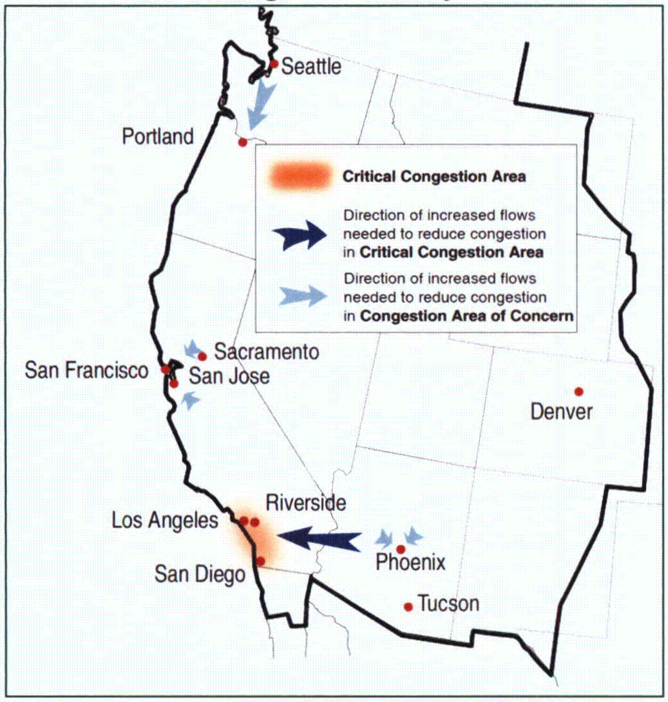
5. Transmission Congestion in the Western Interconnection

5.1. Introduction

This Chapter begins by reviewing the congestion areas in the Western Interconnection that the Department identified in the *2006 National Electric Transmission Congestion Study*. Then it presents TEPPC's broad conclusions about congestion in 2007 across the Western Interconnection, and TEPPC's analyses of projected congestion in the West. Building on these observations, this report then examines each of the 2006 Congestion Areas of Concern and the Critical Congestion Area to ascertain the degree to which conditions in these areas have changed, informed by both the historical congestion information and current and projected conditions documented in various studies. The review of each area concludes with the Department's determination of whether the area continues to be so congested that it merits continued identification as a congestion area. The chapter also addresses major constraints in the Interconnection that lie outside the previously identified congestion areas, and whether any of the areas affected by these constraints should be identified as new congestion areas.

Figure 5-1. Western Congestion Areas Identified in the *2006 National Electric Transmission Congestion Study*



Source: U.S. Department of Energy (DOE) (2006a). *National Electric Transmission Congestion Study*, at http://www.oe.energy.gov/DocumentsandMedia/Congestion_Study_2006- 9MB.pdf, p. ix.

The *2006 National Electric Transmission Congestion Study* identified four congestion areas in the Western Interconnection: the Southern California Critical Congestion Area, the Seattle-Portland Congestion Area of Concern, the San Francisco Bay Congestion Area of Concern, and the Phoenix-Tucson Congestion Area of Concern. These areas are shown in Figure 5-1.

5.2. Recent Historical Congestion in the Western Interconnection

The transmission system in the Western Interconnection is based to a large extent on long-distance lines that connect remote generation to load centers.[192] There are 23 major transmission paths in the West, representing the major transmission links between control areas and between the major resource and load areas of the interconnection.[193] These paths are shown in Figure 5-2 below; path identification convention in the West can include more than one transmission line within a single "path" (as indicated where a solid bar crosses multiple lines), and most paths are identified with a number (shown

[192] In some instances, notably along the West Coast, transmission lines were built to enable seasonal exchanges of power (from north to south in summer and from south to north in winter).

[193] TEPPC Historical Analysis Work Group (2009). *2008 Annual Report of the Western Electricity Coordinating Council's Transmission Expansion Planning Policy Committee, Part 3 – Western Interconnection Transmission Path Utilization Study*, at http://congestion09.anl.gov/, p. 3.

in a small square) rather than a location-specific name. The text box, "Key Transmission Paths in the Western Interconnection," offers further detail on why these paths were identified.

In its analysis of the 2007 transmission usage data, TEPPC sorted the data using several related measures: path loading (usage at 75, 90 and 99% of allowed path loading relative to path limits, also called U75, U90 and U99); over different seasons; direction-neutral maximum flow per path; and load levels. The study team found that different sorting methods produced significantly different results when the paths were ranked to determine which ones were most heavily used. Despite this variation in rankings, TEPPC found some common results in terms of the six most heavily used paths (relative to their path limits) under different ranking methods, as shown in Table 5-1.

After reviewing the various rankings, TEPPC concluded that the most heavily used paths in the West in 2007 were:

- Bridger West (Path 19)
- Montana to Northwest (Path 8)
- Southwest of Four Corners (Path 22)
- Four Corners 345/500 kV Transformer (Path 23)
- Pacific AC Intertie (California-Oregon Interface, Path 66)
- Pacific DC Intertie (Path 65)
- TOT 2C (Utah-Nevada, Path 35)

Key Transmission Paths in the Western Interconnection

The Western Interconnection has a long history of cooperative transmission analysis and planning, conducted by WECC. To make system planning and analysis more manageable, WECC has aggregated groups of transmission lines and related facilities that together enable the transfer of power between areas into "transmission paths." Over a period of years, WECC has developed a "path rating catalog" that today identifies 67 distinct paths that represent the most important linkages within the WECC footprint. Each path is identified with a number (e.g., Path 26) and sometimes also with a geographical name (e.g., California-Oregon Intertie or East of River). A path rating indicates the reliability-based electric flow capacity limits of the path in each direction. Much of the analysis that WECC performs is focused on these paths.

Some of the WECC paths are more important than others in terms of managing power flows and maintaining grid reliability. The WECC-TEPPC Historical Analysis Working Group (HAWG) analyzed historical schedule and actual flow information to identify the most important of the paths from the standpoint of congestion analysis. Specifically, HAWG relied on the following criteria in selecting 23 paths for inclusion in its most recent analysis:

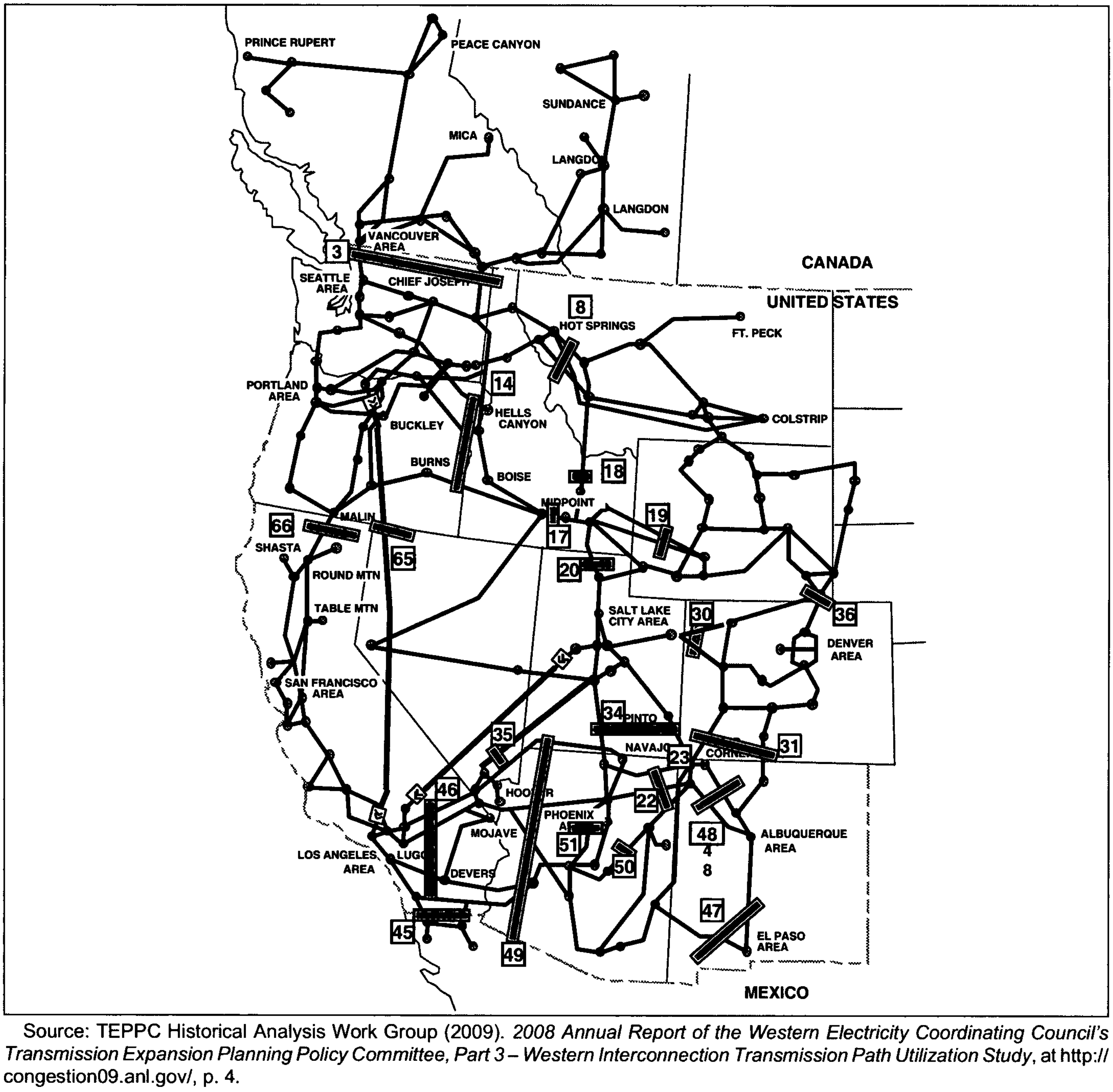
1) The path is commercially important, as identified in previous WECC transmission planning work;
2) The path links an important wind resource area to load centers;
3) The path was identified as problematic in the Regional Transmission Authorities' 2000 biennial transmission plan;
4) The path is frequently subject to unplanned electricity flows (loop flow);
5) The path ensures good coverage for all parts of the Western Interconnection; and
6) The path had schedule data available in eTags.

HAWG expects, to the extent practicable, to track congestion trends in the future using this set of paths. However, the list of key paths examined may change in the future as the WECC electricity infrastructure and usage change; recent experience has shown that congestion can sometimes occur on portions of the Western grid that are not identified as one of WECC's key transmission paths.

- West of Borah (Path 17)
- Southern New Mexico (Path 47)
- TOT 2A (Path 31).[194]

These paths are shown in Figure 5-3 below. During 2007, most of these paths were sufficiently congested that schedule curtailments were required on at least one occasion.[195] The analysis also confirmed expected regional import/export characteristics: "The Rocky Mountain and Desert Southwest were net exporting area[s]; California was a net importing area. The Pacific Northwest was net exporting during the spring and summer (March through

Figure 5-2. WECC Transmission Paths



Source: TEPPC Historical Analysis Work Group (2009). *2008 Annual Report of the Western Electricity Coordinating Council's Transmission Expansion Planning Policy Committee, Part 3 – Western Interconnection Transmission Path Utilization Study*, at http://congestion09.anl.gov/, p. 4.

[194] *Ibid.*, pp. 9 and 22. This excludes the Bridger West path because it is a radial line designed solely to deliver generation from the Jim Bridger power plant up to its maximum capability, and its typical high loading reflects the intended utilization of this line (directly following Bridger dispatch), rather than other grid conditions and possible transmission congestion.

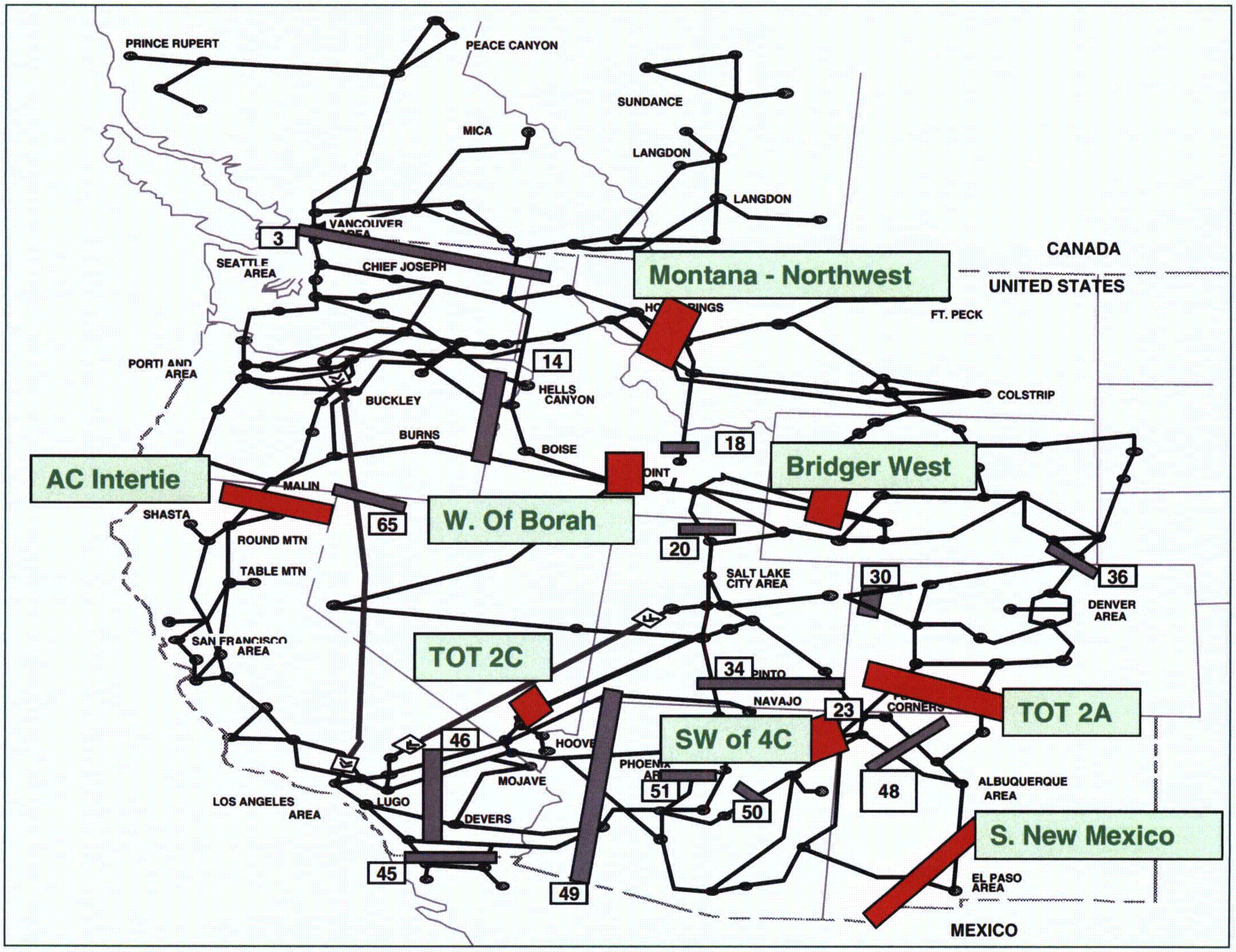
[195] *Ibid.*, p. 27.

Table 5-1. Most Heavily Loaded Transmission Paths in the West Sorted by Alternative Ranking Methods, 2007 Data

Ranking (Top 6 Most Congested Out of 23 Paths)	Ranked by Actual Flow	Ranked by Net Schedule	Ranked by Maximum Directional Schedule (Either Direction)
1	Path 19: Bridger West	Path 19: Bridger West	Path 47: Southern New Mexico
2	Path 22: Southwest of Four Corners	Path 17: Borah West	Path 31: TOT 2A
3	Path 8: Montana to Northwest	Path 35: TOT C	Path 19: Bridger West
4	Path 66: California-Oregon Interface	Path 31: TOT 2A	Path 8: Montana to Northwest
5	Path 23: Four Corners 345/500 kV Transformer	Path 65: Pacific DC Intertie	Path 17: West of Borah
6	Path 65: Pacific DC Intertie	Path 23: Four Corners Transformer	Path 18: Montana to Idaho

Source: TEPPC Historical Analysis Work Group (2009). *2008 Annual Report of the Western Electricity Coordinating Council's Transmission Expansion Planning Policy Committee, Part 3 – Western Interconnection Transmission Path Utilization Study*, at http://congestion09.anl.gov/, p. 21.

Figure 5-3. Most Heavily Used Transmission Paths in WECC, 2007



Source: Perry, D. (2009). "Historical Transmission Congestion Study, Western Interconnection." Presented at the U.S. DOE Office of Electricity Delivery and Energy Reliability Spring 2009 Technical Workshop in Support of DOE 2009 Congestion Study, at http://congestion09.anl.gov/techws/index.cfm, slide 26.

August) and was neutral during the winter months (both importing and exporting)."[196] Generally, the TEPPC historical analysis confirmed that the periods of heaviest flows on WECC transmission paths follow previously observed seasonal loading and import-export patterns.

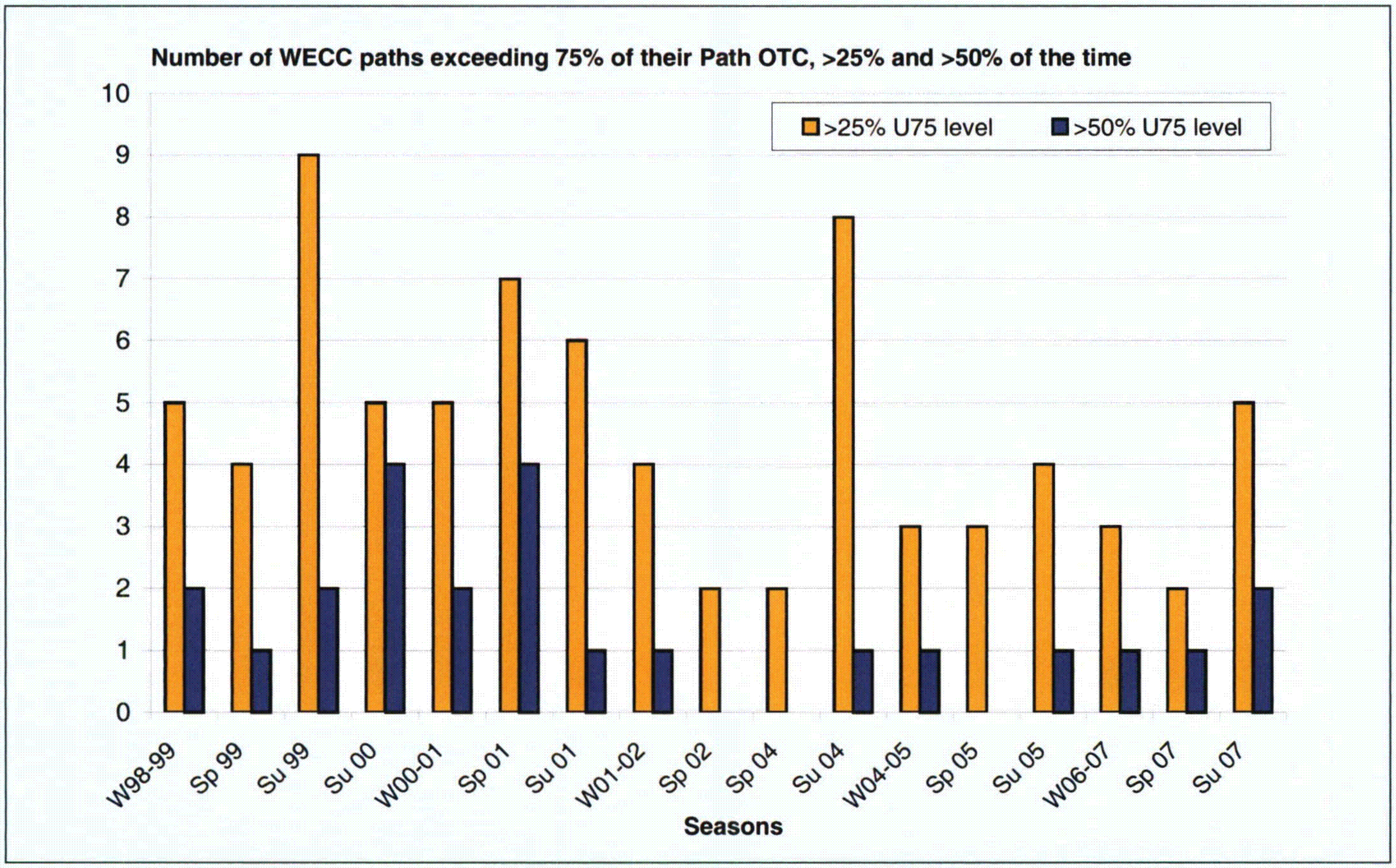
Figure 5-4 shows that actual congestion in the West has been variable but has not increased significantly over the past 8 years. It indicates the number of paths loaded at or above 75% of rated capacity (U75) more than 25% and 50% of the time over the seasons spanning from winter 1998-99 through summer 2007. The figure reveals that as a general trend, U75 loading has come down and remained relatively stable over recent years.

One problem with TEPPC's current analytic approach is that it only measures historical congestion along WECC's traditionally recognized major paths, and thus by definition does not provide information on congestion within smaller geographic areas. For example, as indicated in Figure 5-2 above, TEPPC does not presently evaluate historic congestion for areas that others might deem important for understanding congestion, such as the well-known Path 15 between Northern and Southern California. Similarly, the TEPPC analysis does not shed much light upon conditions between Seattle and Portland, which DOE identified as an area of concern in 2006.

5.3. Projected Congestion in the Western Interconnection

TEPPC conducted a number of simulation analyses for the year 2017 as part of its annual regional transmission planning study program. These simulation studies found that the most heavily constrained transmission paths were Path 20 (Path C Utah-Idaho), Path 31 (TOT2A Colorado-New Mexico),

Figure 5-4. Path Utilization Levels Vary But Have Not Increased: Path Utilization Trend, 1998-2007



Source: TEPPC Historical Analysis Work Group (2009). *2008 Annual Report of the Western Electricity Coordinating Council's Transmission Expansion Planning Policy Committee, Part 3 – Western Interconnection Transmission Path Utilization Study*, Part 3—Western Interconnection Transmission Path Utilization Study, at http://congestion09.anl.gov/, p. 44.

[196] *Ibid.*, p. 28.

Path 35 (TOT2C Utah-Nevada), Path 23 (the Four Corners 345/500 kV transformers), and Path 8 (Montana-Northwest). (See Figure 5-5 below.) These are several of the same paths that were identified as most heavily used in the analysis of 2007 transmission data.

