed this concept.

Participate in utility and manufacturer forums supporting development of carbon dioxide refrigerant heat pump water heater or heat pump.

[62] Jay Stein, "Will Utilities Warm up to Low-Temperature Heat Pumps?". E-Source. <http://www.esource.com/public/pdf/WP-2-LTHP_LowTempHeatPump.pdf>: 4. (accessed May 16, 2006).

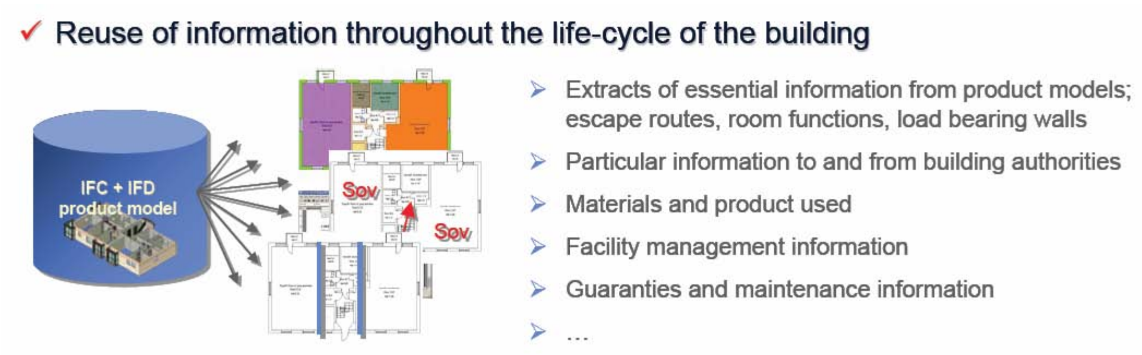
2.5 Integrated Building Design

2.5.1 Technology Overview

Integrated building design uses Computer Assisted Design (CAD) software, using data objects[63] to model commercial buildings, including the building shell, to create a building infrastructure that supports an integrated communications and control environment that is energy efficient, flexible, effective, comfortable, economical and secure. The data objects are used to model the building's energy performance, estimate the building cost, provide materials lists for construction and ultimately operate the building system.

The application of integrated design software using data objects[64] allows the modeling of a building design from conception through operations. The software can be used to model energy needs and use, materials properties including thermal and energy properties, cost of construction materials and the needs for airflow, heating and cooling. The concept also includes ongoing maintenance of buildings systems such as maintaining optimal energy use in the building for lowest-cost operation of the building. Eventually this type of software will be used for designing retrofits of equipment into existing buildings.

The following is a diagram of software impacts of integrated design software: [65]



In the diagram above, IFC stands for International Foundation Class and IFC stands for International Standard for Dictionaries; these describe data object standards.

Designing new commercial buildings or retrofitting existing commercial buildings with new energy management systems, lighting systems and communications systems with wireless controls offers large energy savings, productivity and owner convenience benefits. Using integrated building design tools has the potential to incorporate energy efficiency systems that will work effectively and continuously over the life of the building. These systems would not depend on a specific building energy manager.

An intelligent building incorporates these tools to create an integrated building control system that can provide communication among a number of automated building systems. This would allow the building operator to use a single interface to control lighting, security, heating, ventilating, air-

[63] Object Oriented Programming < http://searchwinit.techtarget.com/sDefinition/0,,sid1_gci212681,00.html> (accessed 19 May 2006)
[64] Ibid
[65] <http://www.iai.no/2005_buildingSMART_oslo/Session%2006/BARBi_in_real_world.pdf> (accessed 19 may 2006)

conditioning, fire suppression, security, communications and other systems across a single broadband infrastructure that will also support the building users' voice and data communication needs.

2.5.2 Opportunity Overview

Smarter building control systems will add the ability to integrate renewables, combined heat and power systems and new local generation technologies such as fuel cells or Sterling engines, making it possible for commercial buildings to become net electricity generators rather than consumers.

According to Lawrence Berkley Lab (LBL) the commercial building sector spends $100 billion yearly on electricity in the United States.[66] If a 30 percent improvement in energy efficiency can be achieved by applying existing technologies in that sector, during the coming decades, it would mean a $30 billion savings in energy consumption. With the Northwest representing 4 percent of U.S. energy use, this would mean a savings across the region of $1.2 billion. Because BPA represents 40 percent of the regional load,[67] there could be a savings of $300 million to BPA customer facilities.

From the building owner or tenant perspective these new integrated building control systems could improve the use of low energy cooling systems; increase the use of daylighting with smart controls; and allow building loads to participate in demand response programs via control of lights, heating, ventilating and air-conditioning by preheating or precooling the facility. Tenant modifications of the building would be much easier and more convenient because HVAC controls, network connections, lighting systems, temperature sensors and thermostats could all be easily re-organized, assuming that they were wireless and movable. Reconfiguration of building space when tenants change is a big cost to building owners, and the ability to easily change lighting, communications and HVAC systems would greatly enhance the attractiveness of buildings built with integrated design tools.

Commercial buildings consume 32 percent of U.S. electricity production, and there are 4.6 million commercial buildings across the United States. According to the Northwest Energy Efficiency Alliance (NEEA), survey of 2001,[68] the Northwest had 2.1 billion square feet of commercial building space. Based on the Council's fifth Power Plan published in 2005,[69] commercial building electrical applications have the potential for over 800 MW of energy efficiency improvements in the period 2005 to 2025.

Integrated building design software is in development, but still is two years from being useful[70]. The U.S. Government Services Administration (GSA) will require the use of this software – data model called Industry Foundation Classes (IFC) – in the designs of major new federal building construction

---

[66] New Commercial Building Energy Efficiency Program Launched <http://www.lbl.gov/Science-Articles/Archive/combldg-energy.html> (accessed 19 May 2006)
[67] BPA portion of regional load per NW Power and Conservation Council
68 Assessment of the Commercial Building Stock in the Pacific Northwest, http://www.nwalliance.org/resources/reportdetail.asp?RID=134> (accessed 19 May 2006)
[69] < http://www.nwcouncil.org/energy/powerplan/default.htm> (accessed 19 May 2006)
[70] Phone conversation with Mark Levi, GSA, San Francisco, CA – 19 May 2006.

by 2007.[71] GSA is convinced of the value of this new technology and has run eight pilot projects with software that uses the IFC standard[72].

Mark Levi of San Francisco's GSA office confirmed that the goal of the GSA effort is to gather IFC data in designs for eventual use in the Energy Plus software,[73] which is the successor to the DOE2[74] building energy modeling software. At the national level GSA is focusing use of the IFC data on conceptual design. GSA's West Coast office is requiring IFC data for building equipment to eventually model building operational systems and develop templates for that use.

2.5.3 R&D Challenges

One challenge to the implementation of integrated building design is that developers and designers tend to pursue the lowest cost building that is possible and rely on tax and utility incentives that are focused, not on the whole building design process, but on particular systems such as HVAC or lighting.

Other challenges in the commercial buildings industry are that there are many organizations involved in the design, construction and operation of commercial buildings. Collaboration and communications in all phases of this process tends to be minimal at best. Designers do not own buildings; people providing financing will not inhabit them; and people constructing buildings do not understand the interactions of systems and impacts of those systems. This high degree of fragmentation has greatly complicated the integration of energy savings into the design process for commercial buildings.

Integrated Building Design techniques need to be demonstrated in an actual commercial building that has high visibility to stimulate demand by showing building owners, designers and tenants the economic advantages. These include lower operating, maintenance and reef configuration costs.

2.5.4 Sector Actors

A. Lawrence Berkley Lab (LBL) – Energy Plus is a new-generation building energy simulation program based on DOE-2 and BLAST, with numerous added capabilities. Current projects include testing and validation, training, program deployment, implementation of features needed to make EnergyPlus useful for standards development and compliance, improved foundation heat transfer calculations, improved moisture calculations, development of HVAC equipment models, development of a duct-loss model, a real-time version of EnergyPlus, and a link between SPARK and EnergyPlus. Work is also underway to develop prototypical building models for U.S. residential and commercial building stock. These models will be used in EnergyPlus to analyze energy use characteristics in different climates.

B. General Services Administration (GSA) is a proponent of requiring new government building construction to be based on EnergyPlus models.

C. IAI - International Alliance for Interoperability, an industry group, develops Industry Foundation Classes (IFC) and an integrated building information model for describing

[71] Ibid
[72] < http://www.iai-international.org/IndustrySolutions/usaGSA.html> (accessed 19 May 2006)
[73] <http://www.eere.energy.gov/buildings/energyplus/> (accessed 19 May 2006)
[74] Ibid

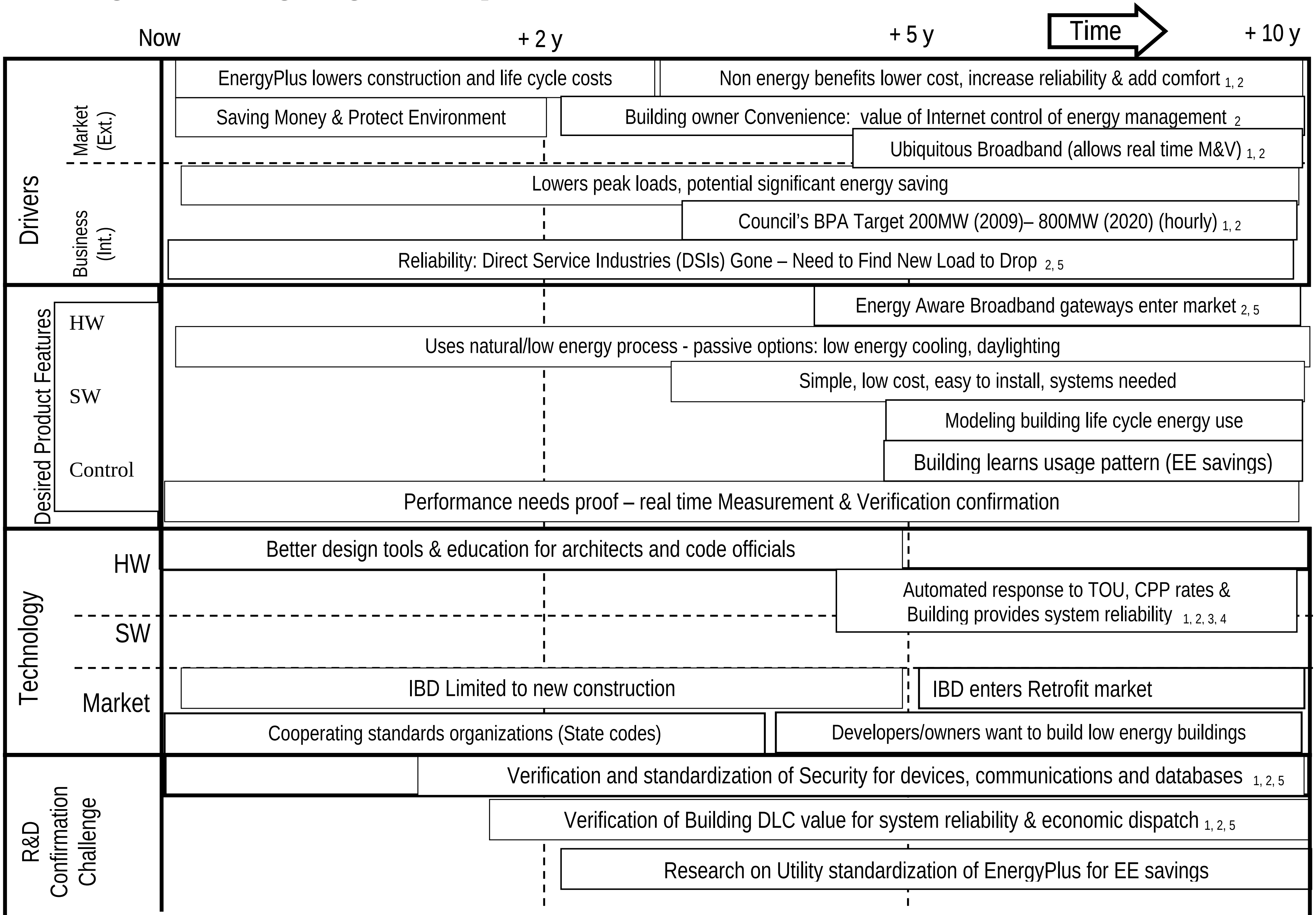
buildings. The IAI also develops methods that allow applications, such as CAD and energy analysis (EnergyPlus), to interoperate with the information model. Interoperability will allow diverse building drawing and simulation tools to share the same building description and to exchange results, thus simplifying building design, construction and operation.