As noted above, the TEPPC analytical approach focuses on the traditional transmission paths in the West, often aggregating several lines into a single path and representing large chunks of generation or load as single large nodes or bubbles. This approach limits the geographic resolution in the modeled results of generation, load, transmission flows, or transmission congestion. As a result TEPPC's current modeling techniques do not look in depth at an area such as Southern California and the flows between Los Angeles and San Diego, or across the Imperial Valley. To date TEPPC has not incorporated the Southern California Import Transfer nomogram into its models. Nor does TEPPC examine local area constraints, such as those that restrict the transmission import capability into the Los Angeles Basin to 10 GW, despite the fact that the combined thermal limit for the lines serving the Basin is 20 GW (and that this constraint would get even tighter if more generation is retired within the Los Angeles Basin). Thus TEPPC's current modeling recognizes electricity flows and possible congestion across the interfaces from Nevada and Arizona into California, but does not recognize the additional constraints within California that limit flows between the large interfaces and Los Angeles.[197]

TEPPC conducted a series of analyses, requested by the Western Interconnection Regional Advisory

Figure 5-5. Map of Principal Transmission Paths in the Western Interconnection

#	Path Name
36	TOT 3
20	PATH C
31	TOT 2A
78 & 79	TOT 2B
35	TOT 2C
23	FOUR CORNERS 345/500 kV
49	EAST OF COLORADO RIVER (EOR)
46	WEST OF COLORADO RIVER (WOR)
15	MIDWAY - LOS BANOS
3	NORTHWEST – CANADA
66	COI
65	PACIFIC DC INTERTIE (PDCI)
8	MONTANA – NORTHWEST
1	ALBERTA – BRITISH COLUMBIA
14	IDAHO – NORTHWEST
37	TOT 4A

Source: TEPPC Historical Analysis Work Group (2009). *2008 Annual Report of the Western Electricity Coordinating Council's Transmission Expansion Planning Policy Committee, Part 1 – Background, Study Plan and Simulation Analysis*, at http://www.wecc.biz/committees/BOD/TEPPC/Shared%20Documents/Forms/AllItems.aspx?RootFolder=%2fcommittees%2fBOD%2fTEPPC%2fShared%20Documents%2fTEPPC%20Annual%20Reports%2f2008&FolderCTID=&View=%7b3FECCB9E%2d172C%2d41C1%2d9880%2dA1CF02C537B7%7d, Figure 5.6-2, p. 46.

[197] See http://www.caiso.com/docs/2002/01/29/2002012909363927693.pdf.

Body (WIRAB), to look at a series of resource portfolios associated with "resource mixes that are consistent with the goal of achieving a 15% reduction in carbon emissions by 2020 relative to 2005 levels."[198] The fundamental assumption for this series of studies was that renewable energy would be increased to 15% of regional electricity production, located in both the United States and Canada. Several of the conclusions from the WIRAB series are notable here:

- Projected renewable energy production was spread broadly across the Western Interconnection, as shown in Figure 5-6 below.
- The most fully loaded U.S. transmission paths under these cases were Path 35 (TOT2C Southwest Utah to Nevada), Path 23 (Four Corners 345/500 kV Transformers), and Path 8 (Montana-Northwest), all of which are integral to the WECC transmission network; analysis suggests that these paths would operate at their limits more than 25% of the time for at least two of the four renewable scenarios plotted.
- With greater renewable generation, loading of major paths on the east side of the Western Interconnection network increases markedly above historical loading levels.[199]
- As the level of energy efficiency increases (on top of 15% renewable energy production), natural gas-fired generation decreases far more than baseload coal generation. This is because coal remains the lowest-cost thermal resource in the generation stack while gas-fired generation is the marginal resource and absorbs the bulk of the efficiency-driven generation reduction.[200]
- With 15% renewables and high energy efficiency, flows and congestion increase on the paths moving energy from the northeast (MT, WY, ID and CO) toward the northwest (WA and OR) and toward the Desert Southwest (CA, AZ and NM). This is because there is more generation reduction in California, and higher energy efficiency savings in the interior states, which allows increased generation in the interior states to flow west toward coastal population and load centers.[201]

TEPPC transmission planning studies are conducted with minimal or no additional transmission facilities assumed to be built into the future network, specifically to enable planners to determine what additional transmission might be needed. A number of specific major new transmission projects (listed in Table 5-2) have been proposed for construction in the West that could help alleviate projected congestion if they are built. Many of these projects are designed to enable utilities serving large loads to access less expensive generation sources; a number are proposed specifically to open up new resource areas to bring new renewable and coal-fired generation to markets. Several of these proposed projects are shown in Figure 5-7.

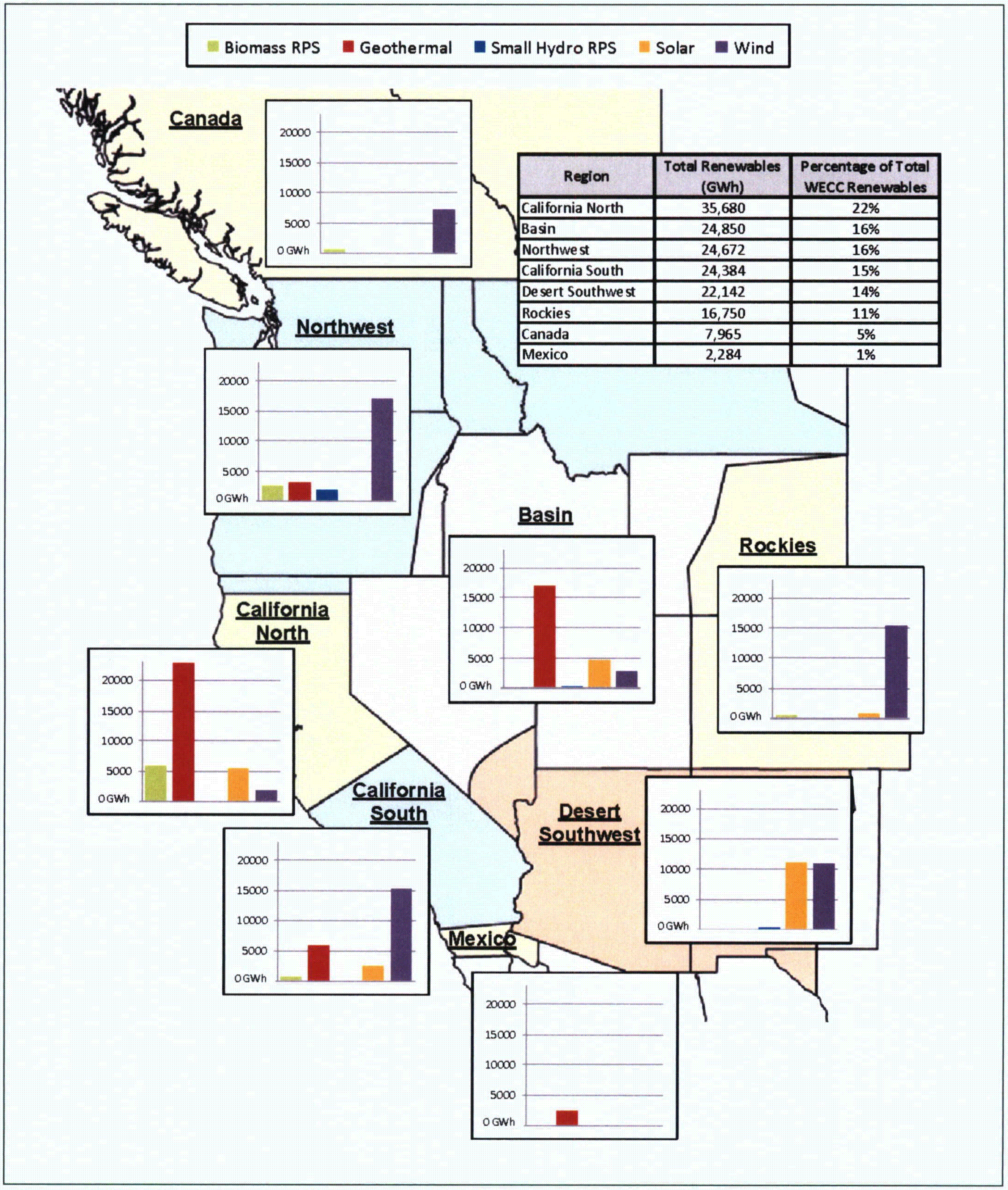
The Department takes no position on the relative merits of or prospects for the individual projects listed in Table 5-2. The Department recognizes that a strong transmission grid (along with increased energy efficiency, demand response, and fuel-efficient dispatchable generation) is needed in the Western Interconnection to maintain reliability, increase development of renewables, and potentially displace petroleum-based fuels in the transportation sector. Accordingly, it will be important for many of these proposed transmission projects to move through the TEPPC planning process, gain state and federal regulatory and environmental approvals, secure appropriate financing and cost recovery assurances, and eventually get built and placed into service.

5.4. Southern California Critical Congestion Area

The Department's 2006 Congestion Study identified Southern California (spanning the metropolitan areas of Los Angeles and San Diego) as a Critical Congestion Area, given the area's persistent

[198] TEPPC Historical Analysis Work Group (2009). *2008 Annual Report of the Western Electricity Coordinating Council's Transmission Expansion Planning Policy Committee, Part 1—Background, Study Plan and Simulation Analysis*, p. 65.
[199] *Ibid.*, p. 89.
[200] *Ibid.*, p. 74.
[201] *Ibid.*, p. 103.

Figure 5-6. Location of Renewable Resources by Region for TEPPC 15% Renewables Case



Region	Total Renewables (GWh)	Percentage of Total WECC Renewables
California North	35,680	22%
Basin	24,850	16%
Northwest	24,672	16%
California South	24,384	15%
Desert Southwest	22,142	14%
Rockies	16,750	11%
Canada	7,965	5%
Mexico	2,284	1%

Source: TEPPC Historical Analysis Work Group (2009). *2008 Annual Report of the Western Electricity Coordinating Council's Transmission Expansion Planning Policy Committee, Part 1 – Background, Study Plan and Simulation Analysis*, at http://www.wecc.biz/committees/BOD/TEPPC/Shared%20Documents/Forms/AllItems.aspx?RootFolder=%2fcommittees%2fBOD%2fTEPPC%2fShared%20Documents%2fTEPPC%20Annual%20Reports%2f2008&FolderCTID=&View=%7b3FECCB9E%2d172C%2d41C1%2d9880%2dA1CF02C537B7%7d, Figure 6.2-1, p. 70.

Table 5-2. Proposed Transmission Projects in the Western Interconnection

Project No.	Project Description	In-Service Date	WECC Status	Project Sponsors
1	Northern Lights – Celilo HVDC Project	2014	Phase 1	TransCanada Energy, Ltd.
2	Northern Lights Chinook (MT – NV) HVDC Line	2015	Phase 0	TransCanada Energy, Ltd.
3	Northern Lights Zephyr (WY – NV) HVDC Line	2015	Phase 0	TransCanada Energy, Ltd.
4	Juan de Fuca Sea HVDC Cable Sea	2010	Phase 2	Sea Breeze Pacific
5	West Coast HVDC Sea Cable	2010	Phase 1	Sea Breeze Pacific
6	Triton 2017 HVDC Sea Cable	???	Phase 1	Sea Breeze Pacific
7	Juan de Fuca II HVDC Sea Cable	???	Phase 1	Sea Breeze Pacific
8	TransWest Express Project	2015	Phase 1	Anschutz Corp, TransWest LLC, Arizona Public Service, PacifiCorp, Wyoming Infrastructure Authority
9	Gateway South Segment #1 – Mona – Crystal 500 kV	2013	Phase 2	PacifiCorp
10	Gateway South Segment #2 – Aeolus – Mona 500 kV	2013	Phase 2	PacifiCorp
11.1	Gateway Central – Populus – Terminal Transmission Project 345 kV	2010	Phase 3	PacifiCorp
11.2	Gateway Central – Mona – Oquirrh 500 kV	2012		PacifiCorp
11.3	Gateway Central – Sigurd – Red Butte – Crystal 345 kV	2013	Phase 1	PacifiCorp
12.1	SWIP North Transmission Project – Midpoint – Thirtymile 500 kV	2011	Phase 2	Great Basin Transmission LLC
12.2	SWIP South Transmission Project – Robinson Summit – Las Vegas 500 kV	2010	Phase 2	Great Basin Transmission LLC
13	Wyoming – Colorado Intertie Project (345 kV line)	2013	Phase 2	TransElect, Wyoming Infrastructure Authority
15	High Plains Express – Backbone path WY-CO-NM-AZ			Salt River Project, Tri-State G&T, Western Area Power Administration, Public Service Company of New Mexico, Xcel Energy, Trans-Elect, Colorado Springs Utilities, Platte River Power Authority, Colorado Springs Utilities, Platte River Power Authority, Wyoming Infrastructure Authority, New Mexico Renewable Transmission Authority, Colorado Clean Energy Authority
17	SunZia Project (Add to Path 47 for 1200 MW+ non-simultaneous capacity NM-AZ)	2013	Phase 1	Southwestern Power Group II, LLC, Salt River Project, Tucson Electric Power, Energy Capital Partner, Shell WindEnergy Inc.
19	Palo Verde Hub – North Gila Project 500 kV	2009	Phase 0	Arizona Public Service
20.1	Gateway West Segment #1A – Winstar – Aeolus – Jim Bridger 500 kV	2014	Phase 2	PacifiCorp, Idaho Power
20.2	Gateway West Segment #1B – Jim Bridger – SE Idaho (Bridger – Populus 2-500 kV)	2012	Phase 2	PacifiCorp, Idaho Power
20.3	Gateway West Segment #1C – SE Idaho – SC Idaho (Populous-Midpoint 500 kV)	2012	Phase 2	PacifiCorp, Idaho Power

Source: Transmission Expansion Planning Policy Committee (TEPPC) (2009). *Transmission Expansion Planning Policy Committee—2009 Synchronized Study Program*. Draft, at http://www.oatioasis.com/SPPC/SPPCdocs/Draft_TEPPC_2009_Study_Plan_05-12-09.pdf, Table 3.2, Transmission Projects for Consideration in Building Expansion Cases to Investigate Congestion Reduction, p. 20.

Table 5-2. Proposed Transmission Projects in the Western Interconnection (Continued)

Project No.	Project Description	In-Service Date	WECC Status	Project Sponsors
20.4	Gateway West Segment #1 – SC Idaho to SW Idaho (Midpoint – Hemmingway 500 kV)	2012	Phase 2	PacifiCorp, Idaho Power
21	Boardman – Hemmingway 500 kV (B2H)	2013	Phase 1	Idaho Power
22	Mountain States Transmission Intertie (MSTI) – Townsend – Borah – Midpoint 500 kV	2013	Phase 2	Northwestern Energy
23	COI Uprate Project – Non-simultaneous rating to 5100 MW	2008	Phase 0	Transmission Agency of Northern California
24	Canada – Northern California Transmission Project – Silkirk – Round Butte/Grizzly 500kV AC & Round Butte/ Grizzly – Tesla/Tracy ±500kV DC	2015	Phase 1	Pacific Gas & Electric
25	Devils Gap Interconnection to Canada – Northern California Interconnection	2015	Phase 1	Avista Corp.
26	Central California Clean Energy Transmission Project (C3ET) Double circuit Midway – Fresno 500kV		Phase 1	Pacific Gas & Electric
27	Lake Elsinore Advance Pumped Storage Interconnection Talega – Escondido/Valley – Serrano 500kV	2007/2009	Phase 1	Nevada Hydro Company, Inc., The Lake Elsinore Valley Municipal Water District
28	San Francisco Bay Area Bulk Trans. Reinforcement Project		Phase 0	Pacific Gas & Electric
29	I-5 Corridor Reinforcement Troutdale – Alston/Paul 500 kV	2015	Phase 1	Bonneville Power Administration
30	West of McNary – McNary – John Day/Big Eddy – Station Z, OR/WA 500kV	2012 & 2013	Phase 1	Bonneville Power Administration
31	Hemingway – Captain Jack 500kV	2014	Phase 1	PacifiCorp
32	Walla Walla – McNary/Boardman 230 kV	2010	Phase 0	PacifiCorp
33	Southern Crossing – Bethel – Boardman 500kV	2013	Phase 1	Portland General Electric
34	Increase Southern Navajo Path 51 Rating to 3200 MW	2010	Phase 2	Arizona Public Service
35	TOT3 Archer Interconnection Project	2019	Phase 2	Basin Electric Power Cooperative
36	Navajo Transmission Project Segment 1 – Four Corners – Navajo/Moenkopi – Mead/Marketplace 500kV	2010	Phase 2	Dine Power Authority
37	Ely Energy Center Project – Robinson Summit – Harry Allen 500kV	2011	Phase 2	Sierra Pacific Resources
38	Sunrise Powerlink Valley – Central 500kV & Central – Sycamore Canyon – Peasquitos 230kV	2010	Phase 2	San Diego Gas & Electric
39	Path 36 (TOT3) Upgrade – Miracle Mile – Ault 230kV	2010	Phase 3	Western Area Power Administration
41	Path 54 Uprate for Springerville #4	2009	Phase 3	Salt River Project

Source: Transmission Expansion Planning Policy Committee (TEPPC) (2009). *Transmission Expansion Planning Policy Committee—2009 Synchronized Study Program.* Draft, at http://www.oatioasis.com/SPPC/SPPCdocs/Draft_TEPPC_2009_Study_Plan_05-12-09.pdf, Table 3.2, Transmission Projects for Consideration in Building Expansion Cases to Investigate Congestion Reduction, p. 20.

Table 5-2. Proposed Transmission Projects in the Western Interconnection (Continued)

Project No.	Project Description	In-Service Date	WECC Status	Project Sponsors
42	Montana – Alberta Tie	2010 2Q	Phase 3	Montana Alberta Tie Ltd.
43	Path 27 Upgrade – IPP DC ±500kV	2009	Phase 3	Los Angeles Department of Water & Power
44	Green Path North Project – (Indian Hills – Upland)	2010	Phase 3	Los Angeles Department of Water & Power, Imperial Irrigation District
45	Devers – Palo Verde 500 kV No. 2	2011	Phase 3	Southern California Edison
46	Harcuvar Transmission Project (Devers – Harcuvar 230 kV)	2012-13	N/A	Central Arizona Water Cons District
47	Path 3 – Northwest – BC – S-N Rating Increase		Phase 1	British Columbia Transmission Corp.
48	Path 55 Brownlee East Increase to 1915 MW	2008	Phase 1	Idaho Power
49	Hughes Transmission Project	2009	N/A	Basin Electric Power Cooperative, Wyoming Infrastructure Authority
50	Wyodak South 230 kV Project			PacifiCorp
51	G3 500 kV Project			Vulcan Power Company

Source: Transmission Expansion Planning Policy Committee (TEPPC) (2009). *Transmission Expansion Planning Policy Committee—2009 Synchronized Study Program.* Draft, at http://www.oatioasis.com/SPPC/SPPCdocs/Draft_TEPPC_2009_Study_Plan_05-12-09.pdf, Table 3.2, Transmission Projects for Consideration in Building Expansion Cases to Investigate Congestion Reduction, p. 20.

transmission congestion problems, large population and important economic role within the nation. Factors influencing the identification as a Critical Congestion Area included the area's growing electric demand, heavy dependence upon electricity imports, and difficulty in building new power plants and transmission lines. These factors are reviewed and updated below.

Southern California remains an important economic and population center for the nation. The region has three large electric utilities and several smaller non-investor-owned utilities:

- SCE serves over 13 million people in a 50,000 square mile area, located in the Los Angeles Basin and the Inland Empire. In 2008 its load peaked at 22,045 MW. The California Energy Commission (CEC) projects that the utility's load will grow by 400 MW per year, with summer peak load forecast to reach 28,039 MW by 2013. Much of SCE's generation is in-area from nuclear, hydro, oil- and gas-fired and qualifying facilities,[202] with imports on AC and DC lines from the Pacific Northwest and Arizona.[203]
- SDG&E serves 1.4 million electric customers in San Diego and southern Orange counties over a 4,100 square mile area. SDG&E's 2008 peak load reached 4,586 MW, and is projected to reach 5,227 MW by 2013.[204] SDG&E imports a significant amount of its electricity supplies from outside its service area.
- The Los Angeles Department of Water and Power (LADWP) serves 1.4 million electric customers in the City of Los Angeles, with a peak load in 2008 over 6,160 MW, projected to rise to 6,469 MW by 2013.[205]

5.4.1. Changes in Load and Demand-Side Resources

Maximum actual peak load in southern California reached 28,669 MW during an extreme heat wave

[202] The federal Public Utilities Regulatory Policies Act of 1978 (PURPA) authorized states to establish regulatory regimes for cogeneration facilities, which were termed "qualifying facilities."

[203] California ISO (CAISO) (2009b). *2009 California ISO Transmission Plan.* Amended June 2009, at http://www.caiso.com/2354/2354f34634870.pdf, p. 160.

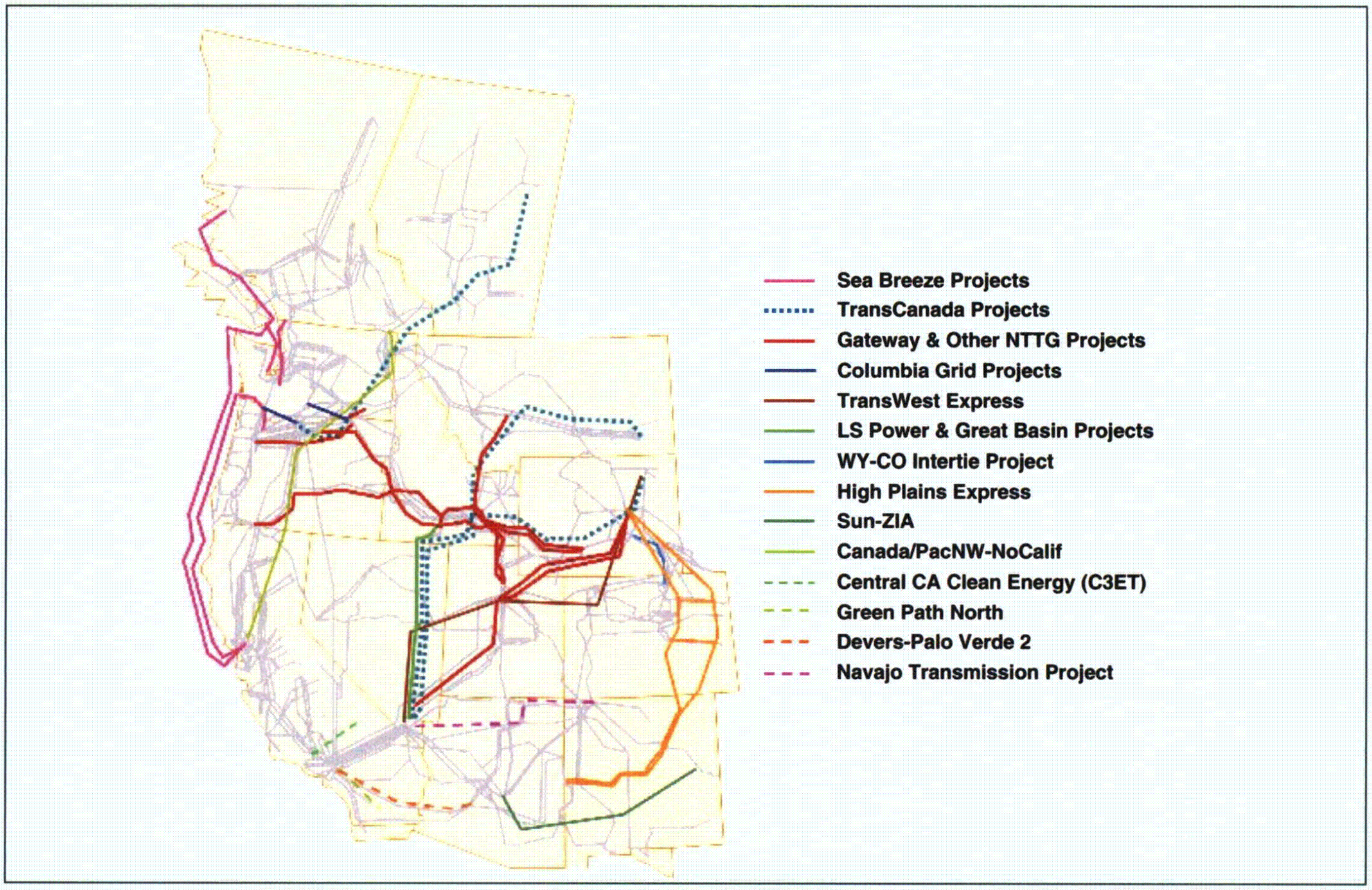
[204] *Ibid.*, pp. 177, 180.