D. CABA – Continental Building Automation Association produced the Technology Roadmap (TRM) for Intelligent Building Technologies, a collaborative $110,000 research project between industry and five Canadian government departments and agencies. CABA managed the project, which focused on commercial, institutional and high-rise residential buildings and produced a final report that provides an in-depth examination of intelligent buildings technologies.

2.5.5 Integrated Building Design Roadmap

The following diagram is intended to briefly: 1) illustrate the most relevant drivers of integrated building design, from internal and external perspectives; 2) list desired (future) product features from cost, operational and technical perspectives; 3) list the types of technology and when future products may be come available; and 4) indicate the R&D challenges to the development of those technologies. The timeframe illustrates current understanding of how this technology may develop over the next 10 years.

2.5.5 Integrated Building Design Roadmap



Legend: Technologies supporting or overlapping with DR 1, Smart Appliance 2, Heat Pump Hot Water Heater 3, Heat Pump without Strip Heat 4, Integrated Building Design 5 HW =Hardware, SW = Software

2.5.6 Suggested Role for BPA:

Proposed action: Sponsor a demonstration of automated diagnostics for building retrofits in a high profile location.

Proposed action: Sponsor education forum(s) on use of the EnergyPlus software model for architects, contractors and building owners in cooperation with the AIA, state codes organizations, BOMA and NEEA.

These actions will help BPA raise the standard for building design and operation in the region.

2.6 Low Energy Cooling

2.6.1 Technology Overview

As summer loads grow rapidly in the Pacific Northwest, the ability to meet those peaks in a dry year with fish constraint pressures becomes more difficult. Global warming could accelerate dry year trends and is predicted to shift river flows to a more run-of-river operational regimen. This would mean runoff earlier in the season and consequently less energy available in summer.

The use of air conditioning has increased in the Pacific Northwest. Both Portland General Electric and PacifiCorp are responding to increasing summer peaks by implementing load management and demand response programs. BPA should help its customer utilities deal with summer peaks by encouraging the use of energy-efficient air-conditioning systems. Evaporative cooling systems offer this potential. As energy prices rise in the future, these systems should provide a better return on the initial investment than standard systems.

Another action to support evaporative cooling in the commercial sector would be to implement time-of-use (TOU) or critical peak pricing (CPP) rates by BPA customers. The trend toward critical peak pricing or TOU rates has been gaining momentum across the United States and particularly in California, where summer peaks have created system emergencies. California is tightly linked to the Pacific Northwest by 7,800 MW of transfer capability which California uses extensively in the summer to power its air-conditioning load. As summer peaks grow in the Pacific Northwest, there is likely to be competition between the two regions for that energy. More efficiency will lead to lower loads, which in turn will enable the Northwest to sell more power into California, keeping rates down for Northwest customers.

2.6.2 Opportunity Overview:

Low-energy cooling techniques include a range of passive cooling techniques, including ground cooling, conductive and mass cooling, solar reflection and evaporative cooling. The advantage of these cooling techniques is that they are based on heat and mass transfer principles and do not require mechanical or electrical energy to operate. For application to the Energy Efficiency technology roadmap, the discussion of low-energy cooling will be limited to evaporative cooling systems that are being tested in California and in the Northwest by the California Energy Commission (CEC) and the Northwest Energy Efficiency Alliance (NEEA) respectively.

The savings potential in the Council's fifth power plan covering the period 2005 to 2025 shows the potential energy efficiency benefits of new replacement and retrofit commercial HVAC systems are over 265 MW.[75] Based on the Council's determination, BPA is responsible for 40 percent or 106 MW, and evaporative cooling systems could provide a percentage of that reduction.

Currently this technology is in development and testing. It is in an early commercial stage as NEEA has demonstration projects of rooftop commercial units in the Pacific Northwest and California. The potential energy savings are higher in hot dry areas such as those east of the Cascade Mountains but also show significant potential west of the Cascades in summer according to NEEA.[76]

---

[75] <http://www.nwcouncil.org/energy/powerplan/plan/Default.htm> (accessed 21 May 2006)
[76] Interview with Jeff Harris NEEA 31 Jan. 2006

2.6.3 R&D Challenges

No financial models are currently available to determine the life cycle value of low-energy cooling. The commercial building development market, where these systems would first be installed, prefers to use types of equipment with the lowest capital cost, thus avoiding the risk of investing in new technology. Developers have little incentive to create energy savings for the end user or renter of a commercial building.

Retrofits of evaporative cooling systems would also be a hard sell to building maintenance managers, because they prefer systems that they know how to operate and maintain. They avoid risks with new technologies that could fail. Consequently high visibility demonstrations of this technology are needed.

2.6.4 Sector Actors

A. PIER: Public Interest Energy Research (funded by CEC) sponsors design and research on evaporative coolers in residential applications to save energy compared with conventional vapor-compression air conditioners.

B. Southwest Energy Efficiency Project (SWEEP) is promoting greater energy efficiency in a six-state region that includes Arizona, Colorado, Nevada, New Mexico, Utah and Wyoming. SWEEP has produced a report on New Evaporative Cooling Systems: An Emerging Solution for Homes in Hot Dry Climates with Modest Cooling Loads.

C. Western Area Power Administration (WAPA) supports evaporative cooling research in its service territory and recommends evaporative cooling to customers.

D. NEEA sponsors evaporative cooling research in Oregon’s Willamette Valley and east of the Cascade Mountains using DesertAire systems.

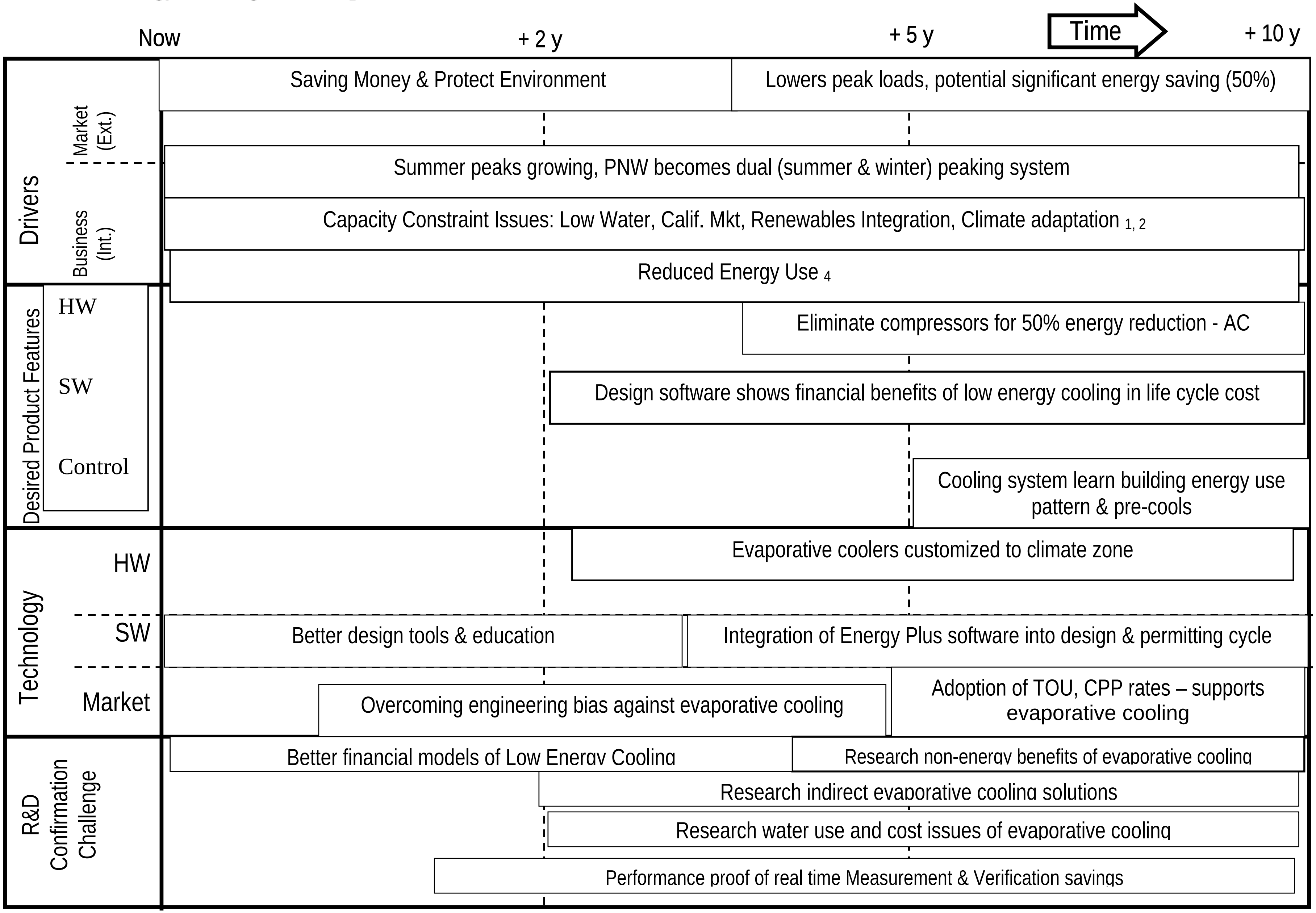
E. DesertAire is an evaporative cooler manufacturer.

F. Coolerado Corporation is an evaporative cooler manufacturer.

2.6.5 Low Energy Cooling Roadmap

The following diagram is intended to briefly: 1) illustrate the most relevant drivers of low-energy cooling, from internal and external perspectives; 2) list desired (future) product features from cost, operational and technical perspectives; 3) list the types of technology and when future products may be come available; and 4) indicate R&D challenges to the development of those technologies. The timeframe illustrates current understanding of how this technology may develop over the next 10 years.

2.6.5 Low Energy Cooling Roadmap



Legend: Technologies supporting or overlapping with DR 1, Smart Appliance 2, Heat Pump Hot Water Heater 3, Heat Pump without Strip Heat 4, Integrated Building Design 5 HW =Hardware, SW = Software

2.6.6 Role for BPA:

Phase 1 2006 – 2008 Further support for demonstrations

- Screen technologies for application to PNW climate zones. Encourage other regional utilities to do the same, particularly those in southern Oregon and east of the Cascades.

- Continue support of NEEA testing of technologies applicable to PNW region, such as DesertAire.

Phase 2 – Beyond 2008 Wide Scale implementation

Future program implementation can be divided into two main types: those that encourage the market to develop ("market pull") and actions that help solve underlying technical issues ("technology push").

Market pull

- Disseminate information on benefits and savings of this technology
- Improve building cooling standards and codes in the PNW to encourage evaporative cooling.

Technology push

- Hold competition for design and development of evaporative cooling systems applicable to the PNW.

These actions will help BPA respond to the Northwest's growing summer peak and increase reliability.

2.7 High efficiency lighting


LED


OLED


HID


FLUORESCENT

2.7.1 Technology Overview

Historically, high-efficiency lighting projects have produced energy savings in the commercial and residential marketplace relatively easily. Commercial end users see the technology as enhancing performance in the workplace and saving energy when integrated with building energy management systems.

Peak lighting demand generally occurs during peak load hours, which means an increase in efficiency can reduce system peaks. Add to this the potential to add demand response to buildings to control lighting, which puts both efficiency and demand response in a single system. PacifiCorp uses this concept to implement 25 MW of direct load control of lighting in the Salt Lake City area.

When used with wireless sensors, wireless lighting controls have the potential to offer increased flexibility over hard wired lighting control systems by avoiding the inconvenience and expense of rewiring. This would be especially advantageous in older buildings that require upgrades when tenants change, because wiring[77] represents 40 to 80 percent of the cost.

The range of potential wireless control technologies standards is too numerous to list.[78] Because manufacturers have been able to embed wireless connectivity solutions in a wide range of consumer electronic products, there should be no technical barrier to incorporating wireless controls with existing lighting products and systems.

An open system design standard is needed for integrating lighting controls into building control systems. Currently there are two competing standards in the building controls, BACnet and LonWorks.[79] Each of these control standards has a strong presence in the building control market. Unfortunately, neither prevails as a clear industry standard, and this could delay adoption of building control systems as the industry waits for a clear winner to emerge.

---

[77] U.S. Lighting Market Characterization Volume II: Energy Efficient Lighting Technology Options, P # 229 <http://www.netl.doe.gov/ssl/PDFs/lmc_vol1_final.pdf>
[78] Ibid P # 228
[79] Ibid 246

2.7.2 Opportunity Overview

High-efficiency lighting consists of a range of lighting technologies that reduce energy use in commercial, industrial and residential sectors. There are basically five technologies: incandescent, fluorescent, high intensity discharge, and the emerging organic and inorganic solid-state light sources.

High-efficiency lighting is of interest from an energy efficiency perspective because lighting accounts for nearly one-sixth of the United States' annual electricity use.[80] According to the Council, approximately 787 MW of energy conservation are available from both commercial and residential lighting replacements, upgrades and retrofits over the next 20 years.[81] High -efficiency lighting technologies should account for a reasonable portion of these savings.

High-efficiency lighting is for the most part still in the R&D stage. DOE will spend more than $400 million over the next eight years on LED research, according to Mark Ledbetter of Pacific Northwest National Laboratory.[82] Additional research is covering the commercialization of non-solid-state lighting, as well as wireless controls. This research is focused on basic technology rather than commercialization.

2.7.3 R&D Challenges

High-efficiency lighting challenges include a traditionally low rate of technology development and product innovation in the lighting and building industries, product cycles that are exceptionally long and slow acceptance of new technology by commercial building owners.

Lighting systems for commercial buildings are often purchased by an electrical contractor rather than the building owner or manager and consequently are often chosen more for capital cost than for efficiency. Because of this central contractor role, the contractors installing the systems set the standards based on lowest system cost, not on the needs of the end user. Consequently profit margins are limited, and the lighting industry is unable to invest in new technology and further product development.

2.7.4 Sector Actors

A. DOE – a major funding source for high-efficiency lighting research.
B. NEEA – a regional market transformation implementation organization.
C. PNNL – DOE's contractor for implementing lighting research.
D. Lighting Research Center – Rensselaer Polytechnic Institute,[83] a research center devoted to lighting technology.

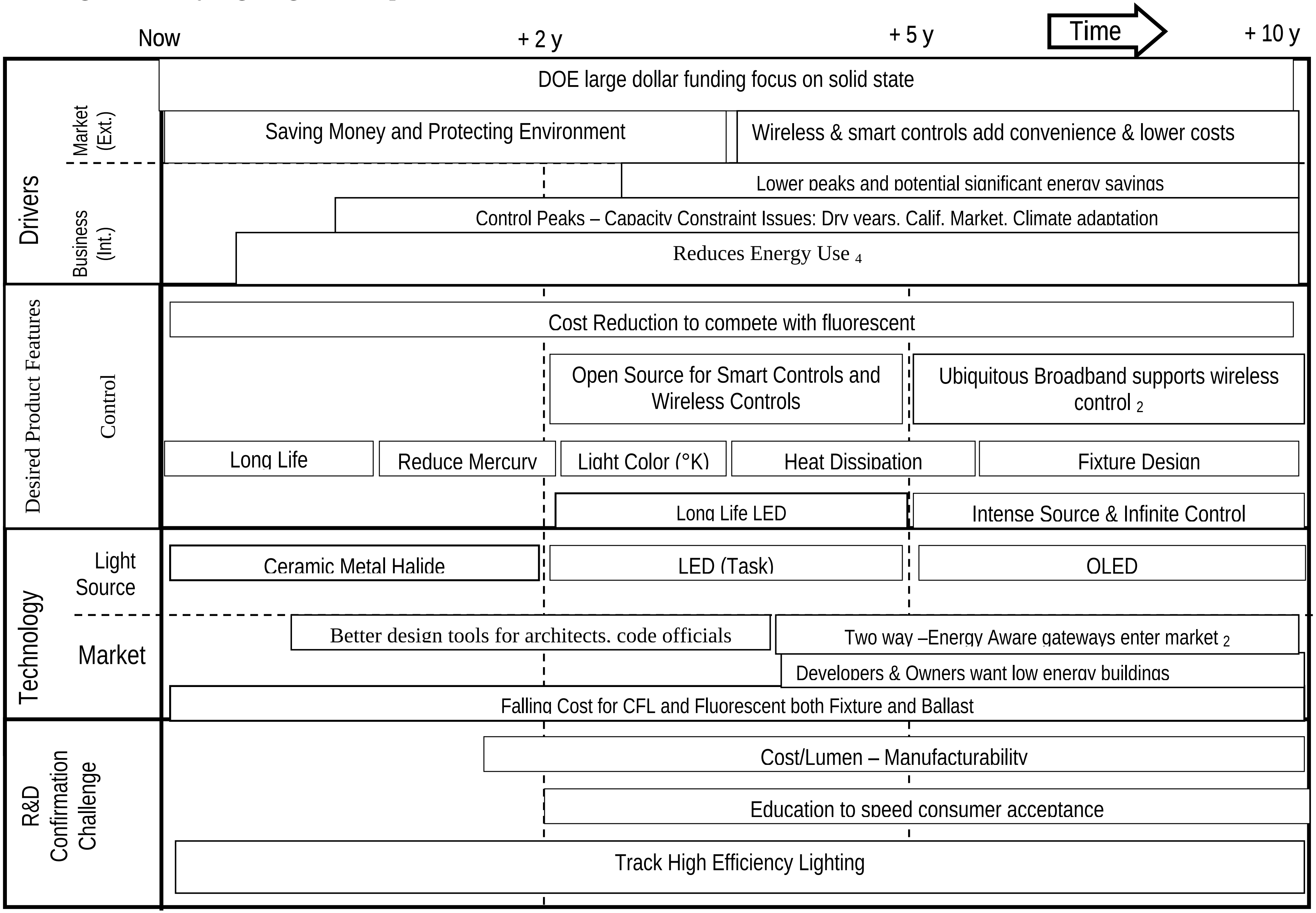
2.7.5 LED and Applications Roadmap

---

[80] Vision 2020 Lighting Technology Roadmap P #4 <http://www.eere.energy.gov/buildings/info/documents/pdfs/lighting_roadmap_compressed.pdf> (accessed 23 May 2006)
[81] NWPCC 5th Power Plan – Conservation P # 3-4 <http://www.nwcouncil.org/energy/powerplan/plan/(03)%20Conservation%20Resources.pdf> (accessed 23 May 2006)
[82] Mike Hoffman's phone conversation with Lighting Design Lab, Randy Smith, 25 Jan. 2006
[83] Lighting Research Center http://www.lrc.rpi.edu/

The following diagram is intended to briefly: 1) illustrate the most relevant drivers of high-efficiency lighting from internal and external perspectives; 2) list desired (future) product features from cost, operational and technical perspectives; 3) list the types of technology and when future products may be come available; and 4) indicate the R&D challenges to the development of those technologies. The timeframe illustrates current understanding of how this technology may develop over the next 10 years.

2.7.5 High Efficiency Lighting Roadmap



Legend: Technologies supporting or overlapping with DR 1, Smart Appliance 2, Heat Pump Hot Water Heater 3, Heat Pump without Strip Heat 4, Integrated Building Design 5

2.7.6 Suggested Role for BPA:

BPA has historically worked with the Lighting Research Center to influence lighting research, especially in cutting edge solid-state technologies. The most relevant research to BPA is the use of lighting controls for demand response. For now, BPA should track only advancements in high-efficiency lighting technology.

This action will allow BPA to introduce new lighting technology and reduce implementation costs for energy efficiency.

2.8 Industrial Process

2.8.1 Technology Overview

Although forest products have traditionally been a strong export market for U.S. manufacturers, global competition by low-cost producers is increasing. The capital intensity of the industry and focus on quarterly results has limited the industry's ability to take risks and invest in new technology. In the PNW, forest products are a mature industry that is critical to job retention in the region.

Forest products rely on a vast renewable resource base to manufacture a wide variety of products essential to modern society. Emerging nanotechnologies could radically reduce the energy used in the forest products industry and improve the industry's economic competitiveness globally.[84] This has the potential to transform the industry in virtually all respects.

2.8.2 Opportunity Overview Industrial process

The application of nanotechnology to forest products is the only industrial process for consideration in this technology roadmap. Nanotechnology is engineering of functional systems at the molecular scale.[85]

BPA energy efficiency engineers chose this industrial process after reviewing the DOE "Industries of the Future Roadmap." Industries removed from consideration included aluminum, chemicals, glass, metal casting, mining, steel and petroleum refining. They were not considered because the industry does not exist in the region, has moved out of the region, is shutting down, or has not been interested in or participated in energy efficiency programs historically.

The industrial sector has a regional conservation potential of 350 MW, with BPA's share 140 MW. Fully one third of all U.S. energy use is consumed in industrial processes, and forest products ranks among the top eight energy-intensive industries.[86] At least 18 percent of U.S. industrial energy use can be attributed to forest products manufacturing.[87]

The application of nanotechnology to forest products is in the very early research stage. So far, only a few academic conferences hosted by DOE have focused on this area. Within the region, only Oregon State University and Weyerhaeuser Corporation have been active participants in conferences.[88] Current research of note is the track work on pulp and paper sensors at Lawrence Berkley Labs, which indicates the potential to cut energy consumption by 1 to 3 percent on a paper machine,[89] or as much as 1 MW per paper machine.