[205] California Energy Commission (CEC) (2007a). *California Energy Demand 2008-2018: Staff Revised Forecast*, at http://www.energy.ca.gov/2007publications/CEC-200-2007-015/CEC-200-2007-015-SF2.PDF, Table 3, p. 17.

in 2006. Recent state projections, based on expected average weather conditions, forecasted that peak demand will grow at a rate of 1.59% per year and reach 28,604 MW by 2013.[206] That forecast, however, predates the current economic recession.

California has long been a leader in energy efficiency and demand response; the ACEEE ranked California as the foremost state in the nation in terms of the quality of its energy efficiency policies and accomplishments.[207] ACEEE has also lauded California for its innovative energy efficiency programs and policies, including decoupling and shareholder incentives for investor-owned utilities, designation of efficiency as the highest-priority new resource, large budgets for efficiency programs, and aggressive savings goals.[208] The state adopted an ambitious Long Term Energy Efficiency Strategic Plan in 2008 that places energy efficiency as the highest priority for meeting California's energy needs, with the goal of transforming energy use and reducing greenhouse gas emissions through "Big, Bold Strategies."[209]

Figure 5-7. Proposed Major Transmission Projects in WECC



Notes: Plot includes selected projects from Table 3.2 of 2008 TEPPC Study Plan (v7). Projects have been grouped to simplify coding. Although this map shows the Devers-Palo Verde 2 line reaching all the way to the Palo Verde power plant, the permit request for that line was withdrawn from the Arizona Corporation Commission.

Source: Nickell, B. (2009). "Transmission Expansion Planning Policy Committee, 2008 Study Results." Presented at the U.S. DOE Office of Electricity Delivery and Energy Reliability Spring 2009 Technical Workshop in Support of DOE 2009 Congestion Study, at http://congestion09.anl.gov/techws/index.cfm, slide 21.

[206] *Ibid.*

[207] Eldridge, M., et al. (2008) *The 2008 State Energy Efficiency Scorecard*, ACEEE Report Number E086, at http://www.aceee.org/pubs/e086_es.pdf, p.4.

[208] Kushler, M., D. York and P. White (2009). *Meeting Aggressive New State Goals for Utility Sector Energy Efficiency: Examining Key Factors Associated with High Savings*. ACEEE Report Number U091, at http://www.aceee.org/pubs/U091.pdf, p. 111.

[209] California Public Utilities Commission (CPUC) (2008a). *California Long Term Energy Efficiency Strategic Plan*, at http://www.californiaenergyefficiency.com/docs/EEStrategicPlan.pdf.

Between 2006 and 2008 state regulators authorized $3 billion in energy efficiency investments by California's investor-owned utilities, which produced a total of 10,341 MWh and 1,776 MW savings for the 2006-2008 period.[210] State agencies report significant savings in Southern California:

- SCE's energy savings equaled 575 GWh in 2004, and grew to 1,638 GWh in 2008,
- SCE's peak demand savings equaled 45 MW 115 MW in 2004, and grew to 329 MW in 2008,
- SDG&E's energy savings equaled 225 GWh in 2004 and grew to 387 GWh in 2008, and
- SDG&E's peak demand savings equaled 45 MW in 2004 and reached 69 MW in 2008.[211]

LADWP has a successful energy efficiency program that includes giving new energy-efficient refrigerators to low-income customers, giving out over 2.4 million compact fluorescent light bulbs to replace incandescent bulbs, and conducting extensive customer education programs about the benefits of energy conservation and how to achieve them.[212] LADWP reports saving 115 GWh with efficiency programs in fiscal year 2008, and expects to save 290 GWh in fiscal 2009.[213]

The state has adopted rules that require major improvements in energy efficiency. These include the provision that new home energy use must be 35% better than 2005 energy code levels by 2011, and reach zero net energy levels by 2020; that new commercial buildings must attain zero net energy use by 2030; and that existing commercial buildings must reduce energy use by 20% by 2030.[214]

California also relies upon aggressive utility and CAISO-managed demand response programs, as shown in Table 5-3.

California and its utilities are also leaders in installing distributed renewable generation. California dominates the nation's photovoltaics market, aided

Table 5-3. Summary of Utility-Operated Demand Programs

Utility	Program	Enrolled MW			
		July 2007	July 2008	August 2007	August 2008
SCE	Price-Responsive	240	369	256	381
PG&E	Price-Responsive	608	735	623	752
SDG&E	Price-Responsive	117	150	121	154
	Total	*964*	*1,254*	*999*	*1,287*
SCE	Reliability-Based	1,283	1,436	1,305	1,458
PG&E	Reliability-Based	322	451	323	466
SDG&E	Reliability-Based	93	89	98	83
	Total	*1,698*	*1,976*	*1,726*	*2,007*
	Combined Total	**2,662**	**3,230**	**2,725**	**3,294**

Source: CAISO (2009c). *Market Issues & Performance: 2008 Annual Report*, at http://www.caiso.com/2390/239087966e450.pdf, Table 2.4, p. 2.4, taken from monthly reports filed by the utilities with the CPUC.

[210] CPUC (2008c). *Energy Efficiency Groupware Application Standard Reports.* Program impacts tables, at http://eega2006.cpuc.ca.gov/Reports.aspx.

[211] CPUC (2008b). *Energy Efficiency Groupware Application.* "Summary of 2006-2008 Energy Efficiency Programs–December 2008," at http://eega2006.cpuc.ca.gov/Default.aspx, and 2005 data from California Energy Commission (CEC) (2007). *2007 Integrated Energy Policy Report*, at http://www.energy.ca.gov/2007publications/CEC-100-2007-008/CEC-100-2007-008-CMF.PDF.

[212] See Los Angeles Department of Water & Power (LADWP) (2008). "L.A.'s Energy Demand Soars Toward All Time High." LADWP Press release, at http://www.ladwpnews.com/go/doc/1475/212546/; LADWP (2009). "LADWP Gives Away 2 Million Compact Fluorescent Light Bulbs to Residential Customers." LADWP Press release, at http://www.ladwpnews.com/go/doc/1475/264244/; and LADWP (2008). "LADWP Recognized as a Leader in Climate Change as the Recipient of 2008 Green California Leadership Award," at http://www.ladwpnews.com/go/doc/1475/198670/.

[213] Raphael, C. (2009). "LADWP, Blooming Late, Reports Big Gains with Efficiency," *California Energy Markets*, p. 12.

[214] Grueneich, D. (2008). "California Initiatives To Be Considered in DOE's 2009 Congestion Study." Presented at the U.S. Department of Energy Workshop on 2009 Congestion Study. San Francisco, California. See Materials Submitted at this Meeting, at http://www.congestion09.anl.gov/pubschedule/index.cfm, p. 3.

by the 10-year, $3 billion California Solar Initiative with a rebate program for large renewables and the New Solar Home Partnership Program subsidizing new PV installations. In 2007 California had a total of 89 MW of grid-connected solar generation. At the end of 2007, LADWP alone had a total of 12.5 MW installed on the customer side of the meter in more than 1,400 solar installations. Statewide, California's Solar Initiative has approved over 10,000 applications representing 250 MW of new PV capacity, much of which is now awaiting installation.[215]

California has also established standardized interconnection terms and feed-in tariffs to facilitate the development of non-solar distributed generation, including a Self Generation Incentive Program addressing wind and fuel cells up to 3 MW in size, a Small Renewable Generation Feed-in Tariff enabling distributed generation systems to sell to investor-owned utilities, and a similar program for combined heat and power facilities.[216]

5.4.2. Changes in Generation and Transmission

The Department's concerns about the challenges and uncertainties facing Southern California are summarized by the California ISO's market monitor:

> While seven consecutive years of stable and competitive market performance is encouraging, the industry must remain vigilant in addressing its ever-growing infrastructure needs, particularly for Southern California. Though approximately 7,500 MW of new generation has been added to Southern California since the energy crisis [of 2001], which enabled the retirement of 4,300 MW of older inefficient generation, net generation additions for that region have only just kept pace with load growth. Consequently, reliability needs for that region continue to be met, in part, by older, less efficient generation, which cannot be sustained indefinitely. Moreover, major state environmental policies, such as greenhouse gas reductions, Renewable Portfolio Standards (RPS), and a potential ban on once-through cooling systems, will call for even more aggressive and coordinated action on addressing infrastructure issues.[217]

The greenhouse gas (GHG) reduction policies mandate reductions in allowable carbon and other GHG emissions from power generation, and proposed cap-and-trade rules will increase the cost of new fossil generation options. The RPS requires that up to 33% of California's electricity consumption be generated from renewable sources by 2020, which will reduce Southern California's in-area generation options and increase transmission infrastructure and real-time grid operational challenges. The once-through cooling rules, driven by the federal Clean Water Act, require that power plant cooling water systems use the best available technology to minimize adverse environmental impact; this could mean that California's 21 aged power plants using once-through cooling would have to undergo costly modifications, be shut down, or be replaced. At present the final rules are not known and it is not possible to know what potential plant retirements may lie ahead. [218] The air quality rules established for Southern California require new power plants to acquire emission reduction credits through the offset market; these offsets are "almost non-existent and, even if available, expensive to buy."[219]

[215] Grueneich, Commissioner Dian M. (2008). "California Initiatives To Be Considered in DOE's 2009 Congestion Study," p. 13.
[216] *Ibid.*, p. 14.
[217] CAISO (2009c). *Market Issues & Performance: 2008 Annual Report*, at http://www.caiso.com/2390/239087966e450.pdf, p. 19.
[218] Although a recent Supreme Court opinion (Entergy Corp. v. Riverkeeper, Inc., et al., No. 07-588, decided April 1, 2009) gives the Environmental Protection Agency permission to use a cost-benefit analysis and balance benefits against costs in developing plans to implement the once-through cooling provisions (which may change federal once-through cooling requirements going forward), this ruling may have no impact on how California's environmental regulators treat once-through cooling generators. California's Senate Bill 42 was amended in March and April 2009 to require the State Water Resources Control Board to adopt and implement a schedule to phase out existing once-through cooling facilities, and prohibit a state agency from approving any new power plant that uses once-through cooling. See U.S. Supreme Court (2009). "Entergy Corp. v. Riverkeeper, Inc., et al." No. 07-588, at http://www.supremecourtus.gov/opinions/08pdf/07-588.pdf; California Coastal Commission (2009). "Legislative Report for April 2009," at http://documents.coastal.ca.gov/reports/2009/4/W25-4-2009.pdf; and "Legislative Report for May 2009," at http://documents.coastal.ca.gov/reports/2009/5/W28-5-2009.pdf.
[219] CAISO (2009b). *2009 California ISO Transmission Plan*, p. 41.

The net result is that it is difficult and expensive to build new generation in Southern California, some existing generation may have to be retired, and new renewables may be hard to site close to load centers, thus increasing dependence on transmission imports and likely increasing transmission congestion within Southern California. Calculations by the CAISO's Market Monitor confirm the point, with Table 5-4's conclusions discussed in the quotation below:

> [Table 5-4] . . . shows an annual accounting of generation additions and retirements since 2001, with projected 2009 changes included along with totals across the nine year period (2001-2009). Including estimates for 2009, the total net increase in installed generation in the CAISO Control Area over the nine years spanning 2001-2009 is projected to be approximately 12,600 MW. When accounting for an estimated 2 percent load growth over the same seven year period of approximately 8,600 MW, the net supply margin increased by roughly 4,000 MW since the energy crisis. Interestingly, [the table] indicates that generation additions in Southern California (SP15) are projected to just keep pace with load growth and unit retirements, resulting in a minor net increase of approximately 30 MW, but in Northern California (NP26) there was approximately a 4,000 MW increase in new generation after accounting for load growth and generation retirement.[220]

New Generation

In the San Diego area:

- Palomar Energy is a 541 MW combined cycle plant owned by SDG&E that began operation in 2006 and was modified in 2008 to enable a rating of 558 MW during high temperature periods.
- The Otay Mesa combined cycle plant (561 MW) is completing construction and is expected to come on line in 2009.
- A 99 MW gas-fired peaker plant at Orange Grove is scheduled to be in operation in August 2009, and a 49 MW plant at the Margarita substation is under construction. The 49 MW Pala peaker plant was cancelled.

Table 5-4. CAISO Generation Additions and Retirements

	2001	2002	2003	2004	2005	2006	2007	2008	Projected 2009	Total Through 2009
SP15										
New Generation	639	478	2,247	745	2,376	434	485	45	1,650	9,099
Retirements	0	(1,162)	(1,172)	(176)	(450)	(1,320)	0	0	0	(4,280)
Forecasted Load Growth[a]	491	500	510	521	531	542	553	564	575	4,787
Net Change	**148**	**(1,184)**	**565**	**48**	**1,395**	**(1,428)**	**(68)**	**(519)**	**1,075**	**32**
NP26										
New Generation	1,328	2,400	2,583	3	919	199	112	0	1,491	9,035
Retirements	(28)	(8)	(980)	(4)	0	(215)	0	0	(26)	(1,261)
Forecasted Load Growth[a]	389	397	405	413	422	430	439	447	456	3,798
Net Change	**911**	**1,995**	**1,198**	**(414)**	**497**	**(446)**	**(326)**	**(447)**	**1,009**	**3,976**
ISO System										
New Generation	1,967	2,878	4,830	748	3,295	633	598	45	3,141	18,135
Retirements	(28)	(1,170)	(2,152)	(180)	(450)	(1,535)	0	0	(26)	(5,541)
Forecasted Load Growth[a]	880	897	915	934	953	972	991	1,011	1,031	8,585
Net Change	**1,059**	**811**	**1,763**	**(366)**	**1,892**	**(1,874)**	**(394)**	**(966)**	**2,084**	**4,008**

[a]Assumes 2% peak load growth.
Source: CAISO (2009c). *Market Issues & Performance: 2008 Annual Report*, at http://www.caiso.com/2390/239087966e450.pdf, Table E.2, p. 6.

[220]CAISO (2009c). *Market Issues & Performance: 2008 Annual Report*, p. 5.

- New renewable generation sources include the 50 MW Kumeyaay Wind Farm that began commercial operation in late 2005, the 40 MW Lake Hodges pumped storage plant now under construction, and the 27 MW Bull Moose biomass plant that was scheduled to be in-service in April 2009.
- After both Otay Mesa and the Sunrise Powerlink line are in operation, the 689 MW South Bay power plant will be retired.[221]

In the SCE area, the 45 MW Dillon wind plant began operation in 2008.

Table 5-5 shows the new generation south of Path 26 that the CAISO expects to become operational in 2009. The CAISO comments, "Only 45 MW of new generation began commercial operation within the CAISO control area in 2008 . . . . This figure is significantly below the 1,800 MW that was projected for 2008 . . . . New generation projects are complicated and costly, and consequently are subject to significant delays. Most of the projects projected to become commercial in 2008 were delayed . . . ."[222]

The CAISO anticipates no power plant retirements in Southern California in 2009.

Looking ahead, there is reason to question how much new generation will be built in California in the near term. The CAISO's market monitor calculates each year how much in revenues a new generation facility could have earned in California's spot market; the market monitor reports that in 2008, for the sixth year, estimated spot market revenues fell short of a new combined cycle unit's annual fixed costs—in other words, without a long-term power purchase contract and/or public subsidies assuring above-spot market revenues, a new generator would lose money.[223] Added to the public and regulatory challenges of building new power infrastructure in California, this result helps to explain why there is not more fossil-fired generation being built in Southern California.

New Transmission

SCE's Devers-Palo Verde transmission line expansion (once expected to be on line in 2009) was delayed due to a siting denial in 2007 by the Arizona

Table 5-5. New Generation Expected On Line in Southern California in 2009

Generating Unit	Resource Capacity (MW)	Expected Operational Date
Inland Empire Energy Center Unit 1	405.0	01-Oct-09
Inland Empire Energy Center Unit 2	405.0	01-Oct-09
Fontana RT Solar*	2.0	01-May-09
Garnet Energy Center*	3.0	15-May-09
Garnet Energy Center Expansion*	3.5	01-Jun-09
Chiquita Canyon Landfill	9.2	
Kittyhawk Renewable Energy Facility	2.2	01-Jun-09
Sierra Solar Generating Station*	5.0	01-Jun-09
Toland Landfill G-T-E Project	1.0	01-Jun-09
Otay Mesa Energy Center	615.0	01-Oct-09
Miramar Energy Facility II	49.0	31-Jul-09
Orange Grove	99.0	01-Nov-09
Coram Brodie Wind Project*	51.0	01-Dec-09
SP26 Planned New Generation in 2009	**1,650.0**	

*Renewable generation.
Source: CAISO (2009c). *Market Issues & Performance: 2008 Annual Report*, Table 1.3, p. 1.3.

[221] CAISO (2009b). *2009 California ISO Transmission Plan*, p. 184.
[222] CAISO (2009c). *Market Issues & Performance: 2008 Annual Report*, p. 5.
[223] *Ibid.*, p. 3.

Corporation Commission (ACC). In May 2009, SCE announced that it would not refile a request for line approval with the Arizona Commission to build the eastern portion of the line, because "the economic benefits to California customers to build the Arizona portion of the project are now reduced significantly."[224] SCE's updated analysis "shows significant economic, resource and load changes" since 2006 that reduce the need and value of the line and its associated southwest generation.[225] These changes include the development of in-state renewable generation that will reduce the need for imports, increased generation along the path of the line, lower fuel prices and power price differentials between California and Arizona, and reduced load growth in California. SCE indicates, however, that it intends to pursue expansion of the California portion of the line to facilitate additional renewable energy development in Southern California.

SDG&E's Sunrise Powerlink project, a 500 kV line from the Imperial Valley to San Diego, will be the largest upgrade to SDG&E's system in over 20 years. The line received its Certificate of Public Convenience and Necessity from the CPUC in December 2008 and is scheduled to come on line in summer 2012. The line is expected to "increase SDG&E's import capability and provide access to needed generation resources to meet load growth."[226]

CAISO began conducting formal transmission studies and approving major transmission projects in 2007. A review of past years of transmission projects approved in previous study cycles indicates that SCE and SDG&E submitted and received few project approvals in those cycles, accounting for only 10 of the 86 projects approved. Most of those Southern California projects—capacitor banks, voltage support, reconductoring, transformers and switchyard improvements—are scheduled to come on line in 2009 through 2011.[227] The 2010 CAISO Transmission Plan indicates that of the 141 new transmission projects being studied in the ISO Reliability Assessment, only 30 of those projects are in Southern California.[228]

SCE is now building the first of three phases of transmission projects to bring 4,500 MW of wind generation from the Tehachapi region into the Los Angeles Basin. The CPUC approved the first phase (three transmission lines) in March 2007, with an expected in-service date of 2010; a decision on approval for the second phase is expected in 2009.

A significant proportion of the electricity consumed in Southern California is generated in Arizona and Nevada and delivered across an extensive high voltage transmission network, as shown in Figure 5-8 below. There are a number of transmission upgrades planned or under construction that will increase throughput and reduce congestion along these paths.

Figure 5-9, a map from the CAISO, shows the principal points of transmission congestion within the state and the costs of that congestion in 2007 and 2008. The bottom half of the map, below Path 26, includes the bulk of the Southern California Critical Congestion Area. Although the individual path and total costs of congestion are relatively low for these two years relative to the total value of the electricity flows, the figure displays the key transmission constraints within the state and region.

CAISO reports that sources of intra-zonal congestion within Southern California included these points shown in Figure 5-10:

- The Southwest Powerlink corridor, which includes the Imperial Valley and Miguel transmission stations. Miguel is the choke point for transmission from Mexico and Arizona to load in Southern California.

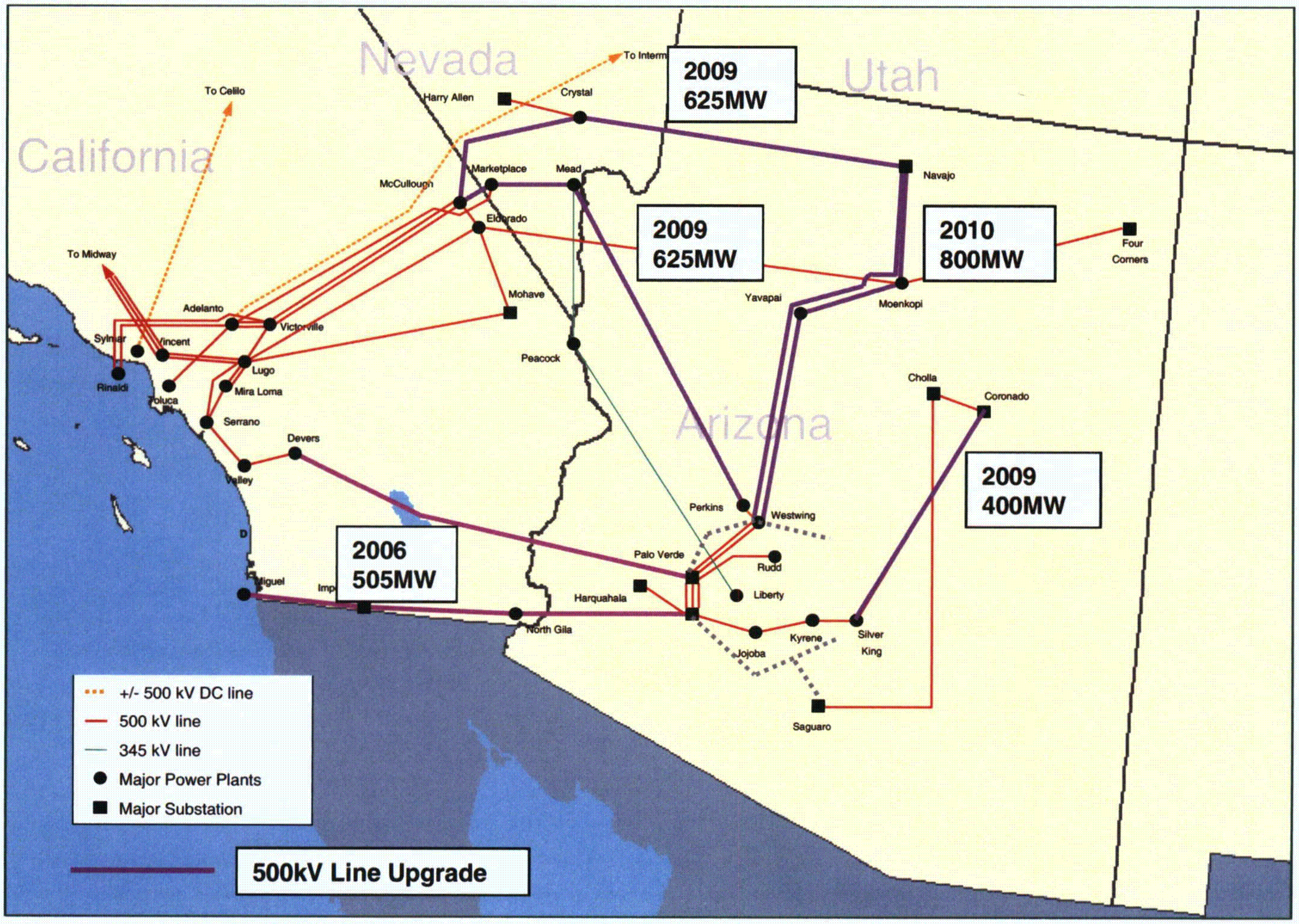
[224] Southern California Edison (2009). "Devers-Palo Verde No. 2 Project Update," at http://www.sce.com/NR/rdonlyres/0A5F8FEB-5357-4C11-BD93-07387DE4B2C1/0/090515_DPV2ProjectUpdate_May2009.pdf.
[225] *Ibid.*
[226] *Ibid.*, p. 179.
[227] *Ibid.*, pp. 32-33.
[228] CAISO (2009a). *2010 ISO Transmission Plan, Final Study Plan*, at http://www.caiso.com/2374/2374ed1b83d0.pdf, Table 2-3, pp. 14-18. Note that the CAISO analyzes SCE and SDG&E project proposals but does not formally report on transmission projects undertaken by LADWP and other municipal power companies in Southern California.