2.8.3 R&D Challenges The challenge for nanotechnology in forest products is to put together a research agenda that will forge consensus on where to spend research funds across the forest products

[84] Nanotechnology for the Forest Products Industry, P # v- vi <http://www.fpl.fs.fed.us/highlighted-research/nanotechnology/forest-products-nanotechnology.pdf >
[85] <http://www.crnano.org/whatis.htm> (accessed 24 May 2006)
[86] <http://www.eere.energy.gov/industry/technologies/industries.html> (accessed 22 May 2006)
[87] Nanotechnology for the Forest Products Industry, P # 5 <http://www.fpl.fs.fed.us/highlighted-research/nanotechnology/forest-products-nanotechnology.pdf >
[88] Ibid P # 75, 76
[89] Interview with Jeff Harris, NEEA 31 Jan. 2006

industry, university researchers and technology developers. Basic technical challenges include a lack of fundamental understanding of materials formations at nanoscale and the absence of adequate measuring technology to characterize materials at the nanoscale.[90]

2.8.4 Sector Actors

A. DOE funds forest industry energy research at the national level.

B. Weyerhaeuser is a PNW manufacturer of forest products that has participated in past nanotechnology research for forest products conferences.

C. University of Washington in Seattle, Wash., is involved in nanotechnology and forestry research.

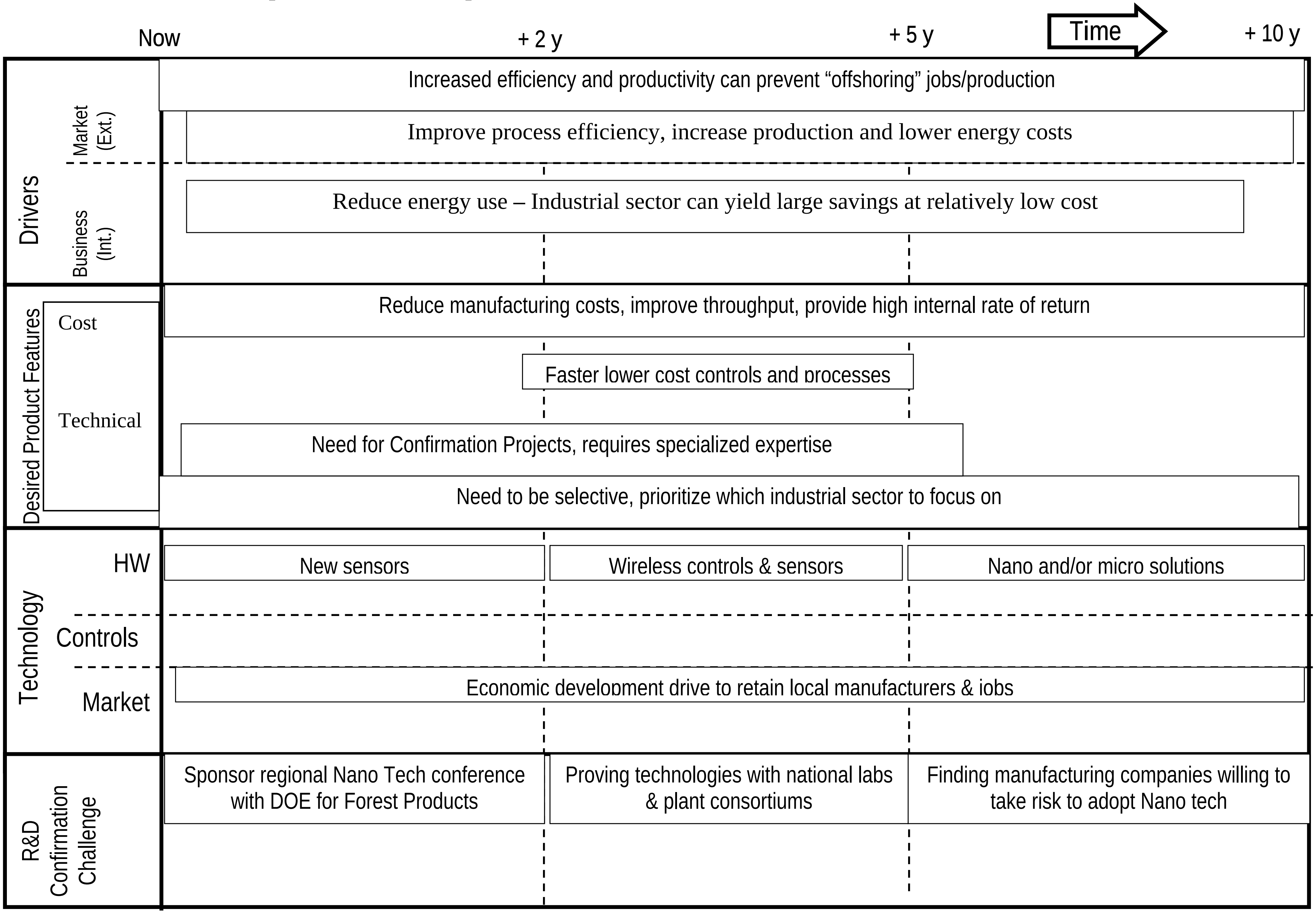
D. Oregon State University in Corvallis, Ore., is involved in nanotechnology and forestry research

2.8.5 Industrial Process Improvement Roadmap

The following diagram is intended to briefly: 1) illustrate the most relevant drivers of industrial processes (nanotechnology for forest products) from internal and external perspectives; 2) list desired (future) product features from cost, operational and technical perspectives; 3) list the types of technology and when future products may be come available; and 4) indicate the R&D challenges to the development of those technologies. The timeframe illustrates current understanding of how this technology may develop over the next 10 years.

[90] Ibid

2.8.5 Industrial Process Improvement Roadmap



Legend: Technologies supporting or overlapping with DR 1, Smart Appliance 2, Heat Pump Hot Water Heater 3, Heat Pump without Strip Heat 4, Integrated Building Design 5

2.8.6 Suggested Role for BPA:

BPA's role in nanotechnology for forest products should be to ensure that the Oregon Nanoscience and Microtechnologies Institute[91] (ONAMI) is involved in the DOE national efforts and connected to regional players. BPA should sponsor a regional event focusing on nanotechnology in forest products with DOE as a cosponsor.

As a facilitator, BPA can encourage regional entities onto a path to basic R&D in this area.

91 <http://www.onami.us/ao_overview.html> (accessed 24 May 2006)

2.9 Grid Integration – Parked for coordination with TBL, Includes Distribution Efficiencies

Appendices:

A. Technology Road Mapping process for 1 day EE workshop

Roadmapping Terms
Roadmapping process
Roadmapping Objective – R&D plan

Sector Context – BPA, Council, NEEA (presentation by organizations)

Group Process
 Identify drivers (i.e. business, consumers, technology, etc.)
 Prioritize: sift and sort to capture

Group Process
 Identify known or coming technologies
 Identify 'disruptive technologies' (opportunities?)
 Matrix exercise
 DAR
 Technology list and rating exercise

Technology analysis and evaluation exercise:

- Identify key product features with high impact on one or more drivers
- Essential Challenges:
    - Identify challenges
    - Review and modify
    - What are we missing? (or ranking exercise)
- R & D Implications
    - Identify implications
    - Review and modify

B. Drivers & priorities from road map session

Grouped Drivers	# Points
System reliability Utility deregulation Utility decision makers (IOUs)	1

Technology forecast
New generation technology
  Advanced NNCs
Manufacturing Scale (time to profitability)
  Equity price
	0

Infrastructure (market chain)	
Tech evaluation and reporting	3
Decision makers, business	0
Internet and computers	10
Information overload Increasing personal wealth End User benefits/needs Decision maker household	9
Green thinkers Environmental Global warming Regional air regs Climate change Greenhouse gas integration	10

Technologies & their value rankings

Technology	Technology Risk	Value to Region	Commercial Risk
Heat pump water heater	Low	High	High
Demand controlled ventilation	Low	Low	High
High output fluorescent lighting	Low	High	Low
“Heating” heat pump w/o resistance	Med	High	Low
LED lighting applications	High	High	High
Industrial Process Improvements	High	High	High
PV/OLED	High	High	High
CO^2 refrigeration	High	High	High
Digital controls	Med	Low	High
Variable speed drive applications	Low	High	Low
Digital self-diagnostic controls	Med	High	Med
DC end use applications	High	Low	High
Integrated building design	Med	High	High
Evaporative cooling	Med	Low (for now)	High
Smart appliances	Med	High	Med
Technology to turn waste into energy	High	High	High
Nano tech	0	0	0
Manufactured commercial buildings	High	High	High
Electric vehicles/Hybrids	High	Low	High
Grid integration	High	Med	High

0 = Not rated

Technologies in priority order

Technology	# Dots
Heat pump water heater	11
Demand controlled ventilation	0
High output fluorescent lighting	2
“Heating” heat pump w/o resistance	8
LED lighting applications	5
Industrial Process Improvements	5
PV/OLED	3
CO^2 refrigeration	5
Digital controls	2
Variable speed drive applications	0

Technology	# Dots
Digital self-diagnostic controls	3
DC end use applications	0
Integrated building design	5
Evaporative cooling (no compressor)	6
Smart appliances	4
Technology to turn waste into energy	0
Nano tech	1
Manufactured commercial buildings	0
Electric vehicles and elec. appliance related to transp.	0
Grid integration	4

Technology(s) - rankings from workshop (Risk & Value columns were used to judge relative priority for point ranks)

Points (from voting)	Technology	Technology Risk (perceived by EE team)	Value to Region (perceived by EE team)	Commercial Risk (perceived by EE team)
11	Heat pump water heaters	Low	High	High
8	Heat pumps w/o resistance	Med	High	Low
6	Evaporative cooling	Med	Low	High
5	LED lighting	High	High	High
5	Industrial process improvement	High	High	High
5	Integrated building design (passive strategies)	Med	High	High

Points (from voting)	Technology	Technology Risk (perceived by EE team)	Value to Region (perceived by EE team)	Commercial Risk (perceived by EE team)
5	CO^2 refrigeration	High	High	High
4	Smart appliances	Med	High	Med
4	Grid integration	High	Med	High
3	PV/Organic LED	High	High	High
3	Digital auto diagnostic controls	Med	High	Med
2	High output fluorescent lighting	Low	High	Low
2	Digital controls	Med	Low	High

These technologies were combined into the following topic areas:

Heat Pump Water Heaters
Heat Pumps without Strip Heat
High Efficiency Lighting
Low Energy Cooling
Industrial Process - Forest Products (drafted), Agricultural processing CO^2 Refrigerants on hold for future)
Integrated Building Design
Grid Integration – (Includes Distribution Efficiency Initiatives) Parked for TBL coordination
Smart Appliances
Demand response (DEMX, direct load control, DR)

The EE group ranked technologies in potential importance to the region. During the process of researching and interviewing experts, the categories were merged into a shorter list of topic areas. The winnowing process went like this: Evaporative cooling became low-energy cooling on review of CEC programs. After a review of the DOE Industries of the Future Roadmap and discussing the viability of the DOE list compared to PNW industry potential with EE engineers that work with the industrial sector, LED, OLED and fluorescent lighting were merged into high-efficiency lighting. Digital controls and diagnostics were merged into integrated building design, and industrial process improvement was limited to forest products and agricultural processing

C. Demand response References

A. FERC
David Kathan. "FERC's Role in Demand response."
"Benefits of Demand response in Electricity Markets and recommendations in achieving them." (Dec. 14, 2005).
http://www.abanet.org/environ/committees/renewableenergy/teleconarchives/121405/12-14-05KathanPPT.ppt (accessed May 16, 2006).