- The area near the San Onofre Nuclear Generation Station while one of the generation units was shut down for a transmission upgrade.
- The Lugo area, a transmission choke point between generation in Nevada (around Las Vegas and Hoover Dam) and load centers in Southern California.
- There is also a reliability constraint on the Victorville-Lugo Nomogram that is affected by flows between the CAISO areas and LADWP (although CAISO notes that this is technically not congestion).

In a recent assessment of the electric infrastructure challenges the state faces, the California State Auditor concluded:

> Since the [2001] energy crisis, California has adopted targets to increase the use of renewable sources of electricity. However, the State is at risk of failing to meet these targets because various obstacles are preventing the construction of the infrastructure needed to generate and transmit electricity from such renewable sources as wind and solar.[229]

Figure 5-8. Transmission Linking Arizona and Nevada to Southern California and Planned Upgrades



Source: Kondziolka, R. (2009). "Western Interconnection Subregional Planning and Development." Presented at the U.S. DOE Office of Electricity Delivery and Energy Reliability Spring 2009 Technical Workshop in Support of DOE 2009 Congestion Study, at http://congestion09.anl.gov/techws/index.cfm, slide 12. Although this map shows the planned Palo Verde-Devers 2 transmission line stretching all the way to the Palo Verde power plant, SCE has withdrawn its permit application for the Arizona portion of the line.

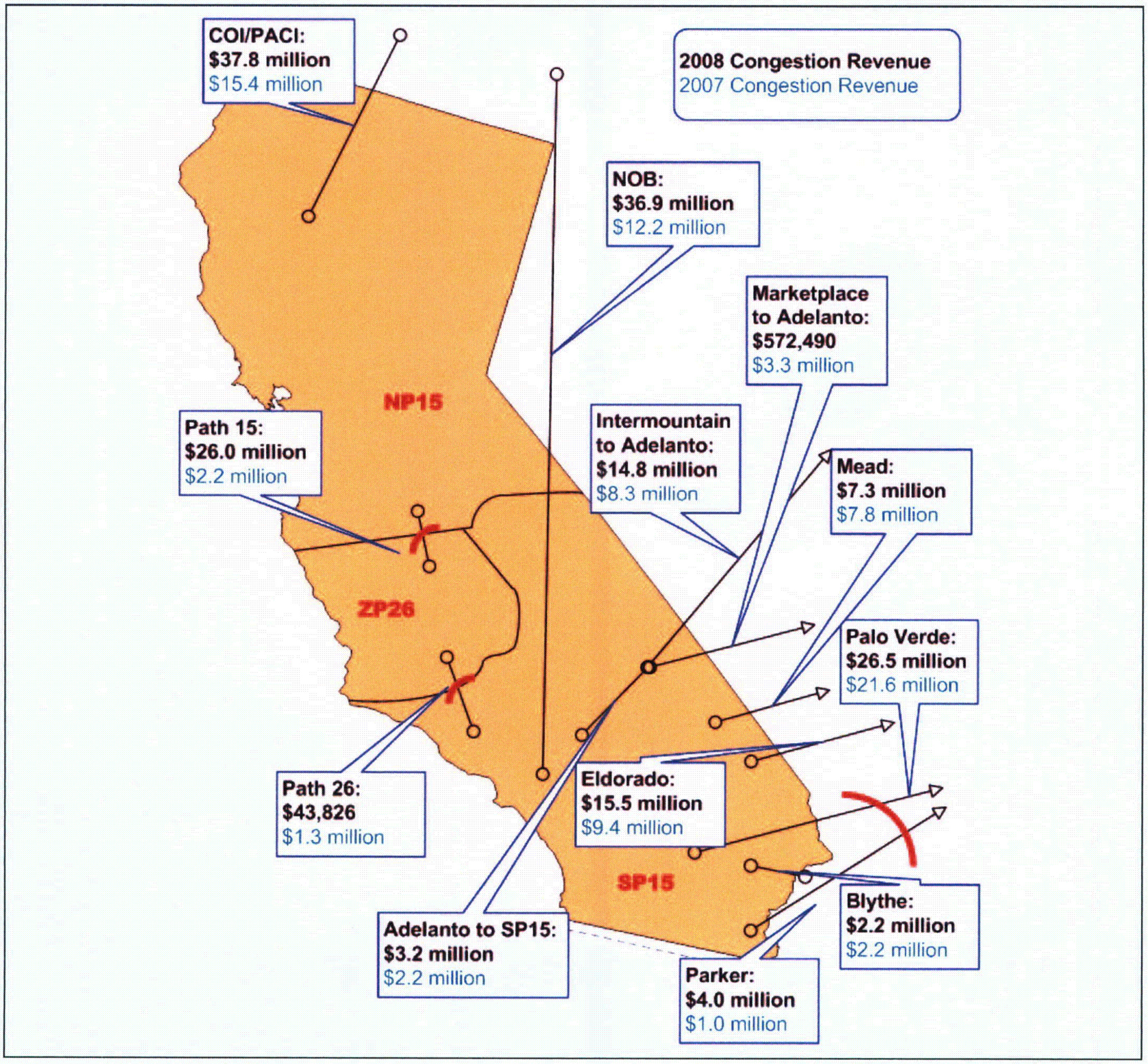
[229] California State Auditor (2009). *High Risk: The California State Auditor's Updated Assessment of High-Risk Issues the State and Select State Agencies Face*, at http://www.bsa.ca.gov.

5.4.3. Conclusions for Southern California

This review leads the Department to reach several conclusions about past and future transmission congestion in Southern California:

- Although the state of California has made major progress in moderating electric load growth and increasing distributed generation and in-region generation, the Southern California region remains challenged.
- New transmission and generation projects in Southern California have barely kept pace with load over the past few years. Although many promising generation and transmission projects are now in the planning or regulatory approval stages, experience shows that few such projects come in on schedule in California.

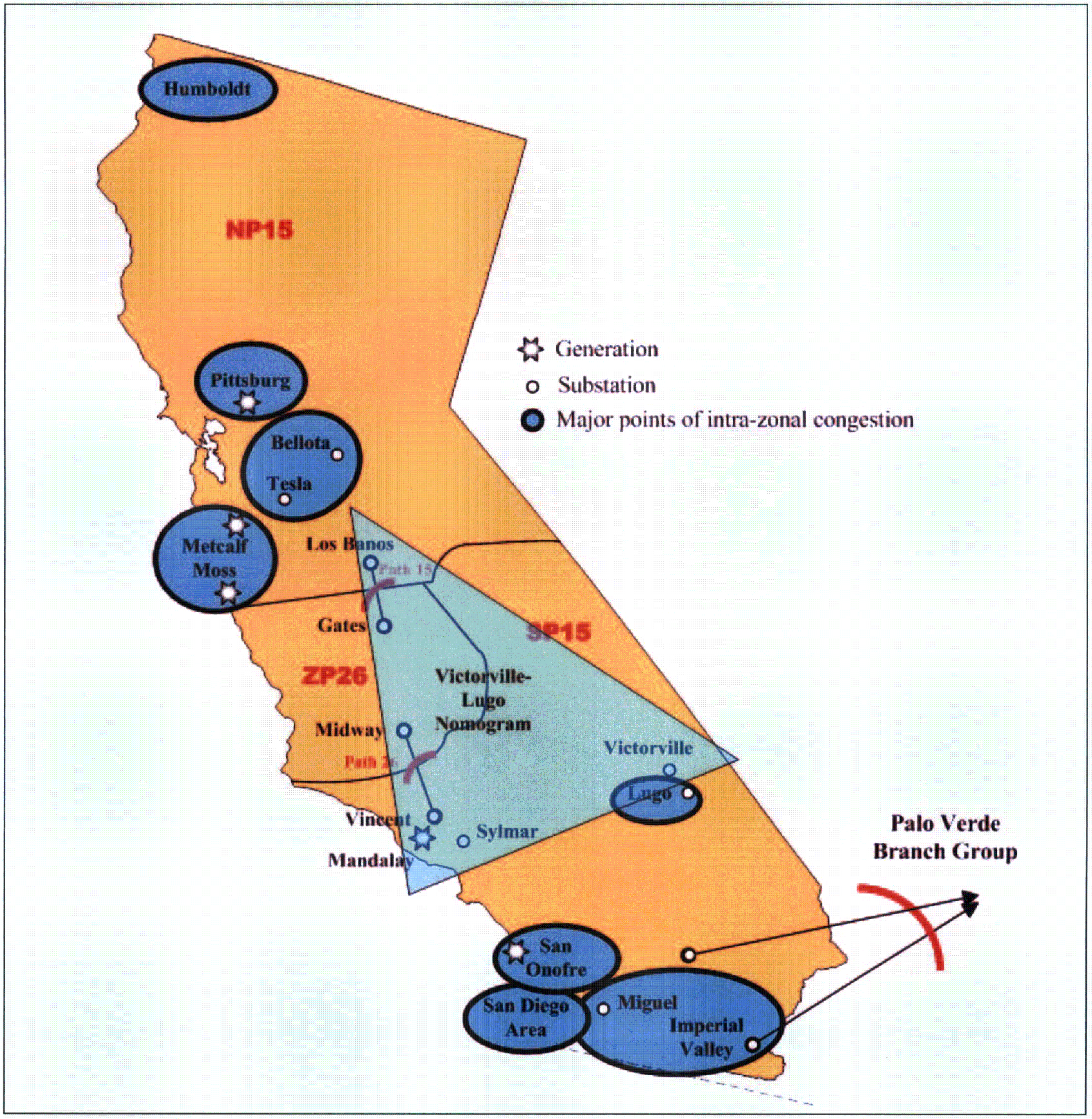
Figure 5-9. Major Congested Interties and Congestion Costs in California



Source: CAISO (2009c). *Market Issues & Performance: 2008 Annual Report*, at http://www.caiso.com/2390/239087966e450.pdf, Figure E-12, p. 18.

- Slow development of new generation and transmission facilities could compromise near-term grid reliability in Southern California, despite growing demand response and smart grid capabilities.
- The state has ambitious plans to increase renewable energy use, but that will require additional transmission development.

Figure 5-10. Key Points of Intra-Zonal Congestion in California



Source: CAISO (2009c). *Market Issues & Performance: 2008 Annual Report*, at http://www.caiso.com/2390/239087966e450.pdf, Figure 6.1, p. 6.4.

- Although the economic costs of transmission congestion in Southern California are relatively low compared to the value of electricity deliveries, there are significant unresolved threats to the reliability of the area's electricity infrastructure.

For these reasons, the Department concludes that Southern California remains a congested area, and that it should continue to be identified as a Critical Congestion Area.

5.5. San Francisco Peninsula Congestion Area of Concern

The *2006 National Transmission Congestion Study* identified the San Francisco Bay Area as an Area of Concern because of the reliability challenge posed by serving the area between San Jose and San Francisco with a single set of lines across the San Francisco Peninsula. In addition, the area had high local generation costs due to local high-cost reliability must-run requirements, and little in-area generation. The San Francisco City and Peninsula—then and now—depend upon import capabilities and generation in the East Bay and South Bay areas and the levels of demand and generation dispatch in those areas.[230] The greater Bay Area is shown in Figure 5-11; this report's area of principal concern (as in 2006) is the San Francisco Peninsula, which includes the City of San Francisco.

5.5.1. Changes in Load and Demand-side Resources

It is difficult to estimate the actual load for the San Francisco Peninsula from public information. A CAISO local capacity analysis estimated that for 2008, the Greater Bay Area (which extends beyond the City of San Francisco and the San Francisco Peninsula proper) had a peak load of 9,870 MW (1 in 10 probability) and local capacity requirements of 4,688 MW, but 6,214 MW of total dependable local area generation.[231] A companion analysis for 2009 showed consistent results for 2013, with a load increase of 1.5%, 6,992 MW of qualifying capacity available compared to 5,344 MW of local capacity needed.[232] These estimates suggest that it is reasonable to expect continued load growth on the Peninsula.

Electric load has continued to grow in Northern California. The CEC projected that peak demand for the control area north of Path 15 would grow from 22,168 MW in 2006 to weather-normalized 21,671 MW in 2008 and 23,158 MW by 2013—a short-term drop followed by a 1.3% annual increase.[233] The CAISO's 2009 reliability assessment used a summer load forecast that showed San Francisco City and Peninsula loads growing from 2,006 MW in 2008 to 2,111 MW in 2013, a 5% increase.[234]

Both the state of California and the largest serving utility in the Bay Area, Pacific Gas & Electric (PG&E), have run aggressive demand-side management programs in the area for many years. PG&E estimates that its efficiency programs saved 375 GWh in 2004, growing to 800 GWh in 2007, and peak demand savings of 80 MW in 2004 growing to 135 MW in 2007.[235] It is reasonable to assume that at least a portion of these savings came from San Francisco (although California's largest energy savings come from portions of the state with hot weather, high rates of new construction, and high potential air conditioning savings, all of which are less achievable in the Peninsula and City).

Since 2005, California has been offering more demand response programs to more customers; PG&E has been aggressively rolling out advanced meters to its customers since 2007 to facilitate time-of-use rate offerings. For August 2007, PG&E reported

[230] CAISO (2009b). *2009 California ISO Transmission Plan*, p. 113.

[231] CAISO (2008b). *2009 Local Capacity Technical Analysis: Final Report and Study*, at http://www.caiso.com/1fba/1fbace9b2d170.pdf, Table 6, p. 22.

[232] *Ibid.*, Table 4, p. 22.

[233] California Energy Commission (CEC) (2007a). *California Energy Demand 2008-2018: Staff Revised Forecast*, at http://www.energy.ca.gov/2007publications/CEC-200-2007-015/CEC-200-2007-015-SF2.PDF, p. 17.

[234] CAISO (2009b). *2009 California ISO Transmission Plan*, derived from Table 4-37, p. 115.

[235] California Energy Commission (CEC) (2007). *2007 Integrated Energy Policy Report*, at http://www.energy.ca.gov/2007publications/CEC-100-2007-008/CEC-100-2007-008-CMF.PDF, Figures 3-8 and 3-9.

that there were 623 MW enrolled in its price-responsive demand response programs, and 323 MW enrolled in reliability-based demand response.[236] The California PUC has ordered PG&E to put dynamic pricing electric rates in place by May 2010 for large commercial and industrial customers, with optional Critical Peak Pricing rates for medium and small commercial and industrial customers and residential customers, but implementation of those rates could be delayed.[237]

Figure 5-11. Electric System of the Greater San Francisco Bay Area

Source: California Energy Commission (CEC), Cartography Office (2008). "Electric System of the Greater San Francisco Bay Area."

[236]CAISO (2009c). *Market Issues & Performance: 2008 Annual Report*, Table 2.4, p. 2.5.

[237]Corrigan, H. (2009). "Utility Dynamic Pricing Case Starts With Questions on Costs, Timing." *California Energy Markets*.

5.5.2. Changes in Generation and Transmission

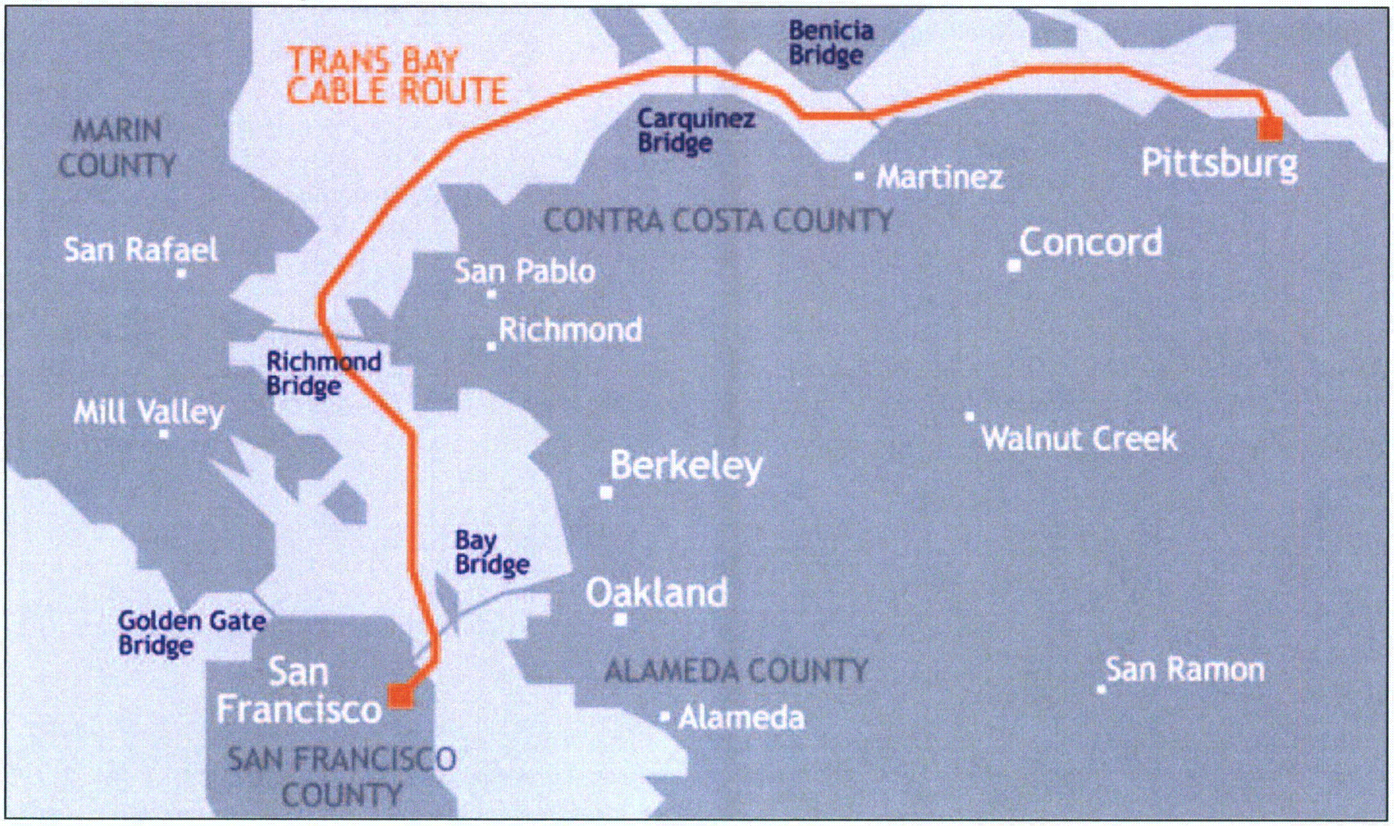
Little new generation has come on-line in the San Francisco area since 2005. The 10.7 MW landfill gas-fired Ox Mountain power plant came on-line on the west side of the Peninsula in December 2008; Unit 3 of Mirant's Potrero 362 MW power plant is scheduled for retirement when the TransBay Cable becomes operational. Small amounts of distributed photovoltaic generation have been installed along the Peninsula, but they are not enough to have a material impact upon local reliability.

The CAISO's 2009 reliability assessment found that the Greater Bay Area system has "adequate internal generation resources and import capability to serve its future load reliably under normal operating conditions," but "many transmission lines and transformers were found overloaded under Category B and Category C contingency conditions."[238] However, that analysis relied on power plants on the Peninsula and in the City that may not be on line during the time frame modeled.

PG&E has completed transformer upgrades at the Martin Substation and a 115 kV cable upgrade from Martin into the City. The utility has plans for various cable reconductoring, upgrades and switch upgrades scheduled for 2010-2012 that would expand Peninsula and City transmission capacity and reliability.[239]

The TransBay Cable Project will make a significant difference to the reliability and cost of electricity in San Francisco. The project is a 59-mile underwater HVDC merchant transmission line (shown in Figure 5-12) that will carry power from PG&E's Pittsburg substation to a converter station in San Francisco. Project construction began in 2007, cable-laying under the San Francisco Bay will begin in fall 2009, and the project is expected to be

Figure 5-12. TransBay Cable Route



Source: Trans Bay Cable. "The TBC Project," at http://www.transbaycable.com/.

[238] CAISO (2009b). *2009 California ISO Transmission Plan*, p. 111.

[239] California (CAISO) (2008c). *2008 California ISO Transmission Plan—A Long-Term Assessment of the California ISO's Controlled Grid (2008-2017)*, at http://www.caiso.com/1f52/1f52d6d93a3e0.pdf; and CAISO (2009b), *2009 California ISO Transmission Plan*, pp. 43, 130, 153.

energized and begin commercial operations in 2010. Once the cable is operational, it will bring an additional 400 MW of electricity into the city through an alternate route that does not pass through San Jose or the Peninsula, reducing San Francisco's reliance on in-city fossil generation.[240]

The CAISO is currently studying the generation and transmission system serving the Greater Bay Area for the period after completion of the TransBay Cable. This analysis, slated for release in the fall of 2009, is examining demand-side opportunities, generation, including retirement and/or continued operation of plants located within the City, as well as additional transmission projects.[241]

5.5.3. Conclusion for San Francisco Peninsula

As noted in the discussion above of Southern California, energy development within California remains a complex and challenging process. Supply expansion and demand modification projects alike can experience delays due to cost, regulatory, environmental and litigation causes. A combination of supply and demand relief are likely to be needed to reduce congestion and maintain reliability on the San Francisco Peninsula, but only a few of the needed measures are making substantive progress over the near term. Until there is a clearer picture of how and when all the needed supply and demand-side elements will materialize and improve conditions on the San Francisco Peninsula, the Department will continue to identify the San Francisco Peninsula as a Congestion Area of Concern.

5.6. Seattle-Portland Congestion Area of Concern

The 2006 Congestion Study identified the area from south of Seattle to Portland as a congested area with both reliability and economic implications. This problem reflected both high loading in winter and summer and increasing wind generation to the east, combined with significantly increased generation in the area between the two cities.

5.6.1. Changes in Load

Load in the entire Pacific Northwest region increased by 3.9% from 2006 to 2008, at an average annual growth rate of 1.9%. In Puget Sound Energy's service territory, peak load increased 1.2% from 4,847 MW in 2006 to 4,906 MW in 2008. Portland General Electric's peak load increased by 0.5% per year, from 3,706 MW in 2006 to 3,743 in 2008.[242] Overall, the Northwest Power and Conservation Council (NPCC) forecasts continuing growth in residential and commercial sector demand, with 1.7% annual average winter demand growth in Oregon and Washington between 2010 and 2020.[243] At the same time, summer demand, driven by air conditioning loads in new construction, is growing more than 2% per year and may overtake winter peak demand in the not too distant future.

Washington and Oregon are recognized for the high quality of their energy efficiency programs. The ACEEE ranked Oregon second and Washington sixth among the 50 states in the "2008 State Energy Efficiency Scorecard,"[244] and cites those

[240] Trans Bay Cable. "The TBC Project," at http://www.transbaycable.com/.

[241] CAISO (2009a). *2010 ISO Transmission Plan, Final Study Plan.*

[242] Portland General Electric (2008). *Form 8-K (Current Report Filing): Filed 09/17/08 for the Period Ending 09/16/08.*, at http://investors.portlandgeneral.com/secfiling.cfm?filingID=1193125-08-196887, slide 7; Portland General Electric (2007). *Form 8-K (Current Report Filing): Filed 5/31/2007 for Period Ending 5/25/2007*, at http://investors.portlandgeneral.com/secfiling.cfm?filingID=784977-07-54, slide 7; Open Access Technology International, Inc. (OATI) (2008). "PSEI Portion of the wesTTrans OASIS." *Peak Load Data December 2008*, at http://www.oatioasis.com/psei/; and Puget Sound Energy (2008). "2007 Form 10-K Annual Report - Part 1," at http://www.secinfo.com/d113uv.t9.htm#2c3q.

[243] Northwest Power & Conservation Council (NPCC) (2009a). "Appendix C: Preliminary Draft Demand Forecast." *Northwest Sixth Power Plan*. Council Document 2009-04, at http://www.nwcouncil.org/library/2009/2009-04.pdf.

[244] Eldridge, M., et al. (2008) *The 2008 State Energy Efficiency Scorecard*, ACEEE Report Number E086, at http://www.aceee.org/pubs/e086_es.pdf, p. 4.

states' efficiency performance and programs as exemplary for the high level of funding and utility incentives.[245] The Pacific Northwest continued to deliver sustained energy efficiency savings, reducing electricity use by 200 MW in 2007 (about half the typical annual electricity demand growth for the region). The NPPC reports that the region has cumulatively reduced peak load by 3,700 MW since 1978.[246] Despite these programs, electricity demand continues to grow.

The impact of these efficiency programs on congestion in the Seattle-Portland corridor is complex and sometimes counter-intuitive. For example, under some conditions, reducing demand in the Seattle area frees up generation that could flow south as far as California—if not obstructed by the transmission constraints between Seattle and Portland—thus increasing the congestion in the area.

5.6.2. Changes in Generation, Transmission and Operations

Nearly 1000 MW of gas-fired, combined cycle generation has been added between Seattle and Portland over the past few years, complicating congestion management in the area.[247] Additional new generation has been developed in Oregon and Washington over the past three years, chiefly new wind assets.

No major transmission assets (greater than 230 kV) were placed in service in the Seattle-Portland region between 2005 and 2008, although a number of significant projects were completed in the broader Pacific Northwest region in the years just prior to 2005.

The Bonneville Power Administration (BPA) has developed several operational and institutional measures that reduce transmission congestion to some degree:

- BPA is using a new redispatch plan to relieve congestion at specific flowgates by using voluntary changes in generation in lieu of curtailments. This pilot program began in 2008 and is now underway at 10 congested flowgates with a wider community of participating generators.[248]
- Improved wind monitoring and production forecasting methods are helping BPA improve its wind generation forecasts.[249]
- Western utilities are working to develop sub-hourly power supply and transmission schedules, to deal with in-hour variations in load and generation.
- In May 2009, BPA began offering conditional-firm transmission service, which allows customers to obtain long-term access to BPA wires with the risk of curtailments during occasional network reliability events. This is consistent with FERC Order 890, which required transmission owners to offer conditional firm service to improve transmission access for intermittent generators. Conditional firm service will increase grid utilization by a new group and class of generators, but by design, it should not increase congestion—it is to use available capacity in periods when there is no congestion.[250]

The Pacific Northwest utilities, working together through the ColumbiaGrid and Northern Tier Transmission Group planning processes, have proposed a number of major transmission projects that could have significant or possible benefit on transmission congestion and reliability in the Seattle to Portland area; these projects include the I-5 Corridor Reinforcement, the Canada-Pacific Northwest

[245] Kushler, M., D. York and P. White (2009). *Meeting Aggressive New State Goals for Utility Sector Energy Efficiency: Examining Key Factors Associated with High Savings*. ACEEE Report Number U091, at http://www.aceee.org/pubs/U091.pdf, p. 111.

[246] NPCC (2008). "Northwest energy conservation hit all-time high in 2007." NPCC press release, at http://www.nwcouncil.org/library/releases/2008/0514.htm.

[247] NPCC (2009b). "Generating Project Development Activity," at http://www.nwcouncil.org/energy/powersupply/Default.htm.

[248] Bonneville Power Administration (2008a). "2008-2009 Reliability Redispatch Pilot and Curtailment Calculator Prototype, July 2008 through September 2009." "Congestion Management Update," at http://www.transmission.bpa.gov/customer_forums/Congestion_Management/docs/July10_RRP_CCP_Update.pdf.

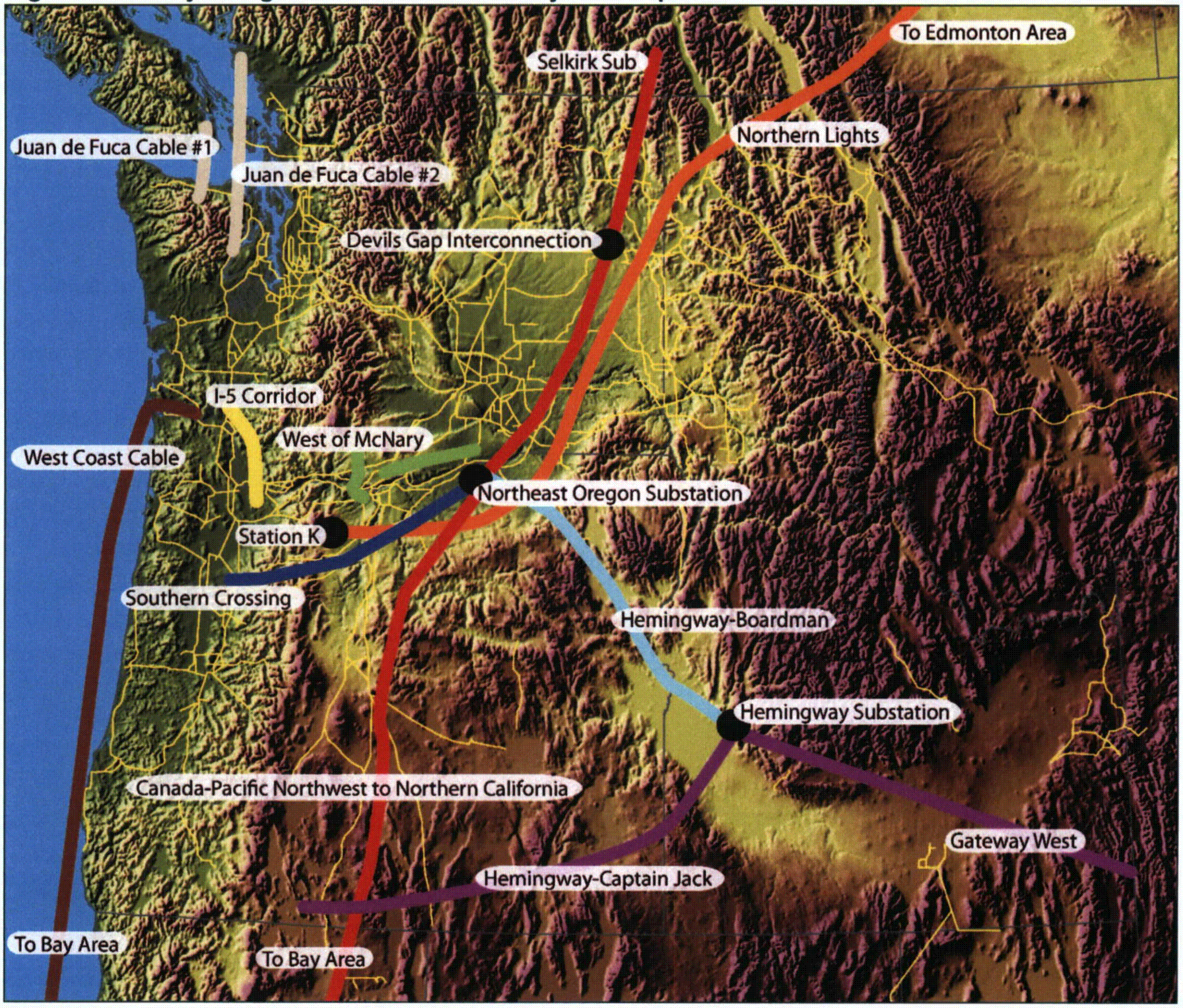
[249] BPA (2009a). "How BPA supports wind power in the Pacific Northwest," at http://www.bpa.gov/corporate/pubs/fact_sheets/09fs/BPA_supports_wind_power_for_the_Pacific_Northwest_-_Mar_2009.pdf.

[250] BPA (2009b). "New BPA transmission product helps customers move power, including wind energy." *BPA News*, at http://www.piersystem.com/go/doc/1582/269425.

to California project, the West Coast Cable, the West of McNary Reinforcement, and the Southern Crossing and Northern Lights projects.[251] These are shown in Figure 5-13 below. Although only the I-5 Corridor Reinforcement project directly increases capacity between the two cities, the other projects would affect the area because they would provide alternate paths (parallel capacity) to move power now flowing on the congested lines.

The transmission project that will have the most immediate impact on this area is the proposed I-5 Corridor Reinforcement Project, which would construct a new 500-kV substation about 100 miles south of Seattle and a new 500 kV yard at a substation near Portland, and build a new 500 kV, 70-mile transmission line between them to increase path capacity by about 1,300 MW. This project would relieve congestion along the existing transmission path and enable BPA to serve point-to-point

Figure 5-13. Major Regional Transmission Projects Proposed in the Pacific Northwest



Source: ColumbiaGrid (2009a). *2009 Biennial Transmission Expansion Plan*, at http://www.columbiagrid.org/biennial-transmission-overview.cfm, Figure 5-a, p. 19.

[251] ColumbiaGrid (2009a). *2009 Biennial Transmission Expansion Plan*, at http://www.columbiagrid.org/biennial-transmission-overview.cfm, p. 21.

transmission requests along this path (including requests from gas-fired generators). It would enable firm transmission service to 1,500 MW of new generation being planned along the Corridor, help Portland General Electric maintain reliable service with improved voltage stability to growing loads, and let BPA avoid potential load curtailments in the Portland area.[252] This is primarily a summer problem, when there are high transfers from Canada and the Northwest to California. However, this project is not expected to come on line before 2014 or 2015.

To the east, there is a growing problem with congestion in the Columbia River Gorge, where there is more wind generation planned in eastern Washington and Oregon than the existing transmission system to the west can accommodate. Over 2,400 MW of wind has already been installed in eastern Oregon and Washington, and another 7,300 MW of wind generation projects are lined up in transmission queues in those states (with another 12,000 MW built or proposed in Idaho, Montana and Wyoming).[253] This generation is either already developed or in transmission queues for interconnection east of the Cascades Mountains and intended to serve loads on the west coast. At least three new transmission projects have been proposed by BPA and Portland General Electric to serve this new wind generation and deliver it to Portland and the western interties (to move south to California); when completed, these lines will relieve the present modest additional loading due to loop flow from wind on the current transmission facilities connecting Portland and Seattle. Over a longer term, however, continued build-out of wind generation in the region is likely to re-introduce loop flow from the generation resources into this area.

5.6.3. Conclusion for Seattle-Portland Area

Completion of all the above projects would probably solve most of the problems that led the Department in 2006 to identify the area between Seattle and Portland as a Congestion Area of Concern. Completion, however, is several years away. Accordingly, the Department will continue to identify the area as a Congestion Area of Concern.

5.7. Phoenix-Tucson Congestion Area of Concern

The 2006 Congestion Study identified the Phoenix-Tucson region as an area of concern because this metropolitan region was seeing explosive population and load growth with significant transmission loading and congestion. Arizona Public Service (APS) and the Arizona Corporation Commission noted that Arizona had additional reliability and congestion problems, notably with respect to the Tucson to Nogales corridor linking south central Arizona to generation in Nogales, and the Southwest's still-limited ability to obtain additional bulk generation from resources in Montana and Wyoming.

The Phoenix metropolitan area is served by APS and the Salt River Project, with additional transmission owned by the Western Area Power Administration. The Tucson area is served by Tucson Electric Power (TEP). A majority of the Phoenix area load is served by imports via transmission. The ACC's 2008 Biennial Transmission Assessment (BTA) for 2008-2017 found that for Phoenix, "the projected local generation reserve margin [1,758 MW] exceeds the required reserve margin (865 MW) for those hours during which RMR [reliability must run] conditions exist."[254] The 2008 BTA found that a RMR condition may continue to exist through 2016, with peak load (3,010 MW) exceeding the reported simultaneous import limits, and maximum load-serving capacity (3,125 MW)

[252] WECC, 2008, "WECC Phase 1 Rating Process Coordinated Planning and Technical Studies," at http://www.oatioasis.com/AVAT/AVATdocs/WECC_Corodinated_PGE_Project.ppt#23; Miller, J. (2008), "Letter to WECC Planning Coordination Committee on I-5 Corridor Reinforcement Project Regional Planning Compliance Report;" and letter from Stephen J. Wright, BPA Administrator and CEO, to Customers, Constituents, tribes and other Stakeholders, February 16, 2009, Attachment C, "Descriptiuon of 2008 Network Open Season Projects Moving Forward with NEPA I-5 Corridor Reinforcement."

[253] ColumbiaGrid (2009a). *2009 Biennial Transmission Expansion Plan*, at http://www.columbiagrid.org/biennial-transmission-overview.cfm, p. 37.

[254] Arizona Corporation Commission (2008c). *Fifth Biennial Transmission Assessment 2008-2017*, Docket No. E-00000D-0376," p. 38.

barely exceeding projected peak load.[255] Overall, however, these findings indicate that the load pocket concerns that led to the Department's identification of Phoenix-Tucson as a Congestion Area of Concern are on the way to being resolved.

5.7.1. Changes in Load and Demand-Side Resources

Population and electric load have continued to grow in Arizona over the past three years, although moderated from their earlier pace by the current economic recession. Arizona's population grew by over 26% between 2000 and 2008, with Phoenix and Scottsdale growing at 14% and Tucson growing at 6.5% over that period.[256] Load in the area is expected to nearly double between 2006 and 2025;[257] before the current recession, the utilities expected peak demand to grow at about 3.5% per year.[258]

As recently as 2008, Arizona's overall energy efficiency efforts were ranked as only middling by efficiency experts, with a report by the ACEEE ranking Arizona 28th among the 50 states for its energy efficiency programs.[259] However, the region's utilities are becoming more aggressive in delivering energy efficiency and demand response. Between 2005 and June 2008, APS reports achieving cumulative annual savings of 531,889 MWh from demand-side management programs.[260] In a recent rate case settlement, APS agreed to establish energy savings goals, along with performance incentives, to use energy efficiency to reduce total energy consumed by 1% by 2010 and 1.5% by 2012.[261] The Environmental Protection Agency has recognized APS as Energy Star Partner of the Year for its successful Energy Star Homes program.[262] The Salt River Project announced in April 2009 that it will increase its energy efficiency and load management budget from $11 million in fiscal year 2008 to $30 million in 2010 and $55 million in 2012, with expected energy savings to reach nearly 1% of annual electricity sales by 2011.[263]

APS awarded a contract in 2008 to acquire and deliver 800,000 advanced meters to its residential, commercial and industrial customers, to help them better manage their electricity usage.[264] APS has hired Comverge to acquire and deliver up to 125 MW of "virtual peaking capacity" (peak demand response) beginning in 2010 for 15 years, primarily from commercial and industrial customers.[265] Similarly, Salt River Project has hired EnerNOC to provide up to 50 MW of demand response capacity from commercial, institutional and industrial customers, under a 3-year contract beginning in 2009.[266]

Arizona's utilities are leaders in solar electric generation. TEP had 6.4 MW of photovoltaic generation on-line by the end of 2007, including a 4.6 MW utility-owned array and 1.2 MW of

[255] *Ibid.*, pp. 37-39.

[256] U.S. Census Bureau (2009). "State and County Quick Facts: Arizona," at http://quickfacts.census.gov/qfd/states/04000.html.

[257] Southeast Arizona Transmission Study (SATS) (2008). *Southeast Arizona Transmission Study Report*, at http://www.westconnect.com/filestorage/SATS%20ReportFinal%20Report_120508.pdf, p. 9.

[258] Southwest Energy Efficiency Project (SWEEP) (2009a). "Arizona Utility Energy Efficiency Programs,"at http://www.swenergy.org/programs/arizona/utility.htm.

[259] Eldridge, M., et al. (2008) *The 2008 State Energy Efficiency Scorecard*, ACEEE Report Number E086, at http://www.aceee.org/pubs/e086_es.pdf, p. 4.

[260] Arizona Public Service Company (APS) (2009a). *Arizona Public Service Company's Comments on Investigation of Regulatory and Rate Incentives for Gas and Electric Utilities*. Docket Nos. E-00000J-08-0314 & G-00000C-08-0314, at http://images.edocket.azcc.gov/docketpdf/0000093901.pdf, p. 2.

[261] Southwest Energy Efficiency Project (SWEEP) (2009d). "Settlement Reached in APS Rate Case, Will Expand Energy Efficiency Programs," at http://www.swenergy.org/news/index.html#2009-05-01.

[262] Arizona Public Service Company (APS) (2009b). "APS Earns National Energy Star Partner of the Year Award for Third Consecutive Year," at http://www.aps.com/main/news/releases/release_516.html.

[263] Southwest Energy Efficiency Project (SWEEP) (2009a). "Arizona Utility Announces Plans for Expanding Energy Efficiency Programs."

[264] Metering International (2008). "Arizona Public Service contracts with Elster for 800,000 smart meters." *Metering.com*, at http://www.metering.com/node/12858.

[265] CleanTech Group (2008). "Comverge in Arizona demand response contract." *CleanTech Group*. September 17, 2008, at http://cleantech.com/news/3454/comverge-arizona-demand-response-contract.

[266] Business Wire (2009b). "EnerNOC Signs 50 MW Contract with Salt River Project." *Business Wire*, at http://www.pr-inside.com/enernoc-signs-50-megawatt-contract-with-r999276.htm.

customer-owned rooftop PV owned by hundreds of TEP customers, with assistance from the SunShare and GreenWatts incentive programs.[267] In 2007, 8.1 MW of photovoltaic cells and modules were shipped to Arizona customers,[268] encouraged by generous state and utility tax exemption, net metering and incentive payment policies.[269] By the end of 2007, Arizona had 18.9 MW of cumulative installed photovoltaic capacity statewide;[270] these numbers are probably increasing, given the state's solar-friendly policies.

The cumulative effect of these and similar energy efficiency, demand response, and distributed generation measures indicate that the utilities, policy-makers and communities of the Phoenix-Tucson area are now working to manage and limit loads through customer-oriented, non-wires solutions.

5.7.2. Changes in Generation and Transmission

For years a primary focus of western transmission planning efforts was to increase transfer capability from Arizona westward into Southern California; recently, with many of those westbound solutions planned or in development, the focus has shifted to solving the growing in-state reliability-related congestion problems.

Arizona utilities and regulators have engaged in the BTA process for a decade. The BTA is a rigorous, well-organized planning process looking out over a 10-year horizon at resource and transmission adequacy for the near- and longer-term. It has been open to stakeholders and members of the public for several years, working closely with regional partners from the transmission and generation communities. Over this period, the ACC has granted permit approval to numerous high-voltage transmission projects, many of which are now beginning or completing construction (Figure 5-14).

Plans for transmission upgrades, expansions and new projects include reinforcements within and between the metropolitan areas, new construction to open up rich in-state wind and solar resource areas, and projects outbound to Southern California to strengthen exports from and through Arizona.

Arizona utilities are also working with neighbors and merchant transmission developers to develop several interstate lines to the northeast and northwest to increase imports from Wyoming and Montana; the latter are shown in Figure 5-15.

Table 5-6 lists the major transmission projects now under development that will affect transmission congestion in and around the Phoenix-Tucson area. This list is notable for the large scale and number of the projects included, and the fact that most have completed the study phase and have advanced to siting and permitting or construction. The chair of the ACC states that over the past 10 years, Arizona has approved 700 miles of high-voltage lines, denying only 3 out of 143 line applications.[271]

It is possible that not every transmission line in this list will proceed through planning to construction to service. Arizona's new Renewable Energy Standard requires 15% of the state's total electricity consumption to come from renewable resources by 2025, with 30% of that amount to be generated from distributed sources such as rooftop solar installations.[272] This change in future generation patterns and effective load could reduce the need for and economics of long-distance transmission imports, as SCE recently discovered with the Devers-Palo Verde 2 project.

[267] Tucson Electric Power (TEP) (2008). "TEP Ranked among Top 10 Solar Electric Utilities in United States." Tucson Electric Power Press release, at http://www.tucsonelectric.com/Company/News/PressReleases/ReleaseTemplate.asp?idRec=295.

[268] Energy Information Administration (EIA) (2007b). "Table 3.10: Shipments of Photovoltaic Cells and Modules by Destination, 2006 and 2007." *Solar Photovoltaic Cell/Module Manufacturing Activities, 2007*, at http://www.eia.doe.gov/cneaf/solar.renewables/page/solarreport/table3_10.pdf.

[269] DSIRE. Arizona Incentives for Renewable Energy, at http://www.dsireusa.org/library/includes/map2.cfm?CurrentPageID=1&State=AZ&RE=1&EE=0.

[270] Sherwood, L. (2008). *U.S. Solar Market Trends 2007*, at http://www.irecusa.org/fileadmin/user_upload/NationalOutreachDocs/SolarTrendsReports/IREC_Solar_Market_Trends_Revision_11_19_08-1.pdf, Appendix C.

[271] Edwards, J. (2009). "Edison Calls Off Pursuit of Devers-Palo Verde No. 2 Line." *California Energy Markets*, p. 15.

[272] *Business Wire* (2009a). "APS Pilot Envisions Interconnected Solar Rooftops." *Business Wire*, at http://www.businesswire.com/portal/site/google/?ndmViewId=news_view&newsId=20090511005274&newsLang=en.

5.7.3. Conclusions for the Phoenix-Tucson Area

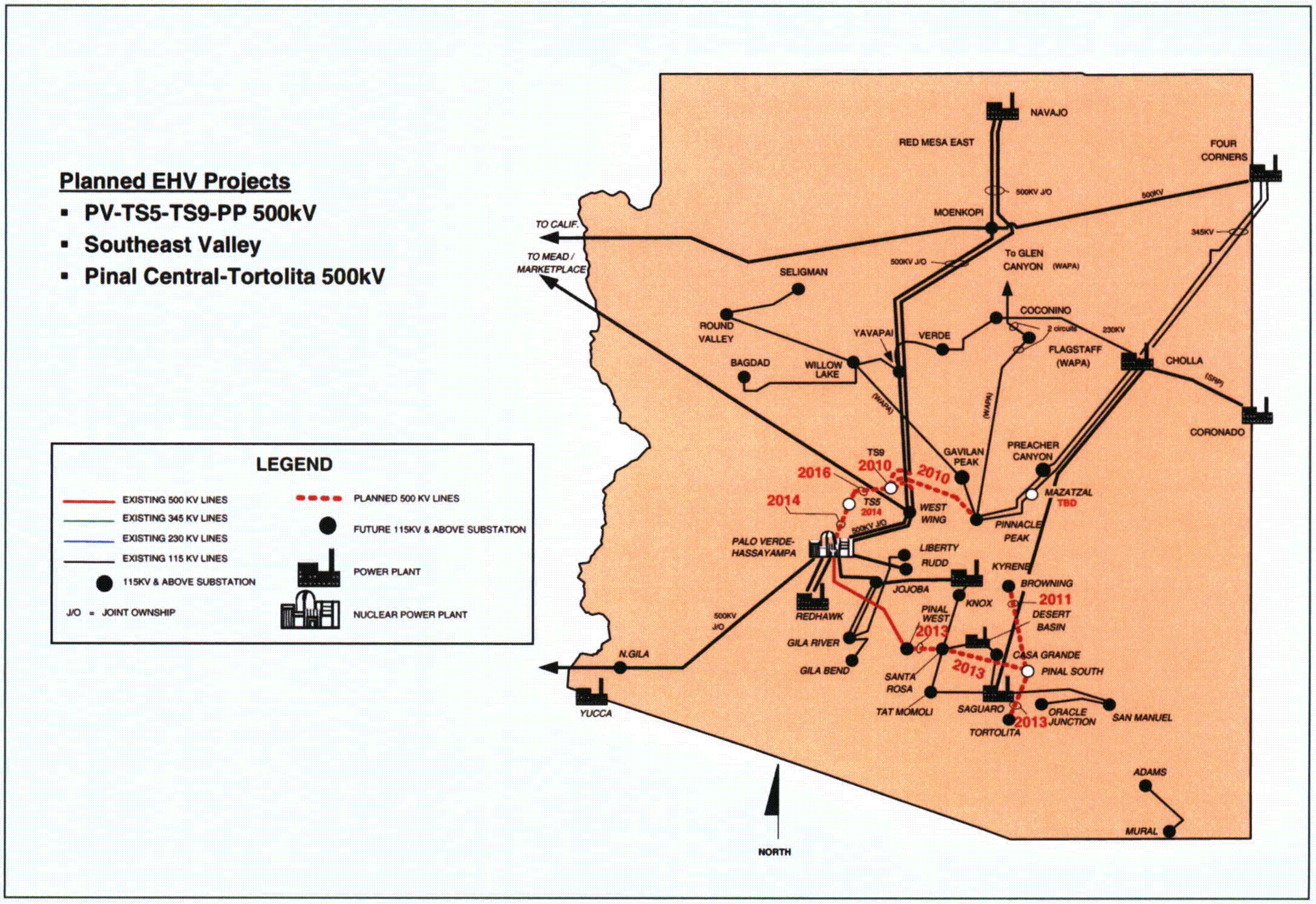
The ACC concluded in its order approving the Fifth Biennial Assessment that "The existing and planned transmission systems serving the Phoenix, Santa Cruz County, Tucson and Yuma areas are adequate and should reliably meet the local energy needs of the respective areas through 2017."[273] The Department agrees with this conclusion and no longer identifies the Phoenix-Tucson area as a Congestion Area of Concern.