B. U.S. DOE. "Benefits of Demand response in Electricity Markets and recommendations in achieving them." (Feb. 2006). http://www.electricity.doe.gov/documents/congress_1252d.pdf (accessed May 16, 2006).

C. NWPPC
"Demand response – 5th Power Plan." (May 2005).
http://www.nwcouncil.org/energy/powerplan/plan/(04)%20Demand%20Response.pdf (accessed May 16, 2006).

D. MISO
Dr. Ronald R. NcNamara. "Incorporating Demand response Into Regional Transmission Planning in the Midwest." (Jan. 25, 2006).
http://www.ferc.gov/EventCalendar/Files/20060125092052-McNamara,%20MISO.pdf (accessed May 16, 2006).

E. ACEEE
Dan York, Martin Kushler, PhD. "Exploring the Relationship Between Demand response and Energy Efficiency: A Review of Experience and Discussion of Key Issues."
(Mar. 2005). http://www.aceee.org/pubs/u052.htm (accessed May 16, 2006).

F. Dan York, Martin Kushler, PhD. "Appendix B: Annotated Bibliography Of Demand-Response References With A Focus On California And New York Experiences." (March 2005). http://www.aceee.org/pubs/u052.pdf (accessed May 16, 2006).

G. CEC
Michael Messenger. "A Proposed Action Plan to Develop more Demand response in California's Electricity Markets." (Apr. 29, 2002).
http://www.westgov.org/wieb/meetings/crepcsprg2002/briefing%20materials/ca_actionplan.pdf (accessed May 16, 2006).

H. California Energy Commission. "Integrated Energy Policy Report Subsidiary Volume: PUBLIC INTEREST ENERGY STRATEGIES REPORT." (Dec. 2003). http://www.energy.ca.gov/2003_energypolicy/index.html (accessed May 16, 2006).

I. Roger Levy. Levy Associates. "A Vision Of Demand response – 2015. " (Jan. 2006). http://www.energy.ca.gov/2006publications/CEC-500-2006-001/CEC-500-2006-001.PDF (accessed May 16, 2006).

J. Mike Messenger. "How to Simultaneously Stimulate the Growth of Energy Efficiency and Demand response Resources at the same time: The California Story." (Oct. 3, 2005). http://www.mwalliance.org/energypros/activities/conference/2005/documents/MikeMessenger.pdf (accessed May 16, 2006).

K. DRAM
U.S. DOE. "Comments of Demand response and Advanced Metering Coalition (DRAM)." (Nov. 3, 2005). http://www.dramcoalition.org/Resource-156/DRAM%20Comments%20to%20DOE%2005.11.22%20%20Submitted.pdf (accessed May 16, 2006).

L. DRRC
Osman Sezgen, Charles Goldman, P. Krishnarao. "Optional Value of Electricity Demand response." (Oct. 2005). http://eetd.lbl.gov/ea/EMS/reports/56170.pdf (accessed May 16, 2006).

M. EEI
Steven Rosenstock. "EEI Member and Non-Member Residential/Commercial/Industrial Efficiency and Demand response Programs for 2005/2006." (Sept. 8, 2005). http://www.eei.org/industry_issues/retail_services_and_delivery/wise_energy_use/programs_and_incentives/progs.pdf (accessed May 16, 2006).

N. NEDRI
Richard Cowart, Dr. Jonathan Raab."Dimensions of Demand response: Capturing Customer Based Resources in New England's Power Systems and Markets." (July 23, 2003). http://www.cis.state.mi.us/mpsc/electric/capacity/cnf/demand/nedrijul_2003.pdf (accessed May 16, 2006).

O. Dimensions of Demand response: Capturing Customer-Based Resources in New England's Power Systems and Markets (NEDRI Final Report Outline – May 1, 2003)

P. CAEM
Grayson Heffner, Freeman Sullivan. "A Critical Examination of ISO-Sponsored Demand response Programs." (Aug. 2005).

Q. MADRI

R. Brad Johnson, David Ellis, Bob Lesch. "MADRI – Washington, D.C. – October 20, 2005 Operation Kill-A-Watt (A Mid-Atlantic Regional Demand response Program)." (Oct. 20, 2005).

S. SCE
T. Edward Lovelace. "The Air Conditioner Cycling Summer Discount Program Evaluation Study." (Feb. 2006).

U. Mark Martinez. "Summer Initiative Expansion of the AB970 Small Commercial Demand-Responsiveness Pilot Program." (Feb 14, 2006).

D. Smart Appliances References

A. Whirlpool

B. Intel Capital

C. Invensys

D. Cascadia Ventures

E. Home Plug Alliance

F. United Power Line Council

G. Cisco

H. U.S. DOE. "Industrial Wireless Technology for the 21st Century". (Dec. 2002). **Industrial Wireless (**accessed May 18, 2006).

I. **Smart Appliances in PNW**

J. **Smart Appliances in Japan today** (accessed May 18, 2006).

K. **Grid Friendly Appliance controller** (accessed May 18, 2006).

L. **Chief Engineer**
http://www.chiefengineer.org/content/content_display.cfm/seqnumber_content/2357.htm
(accessed May 18, 2006).

M. **New Zealand Herald**
(January 16, 2006). **http://www.nzherald.co.nz/section/story.cfm?c_id=5&ObjectID=10363790**
(accessed May 18, 2006).

E. Heat Pump Water Heater References

A. California Energy Commission (CEC) – Has supported study of HPWH design refinements, market optimization and acceptance, durability, benefits to end users, integration with other appliance technologies and safety analysis.

Links to CEC studies:

Pier. "Design Refinement and Demonstration of a Market-Optimized, Residential Heat-Pump Water Heater." (Apr. 2004). http://www.energy.ca.gov/pier/final_project_reports/500-04-018.html (accessed May 19, 2006).

Pier. "Design Refinement and Demonstration of a Market-Optimized Residential Heat-Pump Water Heater." http://energy.ca.gov/pier/buildings/projects/500-98-028-0.html (accessed May 19, 2006).

Pier. "Heat Pump Water Heaters: Reliable, Efficient." http://www.esource.com/public/pdf/cec/CEC-TB-7.pdf (accessed May 19, 2006).

Pier. "Synergistic Water Heating & Distribution Technologies (SWHDT) Program Final Report." http://www.energy.ca.gov/pier/final_project_reports/CEC-500-2005-111.html (accessed May 19, 2006).

Pier. "Synergistic Water Heating and Distribution Technologies."
http://energy.ca.gov/pier/buildings/projects/400-00-038-0-2-2_1.html (accessed May 19, 2006).

Robert Zogg, William Murphy. "Durability Testing Results." (Apr. 2004).
http://energy.ca.gov/reports/500-04-018/2004-05-21_500-04-018_A3.PDF (accessed May 19, 2006).

Pier. "Synergistic Water Heating and Distribution Technologies."
http://energy.ca.gov/pier/buildings/projects/400-00-038-0-2-2_2.html (accessed May 19, 2006).

B. Northwest Energy Efficiency Alliance (NEEA) – Produced a study on water heater market in the Pacific Northwest. Strong advocate of market transformation for HPWH.

"Assessment Of The Residential Water Heater Market In The Northwest." (Dec. 5, 2005).
http://energystarpartners.net/ia/Water_heaters/Documents/KEMA_NorthwestWHmkt_execsum_Dec2005.pdf (accessed May 19, 2006).

"Assessment Of The Residential Water Heater Market In The Northwest Final." (Dec. 5, 2005).http://energystarpartners.net/ia/Water_heaters/Documents/KEMA_NorthwestWHmarket_December2005.pdf (accessed May 19, 2006).

C. Natural Resources Defense Council (NRDC) – Environmental advocacy organization supporting energy efficiency and Non-Wires Solutions in the Pacific Northwest.

To be included on Energy Star Partners (Water Heaters) site, per notes of Dec. 15, 2005, meeting.

D. Oakridge National Laboratories (ORNL) – Technical center for testing HPWH equipment for DOE and CEC. HPWH work ties into ORNL buildings efficiency program.

John Tomlinson. "The Drop in Residential Heat Pump Water Heater."
http://www.ornl.gov/sci/btc/apps/hotwater.html (accessed May 19, 2006).

Van Baxter, R.L. Linkous. "Heat Pump Water Heater Durability Testing – Phase II." (May 2004).
http://www.ornl.gov/sci/btc/pdfs/hpwh-durtst2-TM-2004-111.pdf (accessed May 19, 2006).

E. Dux-Australia – Manufacturer of HPWH in Australia.

Dux. "Dux Heatpump Hot Water Systems." http://www.dux.com.au/products.php?name=HP4TS (accessed May 19, 2006).

F. EcoCute-Japan: Brand name of CO^2 refrigerant based HPWH. Technology was developed by Norsk Hydro and is marketed by a group of Japanese utilities.

Jarn. "Growing CO^2 Heat Pump Water Heater Market."
http://www.jarn.co.jp/News/2004_Q2/40629_Growing_ CO^2.htm. (accessed May 22, 2006).

"Japanese Heat-Pump Water Heater Market Growing." Appliance Magazine, (Sept. 2005). http://www.appliancemagazine.com/zones/consumer/04_laundry/editorial.php?article=1098&zone=4&first=1 (accessed May 22, 2006).

G. ECR (Dunkirk boiler) – Manufacturer of HPWH tested for by ORNL for CEC and used in programs by NYSERDA.

ECR. "The Water$aver Difference." http://www.ecrinternational.com/prod_wattersaver.asp (accessed May 22, 2006).

F. Heat Pump Water Heater:

How It Works

Heat pump water heaters save energy by transferring heat from surrounding air to water within the heater tank. They can be installed to draw heat from indoor air (if internal cooling is desired) or from outdoor air. Even when the outside air temperature is as low as 4° C (40° F), a heat pump water heater can usually extract enough energy to meet most of a typical home's water heating needs. It uses the same principle as refrigerators and air conditioners. The difference is that these appliances remove unwanted heat, while the heat pumps captures heat and puts it to work.