Although not all of the transmission and demand-side projects that will resolve current congestion problems have been completed, several factors support this decision:

- The region's new transmission projects are reaching out to many new generation sources—both in terms of geography and fuel sources—that will enhance redundancy and reliability for the area.
- The recent history of transmission development in Arizona indicates that projects developed through the BTA are approved by the ACC and built on schedule with limited complications or uncertainty due to permitting, routing or cost recovery. It is likely that most of these projects will become operational by their scheduled dates.

The Department will continue monitoring the status of transmission congestion in the Phoenix and Tucson region and the status of the items discussed above.

Figure 5-14. Planned Extra High Voltage Transmission Facilities for the Phoenix and Tucson Area



Source: Smith, B. (Arizona Public Service Company) (2009). "Color Commentary for WestConnect Paths." Presented at the U.S. DOE Office of Electricity Delivery and Energy Reliability Spring 2009 Technical Workshop in Support of DOE 2009 Congestion Study, at http://congestion09.anl.gov/techws/index.cfm, slide 8.

[273] Arizona Corporation Commission (ACC) (2008b). "Decision No. 70635" Docket No. E-00000D-07-0376, at http://images.edocket.azcc.gov/docketpdf/0000091783.pdf, p. 2.

5.8. 2009 Western Congestion Areas

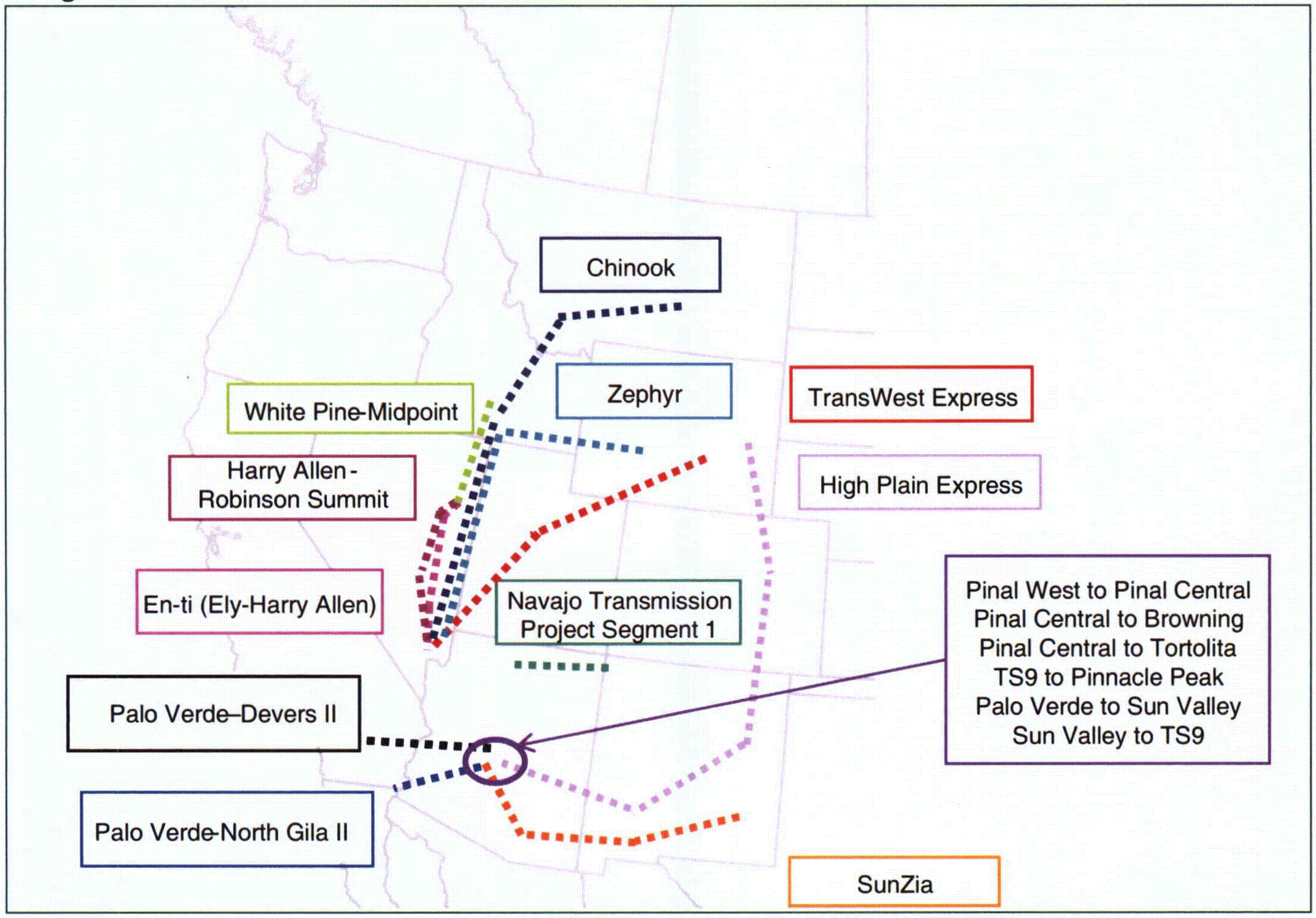
The sections above review the western congestion areas identified in the 2006 National Congestion Study and determine that all but one continue to merit identification as Congestion Areas in 2009. Figure 5-16 shows the Southern California Critical Congestion Area and the Seattle-Portland and San Francisco Congestion Areas of Concern for 2009.

The current TEPPC analysis identifies several other major transmission paths that were highly congested in 2006 and remain highly congested today:

- Bridger West (Path 19)
- Montana to Northwest (Path 8)
- Southwest of Four Corners (Path 22)
- Four Corners 345/500 kV Transformer (Path 23)
- Pacific AC Intertie (California-Oregon Interface, Path 66)
- Pacific DC Intertie (Path 65)
- TOT 2C (Utah-Nevada, Path 35)
- West of Borah (Path 17)
- Southern New Mexico (Path 47)
- TOT 2A (Path 31).

ColumbiaGrid analysis has also identified the paths from British Columbia to the Northwest and Northwest to California as interfaces that are regularly congested (whether seasonally or episodically due to high transfers).[274]

Figure 5-15. Major Transmission Projects Under Study that will Affect Arizona Transmission Congestion



Source: Kondziolka, R. (2009). "Western Interconnection Subregional Planning and Development," Presented at the U.S. DOE Office of Electricity Delivery and Energy Reliability Spring 2009 Technical Workshop in Support of DOE 2009 Congestion Study, at http://congestion09.anl.gov/techws/index.cfm/, slide 13.

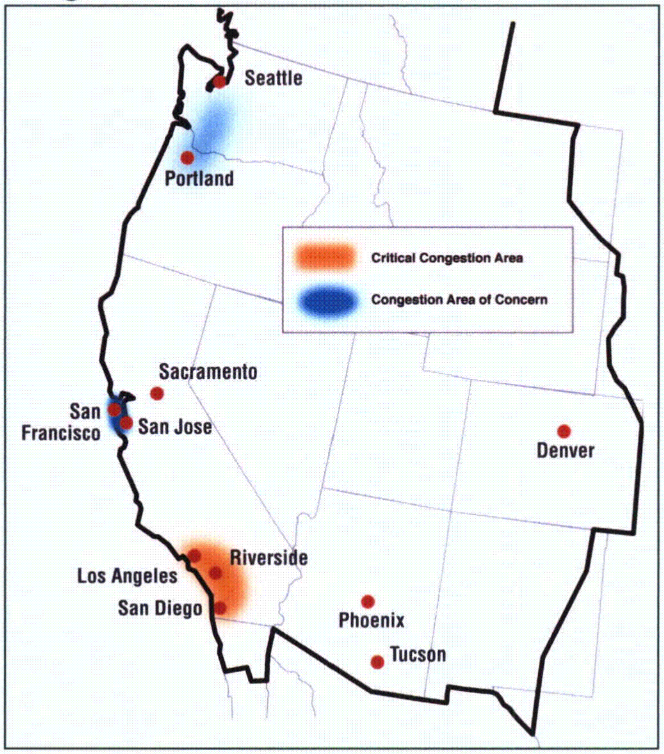
[274] ColumbiaGrid (2009a). *2009 Biennial Transmission Expansion Plan*, at http://www.columbiagrid.org/biennial-transmission-overview.cfm.

Table 5-6. Status of Major Transmission Projects Affecting Arizona Transmission and Resource Availability

Project Name	Voltage	Capacity	Proposed In-Service	Sponsor	Status
Pinal Central to Browning	500 kV	1400 MW	2011 - 2nd Qtr	SRP	In Design & Material/ROW Acquisition
Pinal West to Pinal Central	500 kV	1400 MW	2013 - 2nd Qtr	SRP	In Design & ROW Acquisition
Palo Verde to TS5 (Sun Valley)	500 kV	650 MW	2012 - 2nd Qtr	APS	In Design & ROW Acquisition
TS5 (Sun Valley) to TS9	500 kV	1200 MW	2014 - 2nd Qtr	APS	Siting & Permitting Completed
TS9 (Raceway) to Pinnacle Peak	500 kV	1000 MW	2010 - 2nd Qtr	APS	In Construction
Arizona Gateway South (Double Circuit)	345 kV	2000 MW	2011	TEP	In Siting & Permitting
Navajo Transmission Project	500 kV	1500 MW	2011	DPA	In Path Rating Study Process
Palo Verde to North Gila II	500 kV	1250 MW	2012 - 2nd Qtr	APS	In Design & ROW Acquisition
Palo Verde to Devers II	500 kV	1200 MW	2011 - 4th Qtr	SCE	In Siting & Permitting
TransWest Express (Bi-Pole DC)	500 kV	3000 MW	2015	Anschutz	In Path Rating Process
Chinook and Zephyr (Bi-Pole DC)	500 kV	6000 MW	2015	TransCan	In Siting & Permitting
Pinal Central to Tortolita	500 kV	1200 MW	2013 - 2nd Qtr	TEP	In Siting & Permitting
Eastern Nevada Transmission Intertie	500 kV	2000 MW	2011 - 4th Qtr	NVEnergy	In Siting & Permitting & Path Rating
Great Basin Energy Project	500 kV	1650 MW	2012 - 4th Qtr	LS Power	In Siting & Permitting & Path Rating
Eastern Plains Transmission Project	500 kV	1700 MW	2011	TriState	In Siting & Permitting
SunZia Southwest Trans Project (2 Circuits)	500 kV	3000 MW	2013	SW Power	In Path Rating Process
High Plains Express Initiative (2 Circuits)	500 kV	3500 MW	2016-2017	Xcel	Feasibility Studies

Source: Kondziolka, R. (2009). "Western Interconnection Subregional Planning and Development," slide 14.

Figure 5-16. Western Interconnection Congestion Areas, 2009



This study recognizes the importance of these lines to the reliability and delivered cost of electricity in the western bulk power system. However, the Department has decided not to identify the areas affected by these constraints formally as congestion areas at this time for the following reasons:

- Several of these paths serve either the Phoenix-Tucson area and/or the Southern California corridor (TOT2C, Four Corners transformer, Southwest of Four Corners, and the Pacific DC Intertie), so they have been implicitly addressed in the discussion above of those two recognized congestion areas.
- Similarly, congestion on the Pacific AC Intertie, British Columbia to the Northwest, and Northwest to California will be affected by actions taken to relieve congestion in the Seattle-Portland area as well as by other proposed transmission projects.

As noted above, a wealth of new transmission is being considered for development in the Western

Interconnection. This new transmission will affect future western congestion patterns, as will efforts to develop new renewable resources to meet state renewable portfolio requirements and increased energy efficiency to meet resource and carbon emissions management goals. The Department will continue monitoring these developments, and the paths and congestion areas identified above, to determine whether levels of congestion and usage are becoming better or worse as load, generation and transmission infrastructure change over time.

6. Public Comments, Next Steps Regarding Transmission Planning, and Achieving Transmission Adequacy

This chapter provides information about how to file comments on this study, discusses future work by DOE and others that may affect the Congestion Areas and the Conditional Constraint Areas, and provides DOE's perspective concerning achieving adequate transmission capacity.

6.1. Request for Comments on This Study

The Department invites public comments on this study. Comments may address any aspect of the study's methods and findings. Comments will be particularly useful if they address the following questions concerning improvements for this or future congestion studies:

1. Did this study accurately identify appropriate areas as Critical Congestion Areas, Congestion Areas of Concern, and Conditional Constraint Areas? Are there additional areas that should have been so identified?
2. How should the methods and approach for analyzing historical and future congestion on the grid be improved?
3. Are there better ways to define, identify, and measure congestion, the impacts of congestion, and transmission constraints?

Comment Period and Addresses for Filing Comments

The comment period for this study will be for 60 days, beginning with the day a notice of the availability of the study for public comment is published in the *Federal Register*. As soon as the closing date has been determined, the Department will post the closing date on its Congestion Study web site, congestion09@anl.gov. Comments must be submitted in writing to the Department no later than 5:00 p.m. EST on the closing date, if possible by e-mail to congestion09@anl.gov.

Comments may also be submitted by conventional mail to this address:

Comments on DOE 2009 Transmission Congestion Study
c/o Adriana Kocornik-Mina
Office of Electricity Delivery and Energy Reliability (OE)
U.S. Department of Energy
1000 Independence Avenue SW
Washington DC 20585

All comments received will be made publicly available on the website DOE has created for this study, www.congestion09.anl.gov. The Department will consider all comments received and take them into account in making decisions based in part on the findings of this study.

6.2. Next Steps Regarding Transmission Analysis and Planning

Several important activities and analyses are pending or already under way that are likely to show more clearly where the case for building additional transmission capacity is especially strong. The Department will provide funds for this work under the Recovery Act. These activities and analyses include:

1. *Stronger and more inclusive regional and interconnection-level transmission analysis and planning.* The Department believes that analytic entities in each of the Nation's interconnections should develop a broad portfolio of possible electricity supply futures and identify their associated transmission requirements. These analyses should address, for example, the extent to which energy efficiency programs can reduce or forestall the need for additional transmission capacity, as well as the merits of developing high-potential renewables in remote areas vs.

the merits of developing other renewable resources closer to load centers.

After these analyses have been developed and made available for public review, transmission experts from the electricity industry, the states, federal agencies, and other stakeholder groups are expected to collaborate in the development of interconnection-level transmission plans. Thus, to the extent feasible these plans will identify a coherent core set of transmission projects regarded by a diverse group of experts as needed under a wide range of futures.

2. *Designation by states of geographic zones with concentrated, high-quality renewable resource potential*, or other physical attributes especially relevant to reducing overall carbon emissions at reasonable cost. See, for example, *Western Renewable Energy Zones—Phase 1 Report*,[275] which identifies renewable resource "hubs." These hubs are the approximate centers of high-value resources areas that have also been screened to avoid park lands, wilderness areas, wetlands, military lands, steeply sloped areas, etc. DOE has announced that it seeks proposals from eastern state-based organizations to undertake similar analyses in the eastern United States. Identification of zones of particular interest for the development of additional low-carbon electric generating capacity will be valuable as input to the long-term planning processes described in the preceding paragraph.
3. *Regional or sub-regional renewable integration studies.* The output from wind and solar generation sources is inherently variable, at least over shorter periods of time. Therefore, in a given region, transmission planners must determine how higher levels of renewable generation could be used in combination with other generation sources, demand-side resources, and storage facilities while maintaining grid reliability. Completion of these integration studies, along with careful transmission planning, is essential to enable planners to make informed decisions about how to integrate large amounts of new generation effectively and economically.

6.3. Achieving Adequate Transmission Capacity

Section 409 of the Recovery Act directs the Secretary of Energy to include in this congestion study recommendations for achieving "adequate transmission capacity."

The obstacles to developing transmission capacity have been widely discussed in recent years. Much of this discussion has focused on problems in key subject areas, such as wide-area transmission analysis and planning, cost allocation, and transmission siting. Several legislative proposals have been put forward recently that address these problems, engendering vigorous debate among the Congress, executive branch agencies, regulatory agencies, the electricity industry, and other stakeholders about how best to go forward.

The Department and the Administration are participating actively in this legislative process. This study, however, is not the most appropriate vehicle for presenting the Administration's views on these topics. The Administration will do so at appropriate times in other public documents.

Determining what will constitute future transmission "adequacy" is no simple matter. We are entering a period in which it will be technically feasible to drive transmission systems harder and obtain more services from them, without endangering reliability—provided certain critical conditions are met.[276]

These include:

1. The availability of detailed, near-real-time information about second-to-second changes in the state of the bulk power supply systems.[277]

[275] Western Governors' Association (WGA) and U.S. Department of Energy (DOE) (2009). "Western Renewable Energy Zones – Phase 1 Report," at http://www.westgov.org/wga/initiatives/wrez/.

[276] For an early but prescient analysis of these concerns, see Hauer, J., T. Overbye, J. Dagle and S. Widergren (2002). "Advanced Transmission Technologies," *National Transmission Grid Study: Issue Papers*, U.S. Department of Energy, at http://www.oe.energy.gov/transmission.htm.

[277] See *Steps To Establish A Real-Time Transmission Monitoring System For Transmission Owners and Operators Within the Eastern and Western Interconnects. A Report To Congress Pursuant To Section 1839 Of The Energy Policy Act Of 2005* (2006). Prepared by DOE and FERC, at http://www.oe.energy.gov/DocumentsandMedia/final_1839.pdf. See also, for example, North American Synchrophasor Initiative (NASPI), at www.naspi.org.

2. The availability of effective control devices that will respond extremely quickly to correct or avert potentially hazardous operating conditions.[278]

3. The availability of appropriately trained workforces needed to design, build, operate, and maintain such complex systems.[279]

Clearly, determining how much transmission capacity we will "need" in a given region by a given date will be affected by the planners' expectations and assumptions about these and other important conditions. This congestion study is not an appropriate place for a detailed review of these subjects and the next steps to be pursued regarding them. Interested readers should consult the works cited in the footnotes below, and the reports the Department and others will publish in the months to come detailing the results of the initiatives supported under the Recovery Act.

Given the rising importance of electric infrastructure planning, however, there is a clear need to facilitate better and more transparent planning and policy decisions by improving the quality and availability of data concerning the use of existing transmission facilities. More systematic and consistent data are needed on several transmission subjects, such as:

1. The prices and quantities of short- and long-term transactions in wholesale electricity markets.
2. Scheduled and actual flows on the bulk power system. At present, OASIS data are scattered across many websites, are neither edited nor archived, and not presented in a consistent format. Clearer direction from FERC on how such data are to be presented would be very helpful. Special attention is required to depict more clearly the flows across inter-regional seams.
3. The economic value of curtailed transactions.

[278] See *Title XIII, Smart Grid, Energy Independence and Security Act of 2007*, at http://www.oe.energy.gov/DocumentsandMedia/EISA_Title_XIII_Smart_Grid.pdf. See also, *DOE Office of Electricity Delivery and Energy Reliability, Visualization and Controls Program*, at https://events.energetics.com/v&c08/agenda.html.

[279] See *Workforce Trends In The Electric Utility Industry. A Report To Congress Pursuant To Section 1101 Of The Energy Policy Act Of 2005* (2006b). Prepared by DOE, at http://www.oe.energy.gov/DocumentsandMedia/Workforce Trends Report_090706_FINAL.pdf. See also, *U.S. Power and Energy Engineering Workforce Collaborative*, at http://www.ieee-pes.org/workforce/workforce-collaborative.

Glossary

Ancillary services: Services necessary to support the transmission of electric energy from resources to loads, while maintaining reliable operation of the transmission system. Examples include spinning reserve, supplemental reserve, reactive power, regulation and frequency response, and electricity demand and supply in balance.

Available flowgate capacity: The total potential throughput of combinations of electrically related transmission elements along a defined path, subject to reliability requirements.

Available transfer capability (ATC): A measure of the transfer capability remaining in the physical transmission network for further commercial activity over and above already committed uses. It is defined as Total Transfer Capability less existing transmission commitments (including retail customer service), less a Capacity Benefit Margin, less a Transmission Reliability Margin.

Binding hours: Those hours when a transmission element is operating at its maximum operating safe limit; as a congestion metric, the % of time annually that the element is loaded to its limit.

Binding hours shadow price: A congestion metric that equals the average value of the shadow prices in those hours when a transmission element operates at its limit; the shadow price equals zero when the element is below its limit.

Biomass: In the context of electric energy, any organic material that is converted to electricity, including wood, cane, grass, farm, manure, and sewage.

Bulk power system: All electric generating plants, transmission lines and equipment.

CAISO: California Independent System Operator, serving most of the state of California.

Congestion: The condition that occurs when transmission capacity in a specific location is not sufficient to enable safe delivery of all scheduled or desired wholesale electricity transfers simultaneously.

Congestion rent: As used in this report, congestion rent equals the shadow price per MWh times the MWh flowing through a transmission element, summed over all the hours when that element is operating at its maximum (binding) limit.

Constrained facility: A transmission facility (line, transformer, breaker, etc.) that is loaded near, at, or beyond its system operating limit (SOL) or interconnection reliability operating limit (IROL).

Contingency: An unexpected failure or outage of a system component, such as a generator, transmission line, circuit breaker, switch or other electrical element.

Control area: A geographic and electrical area managed by a transmission or integrated utility, ISO or RTO, the manager of which is responsible for ensuring a continuous real-time balance of electrical supply and demand.

Curtailment: A reduction in service made necessary because all demand cannot be served safely.

Demand: The physical rate at which electric energy is delivered to or by a system or part of a system, generally expressed in kilowatts or megawatts, at a given instant or averaged over any designated interval of time; also, the total amount of electricity customers' use at a given moment, including line losses during delivery.

Demand response: Demand response programs are used to reduce consumers' use of electricity during times of peak demand, with incentives to curtail electricity demand and reduce load during targeted times in response to price signals or incentives indicating system reliability or market conditions.

Demand-side management: Activities or programs undertaken by a retail electricity provider, utility, energy service company to influence the amount or timing of electricity used by customers.

Dispatch: The injection of a generator's output onto the transmission grid by an authorized scheduling utility, or the activity of managing the production of electricity and transmission of it across the grid.

Distributed generation: Small-scale electric generation that feeds into the distribution grid, rather than the bulk transmission grid, whether on the utility side of the meter or on the customer side.

EIA: Energy Information Administration, an organization within the U.S. Department of Energy.

Element: An electrical device with terminals that may be connected to other electrical devices, such as generators, transformers, circuit breakers, bus sections, or transmission lines; an element may be comprised of one or more components.

Energy: A capacity for doing work; electrical energy is measured in watt-hours (kilowatt-hours, megawatt-hours or gigawatt-hours).

Energy efficiency: Refers to programs that are aimed at reducing the energy used by specific end-use devices and systems, typically without affecting the services provided. These programs reduce overall electricity consumption (reported in megawatt-hours), often without explicit consideration for the timing of program-induced savings. Such savings are generally achieved by substituting technically more advanced equipment to produce the same level of end-use services (e.g. lighting, heating, motor drive) with less electricity. Examples include high-efficiency appliances, efficient lighting programs, high-efficiency heating, ventilating and air conditioning (HVAC) systems or control modifications, efficient building design, advanced electric motor drives, and heat recovery systems.

ERCOT: Electric Reliability Council of Texas, an ISO serving 80% of Texas' load.

Facility rating: The maximum or minimum voltage, current, frequency, or real or reactive power flow through a facility that does not violate the applicable equipment rating of any equipment comprising the facility.

Flowgate: An individual or a group of transmission facilities (e.g., transmission lines, transformers) that are known or anticipated to be limiting elements in providing transmission service. This term is used principally in the Eastern Interconnection.

Generation: The process of transforming existing stored energy into electricity; also, an amount of electric energy produced, expressed in kilowatt-hours (kWh) or megawatt-hours (MWh).

Interconnection: When capitalized, any one of the five alternating current (AC) electric system networks in North America (Eastern, Western, ERCOT, Quebec, and Alaska).

ISO: Independent System Operator, an independent, federally regulated entity that coordinates regional transmission in a non-discriminatory manner and ensures the safety and reliability of the electric system within its footprint and in coordination with neighboring entities.

ISO-NE: Independent System Operator for New England, covering the states of Maine, Vermont, New Hampshire, Connecticut, Rhode Island and Massachusetts.

Limiting element: An electrical element that is either 1) operating at its appropriate maximum rating, or 2) would operate at its maximum rating given a limiting contingency; a limiting element establishes a system limit.

LMP: Locational Marginal Price, a method for pricing wholesale power based on actual grid conditions. The LMP at a specific point on the grid reflects the full cost of supplying the next MWh of electricity at that location, including the marginal cost of generating the electricity, the cost of delivering it across the grid, and the value of energy lost in delivery. Differences at a given time in LMPs at different locations reflect the impact of transmission congestion—LMPs at two points will be the same when the congestion they face is the same, but diverge if transmission congestion obstructs delivery of less expensive energy to one of them, raising LMP in the constrained area by the cost of the congestion.

Load: An end-use device (or a customer operating such device) that receives power from the electric system.

Load flow model: A detailed model, also referred to as a power flow model, that represents the interdependencies of energy flow along different paths in the system.

Load pocket: A load center (such as a large metropolitan area) that has limited local generation relative to the size of the load, and must import much of its electricity via transmission from neighboring areas.

Loop flow: The unscheduled use of transmission as electricity moves across the grid on multiple lines (following paths of least resistance).

MISO: The Midwest ISO, the Regional Transmission Operator serving all or portions of Arkansas, Illinois, Indiana, Iowa, Kentucky, Minnesota, Montana, Nebraska, North Dakota, Ohio, Pennsylvania, South Dakota, Virginia, Wisconsin, and West Virginia.

MMWG: NERC's Multi-regional Modeling Working Group, which develops a dataset of information about grid elements (power plants and transmission facilities) and their ratings for use in regional reliability modeling.

Nodal price: See LMP.

Node: A node is used in simulation modeling to represent an aggregation of significant amounts of electrical demand and/or supply, to simplify the modeling calculations (relative to modeling each power plant or load center individually). Each Interconnection is broken down into a set of nodes connected to each other by transmission paths.

Nomogram: A graphic representation that depicts operating relationships between generation, load, voltage, or system stability in a defined network. On lines where the relationship between variables does not change, a nomogram can be represented simply as a single transmission interface limit; in many areas, the nomogram indicates that an increase in transfers into an area across one line will require a decrease in flows on another line.

NYISO: New York Independent System Operator, serving New York State.

Operating transfer capability (OTC): The amount of power that can be transferred in a reliable manner, meeting all NERC contingency requirements, considering the current or projected operational state of the system. OTC is sometimes referred to as TTC, or Total Transfer Capability.

Outage: A period of time during which a generating unit, transmission line, or other facility is out of service.

Peak demand: Maximum electric load during a specified period of time.

PJM: The RTO serving parts or all of the states of Delaware, Illinois, Indiana, Kentucky, Maryland, Michigan, New Jersey, North Carolina, Ohio, Pennsylvania, Tennessee, Virginia, West Virginia and the District of Columbia.

Rating: The safe operational limits of a transmission system element under a set of specified conditions.

Redispatch: When transmission constraints or reliability requirements indicate that specific levels of generation across a set of power plants cannot be maintained reliably, the grid operator redispatches (changes the dispatch or operating instructions) for one or more power plants (increasing generation on one side of the constraint and reducing generation on the other side) to restore a safe operational pattern across the grid.

Reliability: Electric system reliability has two components—adequacy and security. Adequacy is the ability of the electric system to supply customers' aggregate electric demand and energy requirements at all times, taking account scheduled and unscheduled outages of system facilities. Security is the ability of the electric system to withstand sudden disturbances, such as electric short circuits or unanticipated loss of system facilities. The degree of reliability can be measured by the frequency, duration and magnitude of adverse effects on electricity delivery to customers.

Renewable resources: Flow-limited resources that can be replenished through natural processes. They are assumed to be virtually inexhaustible over long periods of time but limited in the amount of energy that is available per unit of time. Some (such as geothermal and biomass) may be stock-limited in that stocks can be depleted by use, but on a time scale of decades or perhaps centuries, they can probably be replenished. Renewable energy resources include: biomass, hydro, geothermal, solar, wind, ocean thermal, tidal, and wave energy.

RTO: Regional Transmission Operator, an independent, federally regulated entity that coordinates regional transmission in a non-discriminatory manner and ensures the safety and reliability of the electric system.

Seams: The interface between regional entities and/or markets at which material external impacts may occur. The regional entities' actions may have reliability, market interface, and/or commercial impacts (some or all).

Shadow price: The shadow price equals the value of the change in all affected generation if one more MWh could flow across a constrained facility then loaded to its maximum limit; the marginal cost of generation redispatch required to obey the transmission constraint.

Spot market: A market characterized by short-term (e.g., hourly and daily) contracts for specified volumes of a given commodity.

SPP: The Southwest Power Pool, serving portions of Arkansas, Kansas, Louisiana, Missouri, New Mexico, Oklahoma, and Texas.

Stability: The ability of an electric system to maintain a state of equilibrium during normal and abnormal conditions or disturbances.

Stability limit: The maximum power flow possible through some particular point in the system while maintaining stability in the entire system or the part of the system to which the stability limit refers.

System: A combination of generation, transmission, and distribution components.

System operating limit: The value (such as MW, MVar, amperes, frequency, or volts) that satisfies the most limiting of the prescribed operating criteria for a specified system configuration to ensure operation within acceptable reliability criteria. System operating limits (SOLs) are based upon certain operating criteria. These include, but are not limited to, pre- and post-contingency ratings for facilities, transient stability, voltage stability, and system voltage.

System operator: An individual or entity at a control center for a balancing authority (BA), transmission operator (TO), generator operator (GO), or reliability coordinator (RC), whose responsibility it is to monitor and control that electric system in real time.

Thermal rating: The maximum amount of electrical current that a transmission line or electrical facility can conduct over a specified time period before it sustains permanent damage by overheating or sags to the point that it violates public safety requirements.

TLR: See entry for "transmission loading relief."

Transfer capability: The measure of the ability of interconnected electric systems to move or transfer power in a reliable manner from one area to another over all transmission lines (or paths) between those areas under specified system conditions. The units of transfer capability are in terms of electric power, generally expressed in megawatts (MW). The transfer capability from area "A" to area "B" is generally *not* equal to the transfer capability from area "B" to area "A."

Transformer: An electrical device for changing the voltage of alternating current.

Transmission: An interconnected group of lines and associated equipment for moving electric energy at high voltage between points of supply and points at which it is delivered to other electric systems or transformed to a lower voltage for delivery to customers.

Transmission constraint: A limitation on one or more transmission elements that may be reached during normal or contingency system operations. The term “transmission constraint” can refer to a piece of equipment that restricts power flows, to an operational limit imposed to protect reliability, or to a lack of adequate transmission capacity to deliver potential sources of generation without violating reliability requirements.

Transmission loading relief: Procedures developed by NERC to deal with a situation in which a transmission facility or path is at or beyond its safe operating limit. In a TLR event, the grid operator can redispatch generation, reconfigure transmission, or curtail loads to restore the system to secure operating conditions.

Transmission path: A transmission path may consist of one or more parallel transmission elements. The transfer capability of the transmission path is the maximum amount of actual power that can flow over the path without violating reliability criteria. The net scheduled power flow over the transmission path must not exceed the path’s transfer capability or operating nomogram limits at any time, even during periods when the actual flow on the path is less than the path’s transfer capability.

U90: The number of hours or percentage of a year when a transmission path is operated at or above 90% of its safe operating limit.

U75: The number of hours or percentage of a year when a transmission path is operated at or above 75% of its safe operating limit.

Voltage: Voltage is the difference in electrical potential between two points of an electrical network, expressed in volts. The North American grid is operated using alternating current at 120 volts and 60 Hertz frequency.

WECC: Western Electricity Coordinating Council, the reliability coordinator serving the western interconnection.

Wholesale power market: The purchase and sale of electricity from generators to resellers (that sell to retail customers) along with the ancillary services needed to maintain reliability and power quality at the transmission level.

APPENDIXES

Appendix A

List of Entities Submitting Comments to DOE Website as Input to the 2009 National Electric Transmission Congestion Study

Alabama Public Service Commission

American Wind Energy Association

Arcuri, Michael A.

Arizona Corporation Commission

Arkansas Public Service Commission

California Public Utilities Commission

Davis, Jr., William E.

eLucem

Entergy Services, Inc.

Hansen, Amy

Imperial Irrigation District

ISO New England

Kentucky Public Service Commission

Maryland Public Service Commission

Montana Department of Commerce

National Association of Regulatory Utility Commissioners

New England Conference of Public Utilities Commissioners

New Jersey Board of Public Utilities

New Jersey Highlands Coalition

New York State Public Service Commission

North Carolina Utilities Commission

Northeast Power Coordinating Council, Inc.

Old Dominion Electric Cooperative

PacifiCorp

Pennsylvania Land Trust Association

Pennsylvania Public Utilities Commission/ Department of Environment

Piedmont Environmental Council

PSEG Companies

PSEG Services Corporation

Public Service Commission of Wisconsin

San Diego Gas and Electric

SERC Reliability Corporation

Southern California Edison Co.

Southern Company Services, Inc.

The Wind Coalition

Utah Governor's Office

Vermont Department of Public Service and Vermont Public Service Board

Virginia, Commonwealth of

WIRES

Appendix B

Organizations Participating in Congestion Study Workshops and Workshop Agendas

Alabama Public Service Commission
Allegheny Energy
American Electric Power
American Public Power Association
American Transmission Company
Argonne National Laboratory
Arizona Corporation Commission
Arizona Public Service
Arkansas Electric Cooperative Association
Arkansas Public Service Commission
Balch & Bruhn LLD
Bangor Hydro-Electric Company
Basin Electric Power Cooperative
Bonneville Power Administration
Bracy Tucker Brown & Valanzano
British Columbia Transmission Corporation
British Petroleum
Brookfield Renewable Power
California Department of Water Resources
California Energy Commission
California Public Utilities Commission
CenterPoint Energy
Central Minnesota Municipal Power Agency
City of Tallahassee, Florida
City Water, Light & Power
Colorado Public Utilities Commission
ColumbiaGrid
Commonwealth Edison Company
Comprehensive Power Solutions
Con Edison
Connecticut Department of Public Utility Control
Connecticut Municipal Electric Energy Cooperative
ConocoPhillips
Curtis, Goodwin, Sullivan, Udall & Schwab, PLC
Day Pitney LLP, for NEPOOL Participants Commission
Delaware Public Service Commission
Deloitte Consulting
District of Columbia Public Service Commission
DTE Energy
Duke Energy
Duquesne Light Company
E/ip
Ecology & Environment
Electric Power Supply Association
ELETROBRÁS
Energy Connect
Energy East
EntegraPower Grp
Entergy Services, Inc.
enXco Development Corp
EPIC Merchant Energy
Exelon Corporation
Federal Energy Regulatory Commission
FirstEnergy
Florida Governor's Energy Office
Florida Power & Light Company
Florida Public Service Commission
Florida Reliability Coordinating Council, Inc.
Flynn Resource Consultants Inc.
FPL Energy

FUNDRIVE.ORG
General Electric Wind
Georgia Public Service Commission
Georgia Transmission Corporation
Horizon Wind Energy
Idaho Power
Idaho Public Service Commission
Illinois Commerce Commission
Imperial Irrigation District
Inside Washington Publishers
Invenergy
Iowa Utilities Board
Ironbound Capital
ISO New England
ITC Holdings
ITC Transmission
K.R. Saline, Inc., representing West Connect
Kansas City Power & Light Co
Kansas House of Representatives
Kentucky Department of Energy Development and Independence
Kentucky Public Service Commission
La Capra Associates
Lafayette Utilities System
Lansing Board of Water & Light
LS Power Development, LLC
Madison Gas & Electric Company
Maine Public Utilities Commission
MAPPCOR
Maryland Energy Report
Maryland Public Service Commission
Massachusetts Attorney General
Massachusetts Department of Public Utilities
Massachusetts Municipal Wholesale Electric Company
Michigan Public Service Commission
Midwest ISO
Minnesota Power
Minnesota Public Utilities Commission
Missouri Public Service Commission
Municipal Electric Authority of Georgia
National Association of Regulatory Utility Commissioners
National Grid
National Rural Electric Cooperative Association
Nebraska Energy Office
Nebraska Public Power District
NERC Interchange Distribution Calculator Working Group
Nevada Power Company/Sierra Pacific Power Company
Nevada Public Utilities Commission
New England Power Generators Association
New Jersey Board of Public Utilities
New Mexico Renewable Energy Transmission Authority
New York City Economic Development Corporation
New York ISO
New York State Department of Public Service
New York State Public Service Commission
NextLight Renewable Power, LLC
North American Electric Reliability Corporation
North Carolina Utilities Commission
North Dakota Public Service Commission
Northeast Power Coordinating Council
Northeast Utilities
Northern Indiana Public Service Company
Northern Tier Transmission
Northwest Power and Conservation Council
NorthWestern Energy
NRG Energy
Ohio Public Utilities Commission
Oklahoma Attorney General's Office
Oklahoma Corporation Commission
Oklahoma Gas/Electric Company
Old Dominion Electric Cooperative
Open Access Technology International, Inc.

Oregon Public Utility Commission
Organization of MISO States
Organization of PJM States
Pacific Gas & Electric Company
PacifiCorp
Paschall Strategic
Patton Boggs LLP
Pennsylvania Public Utility Commission
Pepco Holdings
PJM Interconnection, LLC
Platts
PNM
Progress Energy
Public Service Commission of South Carolina
Public Service Commission of Wisconsin
Public Service Electric & Gas
Public Service Enterprise Group
RBC Energy Services, LP
RBS-Sempra Commodities
RES Americas Inc
Richmond Montessori School
Sacramento Municipal Utility District
Salt River Project
San Diego Gas and Electric Company
Science Applications International Corporation
Sea Breeze Pacific Regional Transmission System
Shell Energy
Signal Hill Consulting (representing Hydro Quebec Energy Services United States)
Silicon Valley Power
South Carolina Public Service Commission
South Dakota Public Utility Commission
South Mississippi Electric Power Association
Southeastern Electric Reliability Council
Southern California Edison
Southern Company
Southwest Power Pool
Southwestern Power Administration
State of Utah
State Utility Forecasting Group
Sustainable Energy Strategies
Tampa Electric
Tennessee Valley Authority
Terra-Gen Power, LLC
Texas CHP Initiative
The Journal Record
The Wilderness Society
TRC Solutions
Tucson Electric Power Company
U.S. Department of Homeland Security
U.S. National Grid
U.S. Senate
Usinternetworking
Ventyx
Vermont Department of Public Service
Vermont Public Service Board
Virginia State Corporation Commission
West Virginia Public Service Commission
Western Area Power Administration
Western Electricity Coordinating Council
Western Grid Group
Western Interstate Energy Board
Western Resource Advocates
Wisconsin Public Service Corporation
Xcel Energy

U.S. Department of Energy
Transmission Congestion Study Workshop
Hyatt Regency San Francisco
San Francisco, California
June 11, 2008

AGENDA

Transcript available:
http://www.congestion09.anl.gov/documents/docs/Transcript_Pre_2009_Congestion_Study_San_Francisco.pdf

8:00 – 9:00 am **Registration**

9:00 – 9:20 am **DOE Presentation**
Plans for the 2009 Congestion Study and Objectives of Workshop

9:20 – 10:30 am **Panel I**

Panelists:
Dave Areghini, Associate General Manager, Power, Construction & Engineering Services, Salt River Project
Tom Carr, Attorney and Economist, Western Interstate Energy Board
The Honorable Dian Grueneich, Commissioner, California Public Utilities Commission
The Honorable Kristin Mayes, Commissioner, Arizona Corporation Commission
Jeff Miller, Vice President & Manager of Planning, ColumbiaGrid
John Roukema, Assistant Director, Silicon Valley Power

10:30 – 10:45 am **Break**

10:45 – 12:00 pm **Panel II**

Panelists:
Wally Gibson, Manager, System Analysis & Generation, Northwest Power and Conservation Council
Ravi Aggarwal, Electrical Engineer, Bonneville Power Administration
Dana Cabbell, Manager, Transmission & Distribution, Southern California Edison
Kurt Granat, Business Development Consultant, PacifiCorp
Tom Darin, Staff Attorney, Energy Transmission, Western Resource Advocates
Jonathan Stahlhut, Transmission Planning Engineer, Arizona Public Service

12:00 – 12:30 pm **Comments from other attendees**

12:30 pm **Adjourn**

U.S. Department of Energy
Transmission Congestion Study Workshop
Skirvin Hilton Hotel
Oklahoma City, Oklahoma
June 18, 2008

AGENDA

Transcript available:
http://www.congestion09.anl.gov/documents/docs/Transcript_Pre_2009_Congestion_Study_Oklahoma_City.pdf

12:00 – 1:00 pm **Registration**

1:00 – 1:05 pm **Welcome**
The Honorable Bob Anthony, Commissioner
Oklahoma Corporation Commission

1:05 – 1:15 pm **DOE Presentation:** Plans for the 2009 Congestion Study and Objectives of Workshop

1:15 – 2:30 pm **Panel I**

Panelists:
The Honorable Tom Sloan, Representative, 45th District, Kansas House of Representatives
The Honorable Susan Wefald, President, North Dakota Public Service Commission
The Honorable Lauren Azar, Commissioner, Public Service Commission of Wisconsin
Sandy Hochstetter, Vice President, Arkansas Electric Cooperative Corporation
Mike Proctor, Chief Utility Economist, Missouri Public Service Commission

2:30 – 2:45 pm **Break**

2:45 – 4:00 pm **Panel II**

Panelists:
Jay Caspary, Director of Engineering, Southwest Power Pool
Jennifer Curran, Director, Transmission Infrastructure Strategy, Midwest ISO
Dan Klempel, Manager, Transmission Compliance, Basin Electric Power Cooperative
Greg Peiper, Director, Transmission Systems Operations Center, Xcel Energy
Manny Rahman, Manager, Transmission Interstate Planning, AEP

4:00 – 4:30 pm **Comments from other attendees**

4:30 pm **Adjourn**

U.S. Department of Energy
Transmission Congestion Study Workshop
Hartford Marriott Downtown Hotel
Hartford, Connecticut
July 9, 2008

AGENDA

Transcript available:
http://www.congestion09.anl.gov/documents/docs/Transcript_Pre2009_Congestion_Study_Hartford.pdf

8:00 – 9:00 am **Registration**

9:00 – 9:15 am **DOE Presentation**
Plans for the 2009 Congestion Study and Objectives of Workshop

9:15 – 10:30 am **Panel I**

Panelists:
The Honorable Garry Brown, Chairman, New York State Public Service Commission
The Honorable Donald Downes, Chairman, Connecticut Department of Public Utility Control
Phil Fedora, Assistant Vice President, Reliability Services, Northeast Power Coordinating Council, Inc.
Lisa Fink, Senior Staff Attorney, Maine Public Utilities Commission
Tom Simpson, Vice President, Energy, New York City Economic Development Corporation
John Keene, Counsel, Division of Regional and Federal Affairs, Massachusetts Department of Public Utilities

10:30 – 10:45 am **Break**

10:45 – 12:00 pm **Panel II**

Panelists:
Laurie Alysworth, Vice President Transmission Projects Engineering and Maintenance, Northeast Utilities
John Buechler, Executive Regulatory Policy Advisor, New York Independent System Operator
Brian Forshaw, Director of Energy Markets, Connecticut Municipal Electric Energy Cooperative
Angela O'Connor, President, New England Power Generators Association
Steve Rourke, Vice President, System Planning, Independent System Operator of New England
Mary Ellen Paravalos, Vice President, Transmission Regulation and Commercial, National Grid

12:00 – 12:30 pm **Comments from other attendees**

12:30 pm **Adjourn**

U.S. Department of Energy
Transmission Congestion Study Workshop
Westin Peachtree Plaza Hotel
Atlanta, Georgia
July 29, 2008

AGENDA

Transcript available:
http://www.congestion09.anl.gov/documents/docs/Transcript_Pre_2009_Congestion_Study_Atlanta.pdf

8:00 – 9:00 am **Registration**

9:00 – 9:15 am **DOE Presentation**
Plans for the 2009 Congestion Study and Objectives of Workshop

9:15 – 10:30 am **Panel I**

Panelists:
Cindy Miller, Senior Attorney, Office of General Counsel, Florida Public Service Commission
The Honorable Jim Sullivan, President, Alabama Public Service Commission
Charles Terreni, Executive Director, South Carolina Public Service Commission
Burl D. Till, III, Manager, Transmission Planning Department, Tennessee Valley Authority
The Honorable Stan Wise, Commissioner, Georgia Public Service Commission

10:30 –10:45 am **Break**

10:45 – 12:00 pm **Panel II**

Panelists:
George Bartlett, Director, Transmission Planning and Operations, Entergy Services
Nathan Brown, Chief Operating Officer, South Mississippi Electric Power Association
Ed Ernst, Director, Transmission Planning, Duke Energy
Terry Huval, Director, Lafayette Utilities System
Ron Carlsen, Project Manager, Senior Vice President, Planning and Policy, Transmission, Southern Company
Jennifer Vosburg, Director, Regulatory and Government Affairs, NRG Energy, Inc. South Central Region