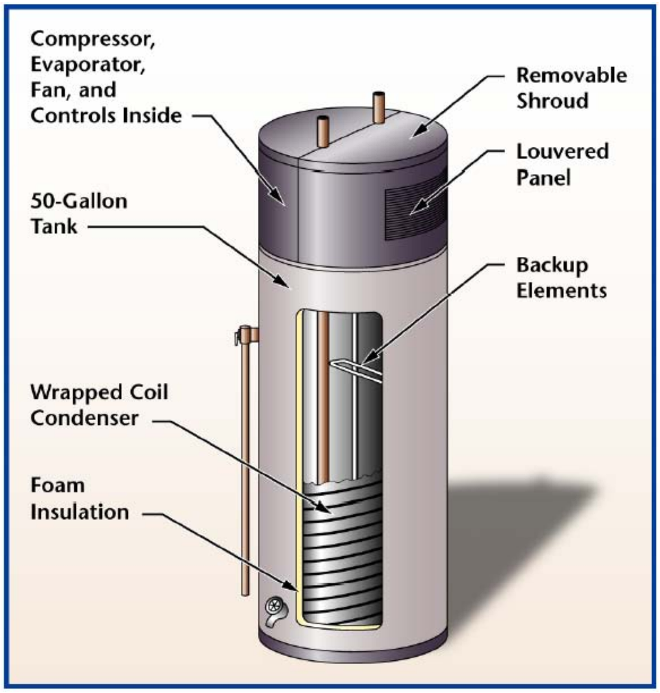
Waste Cooling

When the heat pump water heater removes heat from the surrounding air, it cools it. Air-conditioning energy costs can be reduced by installing ducts to transport cool air throughout the home. A heating and air-conditioning contractor can estimate the cost of installing the necessary ductwork and controls, as well as a system for venting the cooled air outdoors during the winter season.

Applicability

The heat pump water heater provides the best energy savings when used in areas where temperatures are mild. When the air temperature drops below 4° C (40° F) or rises above 38° C (100° F), the heat pump water heater may not meet performance demands and will not operate efficiently. A back-up heating source (such as a booster heater installed near the point of use) may be needed to meet demand. Increased use of back-up water heating could result in lower savings.

Heat Pump Water Heater



There are two types of heat pump water heaters: those that use outdoor air as a source of heat and those that use indoor air. Those that use outdoor air will likely be split systems, with the heat pump unit outdoors, or it may be a system where outdoor air is "piped" to a heat pump indoors, then is discharged outdoors after the heat has been extracted. The storage tank is indoors.

For indoor air systems, both the tank and heat pump will be indoors, possibly integrated, and will extract heat from the surrounding air. During the heating season, the surrounding air will have to be heated. Thus, unless the cooling of the surrounding air has some value in summer, there is virtually no advantage to heat pump water heaters using an indoor air source.

G. Heat Pump Without Strip Heat References

A. Hallowell International

Website: http://www.gotohallowell.com/

Charles Linn. "Can a New Kind of Heat Pump Change the World?" http://archrecord.construction.com/resources/conteduc/archives/0603edit-1.asp (accessed May 19, 2006).

Jay Stein. "Will Utilities Warm Up to Low-Temperature Heat Pumps?" (Feb. 3, 2006). http://www.energypulse.net/centers/article/article_display.cfm?a_id=1199 (accessed May 19, 2006).

B. Nyle: Original marketer of the CCHP technology.

“The cold climate heat pump.” http://www.nyletherm.com/spaceheating.htm (accessed <ay 19, 2006).

Main Green Energy Supply. “Cold climate heat pump.” http://www.energy-innovation.com/products.php?mode=prd&prdid=9 (accessed May 19, 2006).

Ebuild. “Brewer firm resumes heat pump output.” (Apr. 26, 2006). http://www.ebuild.com/guide/resources/product-news.asp?ID=293073&catCode=13 (accessed May 19, 2006).

C. Chelan PUD

Kimberlee Craig. “Cold Climate Heat Pump shows promise, but manufacturing delayed.” (Apr. 1, 2006). http://www.chelanpud.org/newsreleases/2005/ColdClimateHeatPump_040105.htm (accessed May 19, 2006).

D. E-Source

Jay Stein. “Will Utilities Warm Up to Low Energy Heat Pumps?” (Oct. 2005). http://www.esource.com/public/pdf/WP-2-LTHP_LowTempHeatPump.pdf (accessed May 19, 2006).

E. ACEEE

“Advanced Cold Climate Heat Pump/Frostless Heat Pump.” (2004). http://www.aceee.org/pubs/a042_h9.pdf (accessed May 19, 2006).

F. Hitachi Igloo (no web links found)

G. Electro Industries (no web links found)

H. Daikin (no web links found)

I. Samsung (no web links found)

J. NEEA

Washington State University. “Energy Solutions Resources.” http://www.energyexperts.org/energy_solutions/res_details.cfm?resourceID=3517&keyword=heat%20pumps&sector=All (accessed May 19, 2006).

K. CEATI

“Monitoring of Two Air Source Cold Climate Heat Pumps.” (2005). http://www.ceatech.ca/pdetails.php?id=5834 (accessed May 19,, 2006).

CRN. “Cold Climate Heat Pumps: Testing Performance on Co-Op lines.” (Sept. 1, 2005). https://crn.cooperative.com/Results/items/2003/CRNResult_03-22.htm (accessed May 19, 2006).

H. Integrated Building Design

A. Lawerence Berkley Lab (LBL) Integrated Commissioning and Diagnostics http://buildings.lbl.gov/hpcbs/Element_5/02_E5.html (accessed 19 May 2006)

B. General Services Administration (GSA) Demonstration Projects at eight sites < http://www.iai-international.org/IndustrySolutions/usaGSA.html> (accessed 19 May 2006)

C. IAI
Design Tools (accessed May 18, 2006).
Jeffrey Wix. "Assessment of IFC Sufficiency for Building Services Code Checking and Readiness of CAD." http://www.iai-international.org/NewsEvents/IAI_VIU_Workshop_Oct_2004/IAI_ITM_CHIDAM%20_%20Assessment%20of%20%20IFC%20model%20for%20Building%20Services.pdf (accessed May 19, 2006).

D. Wawan Solohin. "Lessons learned from experience of code-checking implementation in Singapore." http://www.iai-international.org/NewsEvents/IAI_VIU_Workshop_Oct_2004/Lessons%20learned%20from%20experience%20of%20code_checking.pdf (accessed May 19, 2006).

E. Harvard Bell and Lars Bjorkhaug. "BARBi in the real world in the real world Presentation for IAI "What's in it for me?" (May 31, 2005). http://www.iai.no/2005_buildingSMART_oslo/Session%2006/BARBi_in_real_world.pdf (accessed May 19, 2006).

F. CEC
Pier. "IAW End-Use Energy Efficiency Presentations & Papers." Pier end-use energy efficiency (accessed May 19, 2006).

G. EERE
DOE. "Building Technology Roadmaps." Building Technology Road Map (accessed May 18, 2006).

H. DOE. "High Performance Commercial Buildings A Technology Roadmap." Commercial Buildings Road Map (accessed May 18, 2006).

I. DOE. "Building Envelope Technology Roadmap." Building envelope Industries of the future (accessed May 18, 2006).

J. DOE. Technologies. Building tech & HVAC (accessed May 18, 2006).

K. DOE. "Window Industry Technology Roadmap." Window tech roadmap (accessed May 18, 2006).

L. CABA
CABA. "Technology Roadmap (TRM) Intelligent Buildings Technologies." Intelligent building technologies, Canada (accessed May 18, 2006).

M. John Fennell.“Building Construction Technology Roadmap.” Building tech roadmap, Australia (accessed May 18, 2006).

N. PATH - NAHB Research Center. “Path Building Technology Roadmaping.” (Jan. 6, 2000). Path roadmap (accessed May 18, 2006).

O. FIATECH – Capital Project Roadmap (accessed 17 Jan. 2006)

I. Low Energy Cooling References

A. CEC

B. PIER

C. SW Energy Efficiency Project
Larry Kinney. “Evaporative Cooling Policy and Program Options: Promising Peak Shaving in a Growing Southwest.” SWEEP - policy options evaporative cooling (accessed May 22, 2006).

D. Western Area Power Administration

E. NEEA

F. DesertAire

G. Coolerado Corporation
“New cooler combines comfort, efficiency.” Coolerdo – residential (accessed May 22, 2006).

H. DOE
“Evaporative Coolers.” DOE - Evap. cooling (accessed May 22, 2006).

I. EERE. “Developing new ways to use thermal energy to meet the energy needs of homes, offices, factories, and communities. (May 2003). Thermally activated roadmap (accessed May 22, 2006).

J. NREL
“Distributed Thermal Energy Technologies.” Distributed thermal Energy (accessed May 22, 2006).

K. Cooling Technology Institute
Cooling Towers (accessed May 22, 2006).

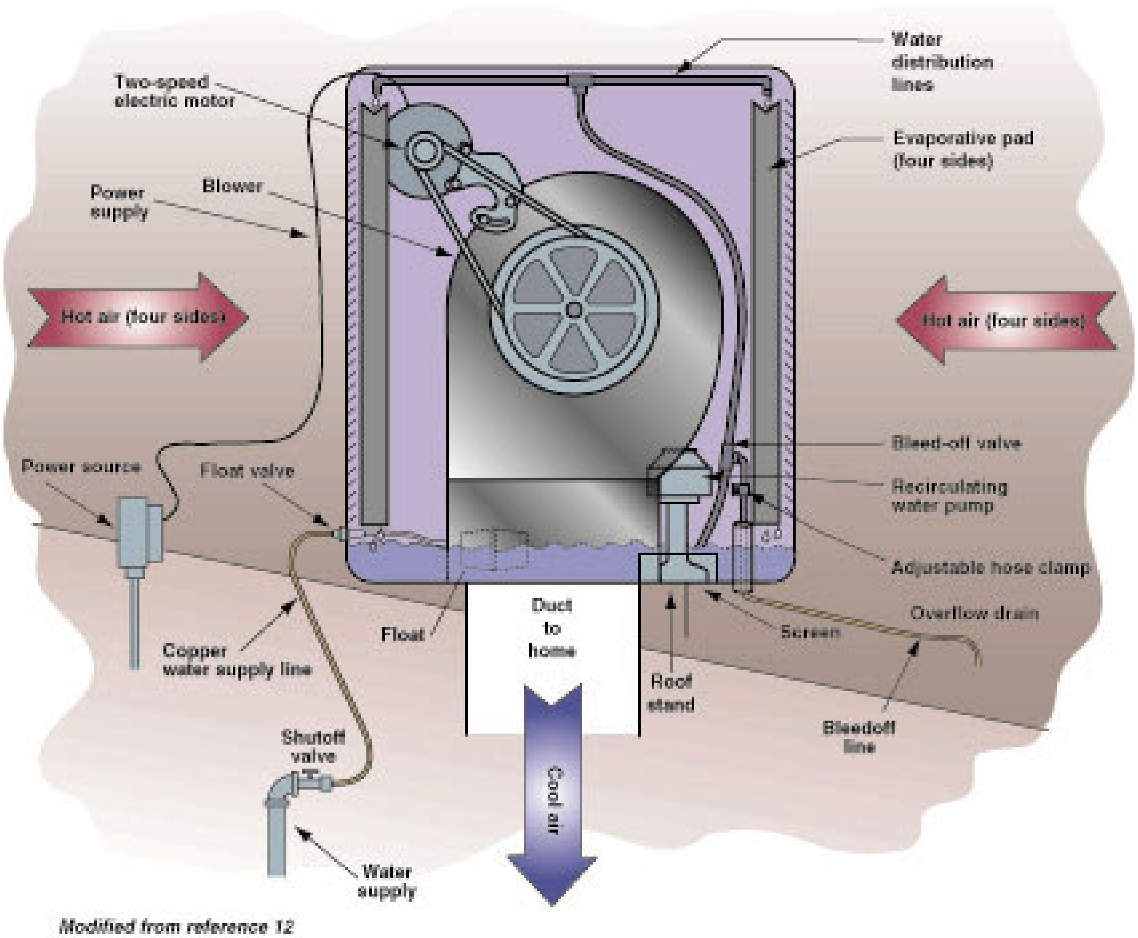
L. Energetics
“The Micro-CHP Technology Roadmap – Meeting 21st Century Energy Needs.” (Dec. 2003). Microchip (accessed May 22, 2006).

J. Low Energy Cooling Technologies:

The era of active HVAC began at the turn of the century, when M. Carrier invented the refrigeration chiller. These systems developed on a large scale after World War II, when mass production in the United States brought cost down. Refrigeration and air-conditioning technologies and the availability of cheap energy allowed architects to keep buildings cool no matter their orientation, insulation level, shading or mass. Many parts of the world abandoned passive cooling design techniques only to renew interest in the last couple of decades or so with the rapid increase in energy costs and environmental concerns.

Cooling technologies investigated in this module are either passive or hybrid. None of the technologies investigated here uses a refrigerant. All technologies, whether used as lone cooling system or combined with other active conventional cooling systems, lead to substantial decrease in cooling energy consumption.

Typical Evaporative cooling



Night ventilation: uses natural means or mechanical power to blow outside air at night into a building and cool its thermal mass, allowing it then to absorb internal or external heat during the following day.

Evaporative cooling: uses wetted pad or water spray on which air is blown to decrease its dry bulb temperature. Evaporate cooling can be "direct" if inlet air is blown directly on the wet medium. In this case, evaporative cooling provides sensible cooling while increasing latent heat content of air. Evaporative cooling can also be indirect, when outside air, cooled directly through the evaporative cooler, transfers its "cool" to the indoor air to be conditioned through an air-to-air heat exchanger. In that case, evaporative cooling provides sensible cooling while keeping constant the latent capacity of air.

Night sky radiative cooling: uses radiative heat transfer toward night sky to cool a thermal mass (usually water) component of a building (usually roof mounted). Night sky temperature can be typically 15°C cooler than dry bulb ambient temperature. Cooled mass will be used as heat sink for building internal and external gains during the following day. Such systems can be entirely passive (water bags called roof ponds) or require some mechanical power to pump water up and down and use water-to-air heat exchanger to distribute cold air inside the building.

Ground cooling with air: uses long-term thermal inertia of ground (a few meters below-ground level yearly temperature varies only a few degrees around mean yearly temperature) to extract "cool" in the summer (and possibly heat in the winter) through air-to-ground heat exchangers. These heat exchangers are usually made of buried pipe networks in which outside or building air is blown to be cooled.

Slab cooling with water: uses building slabs (usually concrete) as cooling energy distributors and emitters. Water is pumped through closed loop piping network in the slab at typical temperature range of 15°C to 18°C. These fairly high temperatures are possible because of the large cooling emission area. They increase the overall efficiency of the cooling process in whichever cooling source is used, active or hybrid/low energy.

Chilled ceiling and displacement ventilation: use mixture of radiative and convective cooling distribution-emission technologies to keep commercial buildings cool with significantly lower energy consumption than with conventional convective systems. The main cooling needs are provided by a radiant chilled ceiling that operates through the same process as radiant cooling slab but with increased emission efficiency due to the fact that cold air drops from the ceiling. Additional latent cooling needs are provided through cooled fresh ventilation air that can thus be kept to minimum required flow rate for indoor air quality purposes. In these displacement ventilation systems, air is supplied at inlets near the floor at 18°C with very low speed (typically 0,2 m/s). It can then spread evenly on the floor surface and make its way up to the vicinity of internal heat sources. It is then exhausted through the ceiling.

Slab cooling with air: uses the thermal inertia of building mass for cooling energy storage by circulating cooled air through channels in the building horizontal (floor, ceiling) and possibly vertical (interior and exterior walls) slabs. The building structure will then be a heat sink for internal or external sensible cooling loads. The cooling source is usually night air, but other hybrid or low-energy cooling sources could also be used.

Ground cooling with water: uses fairly low-temperature aquifer water (typically 10°C), when it is available, as cooling source. Such systems require two (or more) wells to pump water up from and return it down to the aquifer. This primary loop transfers cooling energy to the secondary building cooling distribution loop through a water-to-water heat exchanger. This system can be supplemented if needed by additional cooling systems.

Desiccant cooling: uses desiccant material to absorb moisture (latent load) from air in a dehumidifier. Solid base or liquid-based desiccants can be used. During this dehumidification, heat is released and the dry bulb air temperature increases. This temperature is then reduced (sensible load) by an auxiliary cooling system (active or low energy). In such systems latent load and sensible loads are dealt with separately allowing for good indoor air humidity control.

K. High Efficiency Lighting References

A. DOE
“Executive Summary Vision 2020 The Lighting Technology Roadmap.” DOE Lighting Road Map (accessed May 24, 2006).

Navigant Consulting. “Solid-State Lighting Program Planning Workshop Report .“ (Apr. 2005). Solid State Lighting (accessed May 24, 2006).

B. PGE
Noah Horowitz. “Lighting Pagette Update.” (Nov. 2005). NRDC - Agenda for lighting (accessed May 24 2006).

L. Industrial Process References

A. Weyerhaeuser

B. Univ. of Washington

C. Oregon State University

D. US Dept. of Agriculture, <http://www.fpl.fs.fed.us/highlighted-research/nanotechnology/forest-products-nanotechnology.pdf>

E. CABA, Kenneth Wacks, PhD. “Recent Projects.” Building & smart appliance (accessed May 24, 2006).

F. Climate Vision “Technology Pathways.” http://www.climatevision.gov/sectors/electricpower/pdfs/bioenergy_vision.pdf (accessed May 24, 2006).

M. Industrial Process - CO^2 Refrigerants - for future review

Researchers are making progress in perfecting automotive and portable air-conditioning systems that use environmentally friendly carbon dioxide as a refrigerant instead of conventional, synthetic global-warming and ozone-depleting chemicals.

It was the refrigerant of choice during the early 20th century but was later replaced with man-made chemicals. Now, carbon dioxide may be on the verge of a comeback, thanks to technological advances that include the manufacture of extremely thin yet strong aluminum tubing. New findings about carbon dioxide as a refrigerant include:

- Creation of the first computer model that accurately simulates the performance of CO^2 -based air conditioners. The model could be used by engineers to design air conditioners that use CO^2 as a refrigerant.

- The design of a portable CO^2 -based air conditioner that works as well as conventional military "environmental control units." Thousands of the units, which now use environmentally harmful refrigerants, are currently in operation. The CO^2 unit was designed using the new computer model. A prototype has been built by Purdue University engineers and is being tested.

- The development of a mathematical "correlation," a tool that will enable engineers to design heat exchangers – radiator-like devices that release heat into the environment after it has been absorbed during cooling or future CO^2 -based systems. The mathematical correlation developed at Purdue, which will be published in an engineering handbook, enables engineers to determine how large a heat exchanger needs to be to provide cooling for a given area.

- The development of a new method enabling engineers to predict the effects of lubricating oils on the changing pressure inside CO^2 -based air conditioners. Understanding the drop in pressure caused by the oil, which mixes with the refrigerant and lubricates the compressor, is vital to predicting how well an air conditioner will perform.

Carbon dioxide is promising for systems that must be small and lightweight, such as automotive or portable air conditioners. Various factors, including the high operating pressure required for CO^2 systems, enable the refrigerant to flow through small-diameter tubing, which allows engineers to design more compact air conditioners.

One drawback to CO^2 systems is that they must be operated at high pressures, up to five times as high as commonly seen in current technology. The need to operate at high pressure poses certain engineering challenges and requires heavy steel tubing.

During the 1930s, carbon dioxide was replaced with synthetic refrigerants, called chlorofluorocarbons, or CFCs, which worked well in low-pressure systems. But scientists later discovered that those refrigerants were damaging the Earth's stratospheric ozone layer, which filters dangerous ultraviolet radiation. CFCs have since been replaced by hydrofluorocarbons, which are not hazardous to the ozone layer but still cause global warming.

However, recent advances in manufacturing and other technologies are making carbon dioxide practical again. Extremely thin yet strong aluminum tubing can now be manufactured, replacing the heavy steel tubing.

Carbon dioxide offers no advantages for large air conditioners, which do not have space restrictions and can use wide-diameter tubes capable of carrying enough of the conventional refrigerants to provide proper cooling capacity. But another natural refrigerant, ammonia, is being considered for commercial refrigeration applications, such as grocery store display cases. Engineering those systems is complicated by the fact that ammonia is toxic, requiring a more elaborate design to isolate the ammonia refrigerant from human-occupied spaces. The first ammonia systems are currently being tested in Europe

N. CO^2 Refrigerant Road Map

Manufacturer, BPA, Utility, Consumer Drivers	Environmentally benign refrigerant Capacity at low temps	Higher delivery temperature – customers like	Capacity at low temperature Japanese gas cost very high	Matches PNW heat/cool needs
Technology Solutions	Need simple model to test		Use as water heating Get us payback to 5 years or less	
R&D Challenges	Confirm peak kW reduction Limited National Market	Bring cost down Demo CO_2 HWH	New tech. How to get mnfr/public acceptance? Standards work needed	
Actors	DENSO - Japan.	NEDO		
Road Maps (Links)				
Research Report Links	**CO^2 refrigeration technology**	**CO^2 compressor** **CO^2 compressor in appliances**		
Resources Needed	Compressor availability			

O. EE Road Map Contacts

Name, organization and topic:

1. Randy Smith Lighting Design Lab
High Efficiency Lighting

2. Harvey Sachs ACEEE (Council for an Energy-Efficient Economy)
Industrial Process

3. Thomas Pelsoci Delta Research Company
Closed-Cycle air refrigeration

4. Chris Neme Vermont Energy Investment Corporation
Heat Pump water heaters

5. Jeff Harris NEEA
Heat Pump water heaters – Industrial Process – Low Energy Cooling

6. Steve Selkowitz Lawrence Berkeley Lab
Integrated Building Design

7. Vestal Tutterow Alliance to Save Energy
Industrial Process

8. Marc Ledbetter Pacific Northwest National Lab
HPWH – Lighting – Smart appliances

9. Gale Horst Whirlpool
Smart appliances

10. Duane Hallowell Hallowell Intl
Hot Water & Heat Pump

11. Mary-Anne Piette LBL
Demand response

12. Bruce Nordman LBL
Smart Appliances

13. Jack Callahan BPA
HPWH, HP w/o Strip heat

14. Dick Stroh BPA
Low Energy Cooling

15. Preston Michie BPA
Demand response

P. Philosophy of NYSERDA

Research, Development, and Demonstration

The terms, as they are used at NYSERDA, include demonstration projects. In fact most of NYSERDA's work tends to be applied research, rather than basic research, and includes product development, technology development, demonstration, commercialization, evaluation and monitoring, and feasibility and assessment studies of certain types. NYSERDA prefers applied work because it is an area in which staff has developed expertise, it has shorter time scales than basic research, and, most importantly, New York is more likely to capture the specific benefits of applied work. Basic research tends to be increasingly international in scope, and hence not appropriate for state funding. The rare exception is NYSERDA's support for basic research at New York colleges and universities where federal money is leveraged and New York receives substantial benefits. Otherwise local New York ratepayers and taxpayers might be benefiting residents from other states and countries.

Product Development
Product development has become the most popular type of RD&D project in recent years. It has clear metrics and provides excellent economic development value. Most often the work is with start-up to medium-size companies. At NYSERDA, this type of project falls clearly in the domain of RD&D. Good examples include traditional products, such as boilers, photovoltaic systems and environmental instruments. In all cases, a strong private sector commercial interest exists for working with NYSERDA. The marketplace readily accepts many successful products with no need for specific deployment efforts. However, some products that have special barriers, may need deployment programs to achieve optimum market penetration.

Technology Development
Technology development differs from product development in lacking a clear private interest or, conversely, primarily providing public benefit. Examples include both new testing protocols and products such as large boilers, heat distribution systems and interconnection equipment for dispersed power generators. Other examples include the development of new concepts including performance contracting, measuring environmental externalities and building commissioning. Generally these concepts are developed and tested with RD&D monies and ultimately brought into widespread use by deployment programs, since initially they usually lack strong private sector connections.

Demonstration Projects
Demonstration projects can be done in all sectors – residential, commercial, industrial, municipal – and involve new technologies with substantial technical risk and high initial cost. Such technologies, if proven, could improve energy efficiency, productivity, environmental performance and economics for New Yorkers. Therefore, good test protocols, data analyses and technology transfer plans are necessary elements

of these projects. The general objective of a demonstration project is to improve a project's economics by providing information needed to make good decisions regarding new technology. Usually, the hope is that the technology will prove economically attractive and will be widely adopted, resulting in energy savings and other benefits. However, sometimes it is also important to show that a given technology is not ready for full commercialization and to define further development needs. At NYSERDA, demonstration projects have been in the domain of RD&D, but recently the attribution has become less clear as proposals are put forth for deployment demonstrations such as the REAP project with advanced boiler flues and an Energy Efficiency Services (EES) proposal for industrial bench-marking demonstrations. In general, the main criteria to define whether a project is properly termed research is the amount of technical risk.

Commercialization
Commercialization is generally the last phase of product development and is most often done by the private sector. Occasionally, projects call for NYSERDA RD&D funds when, for example, a pressing public benefit is available and a private company has limited resources to dedicate to the commercialization of the product.

Evaluation and Monitoring
Evaluation and monitoring activities have similar objectives to demonstration projects but are applied to existing systems rather than installed initially as part of the project. Examples include environmental monitoring and evaluation of equipment such as water heaters, refrigerators and lighting systems that exemplify the highest technical and aesthetic characteristics. Evaluation and monitoring projects have a strong public benefit character and historically have been completed through NYSERDA's Research, Development, and Demonstration Program area.

Q. Research Links by topic of EE TRM:

References Search List

1. Heat pump water heaters links
http://www.enviro-friendly.com/how-quantum-works.shtml
http://esource.com/public/pdf/cec/CEC-TB-7.pdf
http://www.ecrinternational.com/prod_wattersaver.asp
http://www.energy.ca.gov/pier/final_project_reports/500-04-018.html
http://www.nyserda.org/Press_Releases/press_archives/2002/10_16_02s2.asp
http://www.ecrinternational.com/ecrinternational/pdfs/ecrbrochure-english.pdf
http://www.ornl.gov/sci/btc/pdfs/hpwh-durtst2-TM-2004-111.pdf durability testing
http://www.ornl.gov/sci/btc/apps/hotwater.html
http://www.bchydro.com/powersmart/elibrary/elibrary694.html
http://ninemsn.homesite.com.au/products/renovate/bathrooms_and_laundries/hot_water_systems/electric/80798
http://jarn.co.jp/News/2001_Q2/104_M_10_Melco.htm

Building Water Heating Roadmap http://www.eere.energy.gov/solar/sda_02_04.html

solar water heating
http://www.nabcep.org/documents/Water%20Heating%20Roadmap%20USDOE.pdf

2. Heat Pumps without Strip Heat
http://www.glue.umd.edu/~yhhwang/publication.htm Listing of refrigerant mixes in heat pumps (U Maryland - $120)

Cold Climate HVAC conf. 2006
http://www.abok.ru/CC2006/program%20CC%2011.04.pdf

http://www.energy.sintef.no/arr/GL2006/

http://www.heatpumpcentre.org/

3. **High Efficiency Lighting**
lighting road map http://www.nrel.gov/docs/fy00osti/28236.pdf
http://www.netl.doe.gov/ssl/PDFs/DOE_SSL_Workshop_Report_Feb2005.pdf Solid State

http://www.eere.energy.gov/buildings/info/documents/pdfs/lighting_roadmap_compressed.pdf

4. **Low Energy Cooling**
Evap cooling http://www.toolbase.org/techinv/techDetails.aspx?technologyID=194
2 stage evap http://www.toolbase.org/techinv/techDetails.aspx?technologyID=262
cooling tech inst. evap. http://www.cti.org/
europe evap http://europa.eu.int/comm/energy_transport/atlas/htmlu/phlectdtechstat.html atlas eu http://europa.eu.int/comm/energy_transport/atlas/homeu.html
DOE eere
http://www.eere.energy.gov/consumer/your_home/space_heating_cooling/index.cfm/mytopic=12360
wapa bulletin coolerdo http://www.wapa.gov/es/pubs/esb/2005/june/jun057.htm
Thermally activated cooling tech http://www.fuelcellsworks.com/Supppage4199.html
distrib thermal http://www.nrel.gov/dtet/about.html
Thermal technoloies
http://www.eere.energy.gov/de/pdfs/thermally_activated_roadmap.pdf
microchp http://www.energetics.com/pdfs/distributed/microchp_roadmap.pdf

5. **CO² & refrigeration technology** http://members.cox.net/jamesmcalm/Calm_Didion-Trade_Offs_in_Refrigerant_Selections-ASHRAE-1997.pdf
SINTEF http://www.sintef.no/content/page1____6271.aspx
https://drum.umd.edu/dspace/handle/1903/1857
http://www.hepco.co.jp/english/research/develop/result2004/res2004-04.html
http://www.denso.co.jp/en/products/consumer/
http://www.tellurex.com/capp.html

6. Industrial Process
Pier papers & presentations http://www.energy.ca.gov/pier/esi/esi_papers.html

Industries roadmaps
http://www.climatevision.gov/sectors/electricpower/tech_pathways.html
Food ee http://europa.eu.int/comm/energy_transport/atlas/htmlu/food_and_beverages.html
building & smart appliance links http://pages.prodigy.net/k-w/Recent-Projects/Recent-Projects.htm#

7. **Integrated Building Design**
Window tech roadmap
http://www.eere.energy.gov/buildings/info/documents/pdfs/27994.pdf
Path roadmap **http://www.pathnet.org/si.asp?id=565**
Comml bldg
http://www.eere.energy.gov/buildings/info/documents/pdfs/roadmap_lowres.pdf
lighting roadmap
http://www.netl.doe.gov/ssl/PDFs/Volume%20II%2009.30.05.pdf Market
http://www.eere.energy.gov/buildings/info/documents/pdfs/lmc_vol1_final.pdf consumption
building envelope
http://www.eere.energy.gov/buildings/info/documents/pdfs/envelope_roadmap.pdf
http://www.eere.energy.gov/industry/aluminum/partnerships.html
http://www.eere.energy.gov/industry/glass/partnerships.html
industries of the future **http://www.eere.energy.gov/industry/technologies/**
building tech info
http://www.eere.energy.gov/buildings/info/publications.html#technology%20roadmaps

Technology Roadmap (TRM) for Intelligent Building Technologies Canada
http://www.caba.org/trm/

Building tech roadmap OZ
http://www.copper.com.au/technology_roadmap/exec_summ.pdf

PIER End-Use Energy Efficiency Presentations & Papers
http://www.energy.ca.gov/pier/iaw/presentations/

building tech & hvac http://www.eere.energy.gov/buildings/tech/roadmaps.html

CABA http://www.caba.org/index.html
Existing home EE roadmap http://www.eere.energy.gov/buildings/tech/roadmaps.html
http://www.eere.energy.gov/buildings/energyplus/ifc.html
http://www.iai-international.org/
http://www.bauwesen.fh-muenchen.de/iai/ImplementationOverview.htm

http://www.tiaxllc.com/aboutus/press_releases/energy_savings_potential_021406.htm

8. Grid Integration
DOE distrib. roadmap **http://www.electricdistribution.ctc.com/pdfs/MYRD_ElecDist_11-3_rv9.pdf**

grid interconncet links
http://www.irecusa.org/connect/statebystate.html?PHPSESSID=4f8a8e5b9376b677b90faa2bcdf5172b

BPA TBL dlc cites http://www.transmission.bpa.gov/orgs/opi/Power_Stability/index.shtm

9. Smart Appliances
industrial wireless http://www.energetics.com/pdfs/technologies_processes/wireless.pdf
http://www.chiefengineer.org/content/content_display.cfm/seqnumber_content/2357.htm
http://www.nzherald.co.nz/section/story.cfm?c_id=5&ObjectID=10363790
http://metropolis.japantoday.com/tokyo/416/tech.asp
http://www.usatoday.com/tech/news/techinnovations/2005-12-19-smart-appliances_x.htm?csp=34

10. Distributed Energy Resources - Demand response (DEMX, direct load control, DG)
ORNL CHP
biomass roadmap http://www.bioproducts-bioenergy.gov/pdfs/FinalBiomassRoadmap.pdf
Biomass inel http://www.inl.gov/bioenergy/docs/biomass_roadmap2003.pdf
CHP midwest http://www.chpcentermw.org/12-00_library.html#publications
work with natl labs http://bioproducts-bioenergy.gov/pdfs/30425_Top4.pdf
hydrogen http://www.energetics.com/pdfs/hydrogen/hydrogen_roadmap.pdf
chp http://www.energetics.com/pdfs/distributed/chp_roadmap.pdf
natl gas tech http://www.energetics.com/pdfs/natgas/natgas_roadmap.pdf

demand response listing http://www.goodcents.com/Info/research.htm
http://www.dramcoalition.org/index.htm

drrc http://drrc.lbl.gov/drrc-obj.html

dg - future energy resources http://www.dgfer.org/Downloads/DGFER_Road_Map.pdf

dr policy & tech issues 2002 http://www.goodcents.com/Info/Policy_Technical%20Issues.pdf

dr in market design - eei 2002
http://www.eei.org/industry_issues/retail_services_and_delivery/wise_energy_use/demand_response/demandresponserole.pdf

load management jordon 2002 http://www.ust.edu/journal/study.php

Council DR http://www.nwcouncil.org/energy/dr/

wi dlc puc rule http://www.wisconsinpublicservice.com/news/electric/rgdc.pdf

load mgmt & monitoring
http://www.electricdistribution.ctc.com/monitoring_load_management_technologies.htm

CEC DR scenarios http://www.energy.ca.gov/2006publications/CEC-500-2006-001/CEC-500-2006-001.PDF

11. Power supplies for electronics

LBL – IEEE (1641) Power Management Controls
http://eetd.lbl.gov/Controls/publications/pubsindex.html