12:00 – 12:30 pm **Comments from other attendees**

12:30 pm **Adjourn**

U.S. Department of Energy
Transmission Congestion Study Workshop
Atomic Testing Museum
Las Vegas, Nevada
August 6, 2008

AGENDA

Transcript available:
http://www.congestion09.anl.gov/documents/docs/Transcript_Pre_2009_Congestion_Study_LasVegas.pdf

8:00 – 9:00 am **Registration**

9:00 – 9:15 am **DOE Presentation**: Plans for the 2009 Congestion Study and Objectives of Workshop

9:15 – 10:30 am **Panel I**

Panelists:
Dave Shelton, Transmission Business Unit, Western Area Power Administration
Lisa Szot, Executive Director, New Mexico Renewable Energy Transmission Authority
The Honorable Rebecca Wagner, Commissioner, Nevada Public Utilities Commission
Lou Ann Westerfield, Director of Policy, Idaho Public Service Commission

10:30 – 10:45 am **Break**

10:45 – 12:00 pm **Panel II**

Panelists:
David Barajas, General Superintendent, System Planning, Imperial Irrigation District
Jim Filippi, Director of Transmission, NextLight Renewable Power and Co-Chair, TEPPC Technical Advisory Subcommittee
Laura Manz, Director, FERC and CAISO Regulatory Affairs, San Diego Gas & Electric Company
Jerry Smith, K.R. Saline, Inc., representing West Connect
Brian Whalen, Manager of Transmission Planning for Nevada Power and Sierra Pacific Power Company

12:00 – 12:30 pm **Comments from other attendees**

12:30 pm **Adjourn**

U.S. Department of Energy
Transmission Congestion Study Workshop
Wyndham Chicago Hotel
Chicago, Illinois
September 17, 2008

AGENDA

Transcript available:
http://www.congestion09.anl.gov/documents/docs/Transcript_Pre_2009_Congestion_Study_Chicago.pdf

7:30 – 8:30 am	**Registration**
8:30 – 8:45 am	**DOE Presentation** Plans for the 2009 Congestion Study and Objectives of Workshop
8:45 – 10:00 am	**Panel I**

Panelists:
Honorable Fred Butler, Commissioner, New Jersey Board of Public Utilities
Dan Cleverdon, Technical Advisor, Public Service Commission of the District of Columbia
Honorable Sherman Elliott, Commissioner, Illinois Commerce Commission
Michael J. Kormos, Senior Vice President-Operations, PJM Interconnection
Honorable Douglas Nazarian, Chairman, Maryland Public Service Commission

10:00 – 10:15 am	**Break**
10:15 – 11:30 am	**Panel II**

Panelists:
Lisa Barton, Vice President of Transmission Strategy and Business Development, American Electric Power
James Haney, Vice President, Transmission, Allegheny Power
Paul Napoli, Director, Transmission Business Strategy, Public Service Electric & Gas Company
Steve Naumann, Vice President, Wholesale Market Development, Government & Environmental Affairs and Public Policy, Exelon Corporation
Ed Tatum, Vice President, Transmission, Old Dominion Electric Cooperative

11:30 – 12:00 pm	**Comments from other attendees**
12:00 pm	**Adjourn**

Spring 2009 Technical Workshop
in Support of
U.S. Department of Energy 2009 Congestion Study

Webcast, transcript, and presentations available at: http://www.congestion09.anl.gov/techws/index.cfm/

Crowne Plaza Chicago O'Hare Hotel & Conference Center
March 25-26, 2009

Agenda

Day 1 – Wednesday, March 25, 2009

9:00 a.m. Registration Check-In & Continental Breakfast

10:00 a.m. **DOE Welcome/Purpose of Workshop**

David Meyer, *Senior Policy Advisor, Office of Electricity Delivery and Energy Reliability, U.S. Department of Energy (DOE-OE)*

10:15 a.m. **Session 1 – Historic Congestion in the Western Interconnection**

The Western Electric Coordinating Council Transmission Expansion Planning and Policy Committee has conducted an analysis of historic congestion in the Western Interconnection. This panel will present TEPPC's findings, discuss the metrics used to assess congestion, and review the implications of the findings with sub-regional transmission experts.

Speakers:

Wally Gibson, *Manager, System Analysis and Generation, Northwest Power and Conservation Council, and Co-Chair, Transmission Expansion Policy and Planning Committee, Western Electric Coordinating Council*
Dean Perry, *Consultant, Western Electricity Coordinating Council*
Kurt Granat, *Principal Transmission Planning Consultant, PacifiCorp*
Bob Smith, *Director, Energy Delivery Asset Management and Planning, Arizona Public Service*

Moderator: **Joe Eto**, *Staff Scientist, Lawrence Berkeley National Laboratory*

12:00 p.m. Lunch – on your own

1:00 p.m. **Session 2 – Historic Congestion in the Eastern Interconnection**

DOE sponsored an analysis of historic congestion in the Eastern Interconnection based on a combination of OASIS and IDC data, and LMP data for the centrally-organized markets. This panel will present the finding from this work and hear the views of eastern transmission experts about interpretation of the study findings.

Speakers:

Jagjit Singh, *VP/Director, Open Access Technology International, Inc.*
Farrokh Rahimi, *VP/Director, Open Access Technology International, Inc.*
Jim Busbin, *Supervisor, Bulk Power, Southern Company Transmission, and Chair, North American Electric Reliability Corporation Interchange Distribution Calculator Working Group*
Mike Walsh, *Senior Director—UDS, EMS, Compliance, and Training,* **Midwest** *ISO*
Steve Herling, *Vice President, Planning, PJM Interconnection, LLC*

Moderator: **Joe Eto**, *Staff Scientist, Lawrence Berkeley National Laboratory*

3:00 p.m. Break

3:15 p.m. **Session 3 – Studies of Future Congestion in the Western Interconnection**

WECC TEPPC has recently completed forward-looking studies of congestion in the Western Interconnection. This panel will discuss the process through which these studies were prepared, the findings from the most recent round of studies, the relationship between TEPPC and sub-regional transmission planning processes, and the linkage between TEPPC and longer-range regional resource and transmission planning processes.

Speakers:

Scott Cauchois, *Co-Chair, Transmission Expansion Policy and Planning Committee, and Board Member, Western Electricity Coordinating Council*
Brad Nickell, *Renewable Integration & Planning Director, Western Electricity Coordinating Council*
Rob Kondziolka, *Manager, Transmission Planning, Salt River Project*
Doug Larson, *Executive Director, Western Interstate Energy Board*

Moderator: **John Schnagl**, *Director, Transmission Adequacy, DOE-OE*

5:00 p.m. Adjourn

Day 2 – Thursday, March 26, 2009

7:30 a.m. Continental Breakfast

8:30 a.m. **Session 4 – Studies of Future Congestion in the Eastern Interconnection**

Pursuant to FERC Order 890, a variety of regional transmission planning activities is emerging in the Eastern Interconnection. This panel will discuss aspects of selected planning activities that are taking place, including recent findings on future congestion, the planning approach, and issues related to coordination among these activities.

Speakers:

John Lawhorn, *Director,* **Midwest** *ISO*
John Buechler, *Executive Regulatory Policy Advisor, New York ISO*
Ron Carlsen, *Planning Manager, Southern Company Transmission*
David Till, *Senior Manager, Transmission Planning, Tennessee Valley Authority*

Moderator: **David Meyer**, *Senior Policy Advisor, DOE-OE*

10:30 a.m. Break

10:45 a.m. **Session 5 – Status Report on DOE 2009 Congestion Study**

David Meyer, *Senior Policy Advisor, DOE-OE*

11:30 a.m. Adjourn

Appendix C

Documents and Data Reviewed for the 2009 National Electric Transmission Congestion Study

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NUCLEAR ENERGY RESEARCH AND DEVELOPMENT ROADMAP

REPORT TO CONGRESS

April 2010

U.S. DEPARTMENT OF
ENERGY
Nuclear Energy

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Figures

LIST OF ACRONYMS

BTU	British Thermal Units
CO_2	Carbon dioxide
DOE	Department of Energy
EE	DOE–Office of Energy Efficiency and Renewable Energy
EIA	Energy Information Agency
EPRI	Electric Power Research Institute
FE	DOE–Office of Fossil Energy
GDP	Gross domestic product
GHG	Greenhouse gas
GWe	Gigawatt (electric)
GWe-yr	Gigawatt-year (electric)
HTGR	High-temperature gas-cooled reactor
HTR	High-temperature reactor
IAEA	International Atomic Energy Agency
II&C	Instrumentation, information and control
IPSR	Integral primary system reactor
ITAAC	Inspections, test, analyses and acceptance criteria
kW-hr	Kilowatt-hour
LWR	Light-water reactor
MPACT	Materials Protection, Accounting and Control for Transmutation
MT	Metric ton
MWe	Megawatt (electric)
MWh	Megawatt-hour
NDE	Nondestructive evaluation
NE	DOE–Office of Nuclear Energy
NEA	Nuclear Energy Agency
NGNP	Next Generation Nuclear Plant
NGSI	Next Generation Safeguards Initiative
NNSA	National Nuclear Security Administration
NRC	Nuclear Regulatory Commission
OECD	Organization for Economic Cooperation and Development
R&D	Research and development
RISMC	Risk-informed safety margin characterization
SC	DOE–Office of Science
SMR	Small, modular reactor
UNF	Used nuclear fuel

EXECUTIVE SUMMARY

To achieve energy security and greenhouse gas (GHG) emission reduction objectives, the United States must develop and deploy clean, affordable, domestic energy sources as quickly as possible. Nuclear power will continue to be a key component of a portfolio of technologies that meets our energy goals. This document provides a roadmap for the Department of Energy's (DOE's) Office of Nuclear Energy (NE) research, development, and demonstration activities that will ensure nuclear energy remains viable energy option for the United States.

Today, the key challenges to the increased use of nuclear energy, both domestically and internationally, include:

- The capital cost of new large plants is high and can challenge the ability of electric utilities to deploy new nuclear power plants.
- The exemplary safety performance of the U.S. nuclear industry over the past thirty years must be maintained by an expanding reactor fleet.
- There is currently no integrated and permanent solution to high-level nuclear waste management.
- International expansion of the use of nuclear energy raises concerns about the proliferation of nuclear weapons stemming from potential access to special nuclear materials and technologies.

In some cases, there is a necessary and appropriate federal role in overcoming these challenges, consistent with the primary mission of NE to advance nuclear power as a resource capable of making major contributions to meeting the nation's energy supply, environmental, and energy security needs. This is accomplished by resolving technical, cost, safety, security and proliferation resistance barriers, through research, development, and demonstration, as appropriate. NE's research and development (R&D) activities will help address challenges and thereby enable the deployment of new reactor technologies that will support the current fleet of reactors and facilitate the construction of new ones.

Research and Development Objectives

NE organizes its R&D activities along four main R&D objectives that address challenges to expanding the use of nuclear power: (1) develop technologies and other solutions that can improve the reliability, sustain the safety, and extend the life of current reactors; (2) develop improvements in the affordability of new reactors to enable nuclear energy to help meet the Administration's energy security and climate change goals; (3) develop sustainable nuclear fuel cycles; and (4) understanding and minimization of risks of nuclear proliferation and terrorism.

R&D OBJECTIVE 1: Develop technologies and other solutions that can improve the reliability, sustain the safety, and extend the life of current reactors

The existing U.S. nuclear fleet has a remarkable safety and performance record, and today these reactors account for 70 percent of the low greenhouse gas (GHG)-emitting domestic electricity production. Extending the operating lifetimes of current plants beyond sixty years and, where possible, making further improvements in their productivity will generate near-term benefits. Industry has a significant financial incentive to extend the life of existing plants, and as such, activities will be cost shared. Federal R&D investments are appropriate to answer fundamental scientific questions and, where private investment is insufficient, to help make progress on broadly applicable technology issues that can generate public benefits. The DOE role in this R&D objective is to work in conjunction with industry and where appropriate the Nuclear Regulatory Commission (NRC) to support and conduct the long-term research needed to inform major component refurbishment and replacement strategies, performance enhancements, plant license extensions, and age-related regulatory oversight decisions. DOE will focus on aging phenomena and issues that require long-term research and are generic to reactor type.

R&D OBJECTIVE 2: Develop improvements in the affordability of new reactors to enable nuclear energy to help meet the Administration's energy security and climate change goals

If nuclear energy is to be a strong component of the nation's future energy portfolio, barriers to the deployment of new nuclear plants must be overcome. Impediments to new plant deployment, even for those designs based on familiar light-water reactor (LWR) technology, include the substantial capital cost of new plants and the uncertainties in the time required to license and construct those plants. Although subject to their own barriers for deployment, more advanced plant designs, such as small modular reactors (SMRs) and high-temperature reactors (HTRs), have characteristics that could make them more desirable than today's technology. SMRs, for example, have the potential to achieve lower proliferation risks and more simplified construction than other designs. The development of next-generation reactors could present lower capital costs and improved efficiencies. These reactors may be based upon new designs that take advantage of the advances in high performance computing while leveraging capabilities afforded by improved structural materials. Industry plays a substantial role in overcoming the barriers in this area. DOE provides support through R&D ranging from fundamental nuclear phenomena to the development of advanced fuels that could improve the economic and safety performance of these advanced reactors. Nuclear power can reduce GHG emissions from electricity production and possibly in co-generation by displacing fossil fuels in the generation of process heat for applications including refining and the production of fertilizers and other chemical products.

R&D OBJECTIVE 3: Develop Sustainable Nuclear Fuel Cycles

Sustainable fuel cycle options are those that improve uranium resource utilization, maximize energy generation, minimize waste generation, improve safety, and limit proliferation risk. The key challenge is to develop a suite of options that will enable future decision makers to make informed choices about how best to manage the used fuel from reactors. The Administration has established the Blue Ribbon Commission on America's Nuclear Future to inform this waste-management decision-making process. DOE will conduct R&D in this area to investigate technical challenges involved with three potential strategies for used fuel management:

- *Once-Through* – Develop fuels for use in reactors that would increase the efficient use of uranium resources and reduce the amount of used fuel requiring direct disposal for each megawatt-hour (MWh) of electricity produced. Additionally, evaluate the inclusion of non-uranium materials (*e.g.*, thorium) as reactor fuel options that may reduce the long-lived radiotoxic elements in the used fuel that would go into a repository.
- *Modified Open Cycle* – Investigate fuel forms and reactors that would increase fuel resource utilization and reduce the quantity of long-lived radiotoxic elements in the used fuel to be disposed (per MWh), with limited separations steps using technologies that substantially lower proliferation risk.
- *Full Recycling* – Develop techniques that will enable the long-lived actinide elements to be repeatedly recycled rather than disposed. The ultimate goal is to develop a cost-effective and low proliferation risk approach that would dramatically decrease the long-term danger posed by the waste, reducing uncertainties associated with its disposal.

DOE will work to develop the best approaches within each of these tracks to inform waste management strategies and decision making.

R&D OBJECTIVE 4: Understand and minimize the risks of nuclear proliferation and terrorism

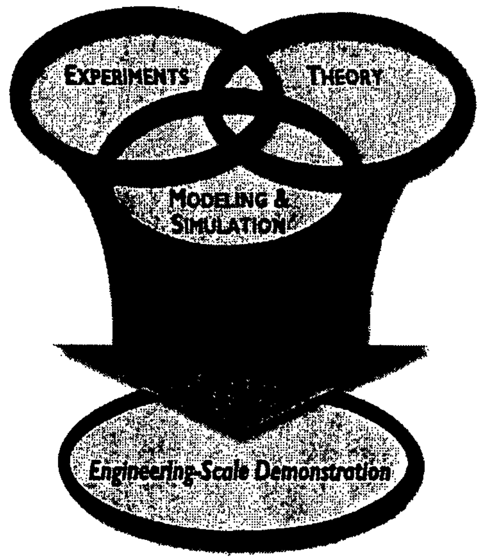
It is important to assure that the benefits of nuclear power can be obtained in a manner that limits nuclear proliferation and security risks. These risks include the related but distinctly separate possibilities that nations may attempt to use nuclear technologies in pursuit of a nuclear weapon and that terrorists might seek to steal material that could be used in a nuclear explosive device. Addressing these concerns requires an integrated approach that incorporates the simultaneous development of nuclear technologies, including safeguards and security technologies and systems, and the maintenance and strengthening of non-proliferation frameworks and protocols. Technological advances can only provide part of an effective response to proliferation risks, as institutional measures such as export controls and safeguards are also essential to addressing proliferation concerns. These activities must be informed by robust assessments developed for understanding, limiting, and managing the risks of nation-state proliferation and physical security for nuclear technologies. NE will focus on assessments required to inform domestic fuel cycle technology and system option development. These analyses would complement those assessments performed by the National Nuclear Security Administration (NNSA) to evaluate nation state proliferation and the international nonproliferation regime. NE will work with other organizations including the NNSA, the Department of State, the NRC, and others in further defining, implementing and executing this integrated approach.

R&D Areas

The Department expects to undertake R&D in a variety of areas to support its role in the objectives outlined above. Examples include:

- Structural materials
- Nuclear fuels
- Reactor systems
- Instrumentation and controls
- Power conversion systems
- Process heat transport systems
- Dry heat rejection
- Separations processes
- Waste forms
- Risk assessment methods
- Computational modeling and simulation

Figure 1. Major Elements of a Science-Based Approach



R&D Approach

A goal-driven, science-based approach is essential to achieving the stated objectives while exploring new technologies and seeking transformational advances. This science-based approach, depicted in Figure 1, combines theory, experimentation, and high-performance modeling and simulation to develop the fundamental understanding that will lead to new technologies. Advanced modeling and simulation tools will be used in conjunction with smaller-scale, phenomenon-specific experiments informed by theory to reduce the need for large, expensive integrated experiments. Insights gained by advanced modeling and simulation can lead to new theoretical understanding and, in turn, can improve models and experimental design. This R&D must be informed by the basic research capabilities in the DOE Office of Science (SC).

NE maintains access to a broad range of facilities to support its research activities. Hot cells and test reactors are at the top of the hierarchy, followed by smaller-scale radiological facilities, specialty engineering facilities, and small non-radiological laboratories. NE employs a multi-pronged approach to having these capabilities available when needed. The core capabilities rely on DOE-owned irradiation, examination, chemical processing and waste form development facilities. These are supplemented by university capabilities ranging from research reactors to materials science laboratories. In the course of conducting this science-based R&D,

infrastructure needs will be evaluated and considered through the established planning and budget development processes.

There is potential to leverage and amplify effective U.S. R&D through collaboration with other nations via multilateral and bilateral agreements, including the Generation IV International Forum. DOE is also a participant in Organization of Economic Cooperation and Development/Nuclear Energy Agency (OECD/NEA) and International Atomic Energy Agency (IAEA) initiatives that bear directly on the development and deployment of new reactor systems. In addition to these R&D activities, international interaction supported by NE and other government agencies will be essential in establishment of international norms and control regimes to address and mitigate proliferation concerns.

1. INTRODUCTION

Access to affordable, abundant energy – chiefly from fossil fuel sources – has been a key enabler of economic growth since the Industrial Revolution. However, as the first decade of the 21st century draws to a close, the United States finds itself confronted with economic, environmental, and national security challenges related in part to the manner in which our society produces, distributes, and uses energy. Continued access to plentiful, secure, and environmentally benign energy is fundamental to overcoming these challenges.

Nuclear energy is an important element of the diverse energy portfolio required to accomplish our national objectives. NE conducts research and development, and demonstrations, as appropriate, that will help enable the benefits of clean, safe, secure and affordable nuclear energy to continue and expand.

> Nuclear power is a proven, clean, affordable, domestic energy source that is part of the current U.S. energy portfolio.

This document identifies opportunities and challenges associated with continued and increased use of fission energy to enhance our nation's prosperity, security, and environmental quality; outlines the NE role and mission in enabling the benefits of nuclear energy for our nation; and presents a strategy and roadmap to guide the NE scientific and technical agenda. The report presents a high-level vision and framework for R&D activities needed to keep the nuclear energy option viable in the near term and to expand its use in the decades ahead.

Section 2 describes the current energy production and utilization landscape in the United States. Section 3 articulates NE's fundamental mission and role in enabling nuclear energy solutions and presents the four R&D objectives for nuclear energy development that are the focus of NE activities. The details of the roadmap are presented in Section 4. The R&D approach presented in Section 5 embodies a goal-oriented, science-based R&D portfolio that includes both evolutionary and transformational, high-risk–high-payoff R&D, including those research areas that encompass multiple objectives. Finally, Section 6 provides a summary of the objects presented in this report.

This report is not an implementation plan, but rather provides a basis that will guide NE's internal programmatic and strategic planning for research going forward.

The report focuses on R&D activities sponsored by NE. The U.S. nuclear industry plays a central role in overcoming barriers and is ultimately responsible for the commercial deployment of the resulting technologies. NE intends to proceed in a manner that supports a strong and viable nuclear industry in the United States and preserves the ability of that industry to participate in nuclear projects here and abroad.

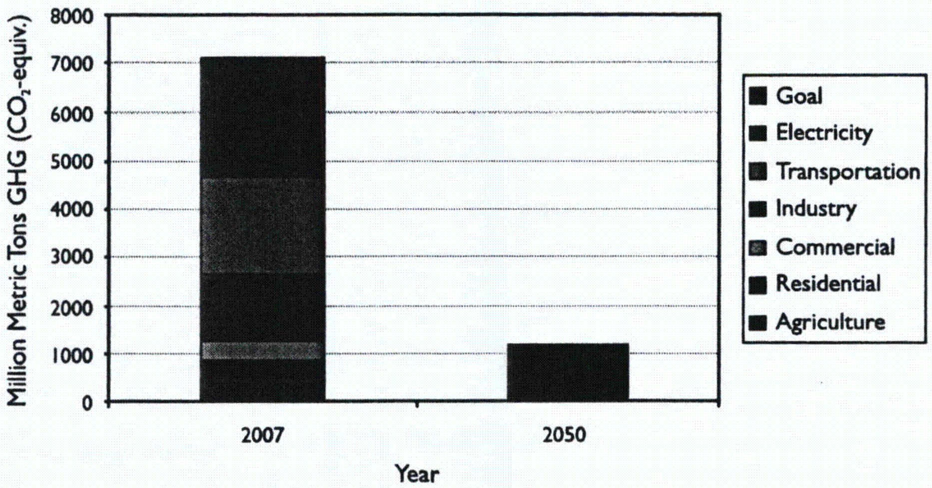
> To achieve its energy security and GHG reduction objectives, the U.S. must develop and deploy clean, affordable, domestic energy sources as quickly as possible.

Finally, it should be noted that in some limited cases, NE's mission extends beyond terrestrial deployment of nuclear energy into other arenas, such as space applications of both fission and radioisotope power systems. Some technology development needs identified in this document also benefit space applications, but these mission arenas are not addressed in this roadmap. Educational programs, while vital, are interwoven through the technical programs and are not discussed as separate entities.

2. BACKGROUND

All governments of the world share a common challenge to ensure their people have access to affordable, abundant, and environmentally friendly energy. Secretary of Energy Steven Chu has reiterated the Administration's position that nuclear is an important part of the energy mix. He has recognized the importance of nuclear energy in meeting this challenge and supports R&D that can help increase the benefits of nuclear energy. A key objective that will shape the energy landscape of the United States is the transition to clean energy sources with reductions in GHG emissions (with a quantitative goal of 83% reduction below 2005 emissions levels by 2050, shown in Figure 2).

Figure 2. U.S. Greenhouse Gas Emissions[1]



2.1 The Energy Landscape

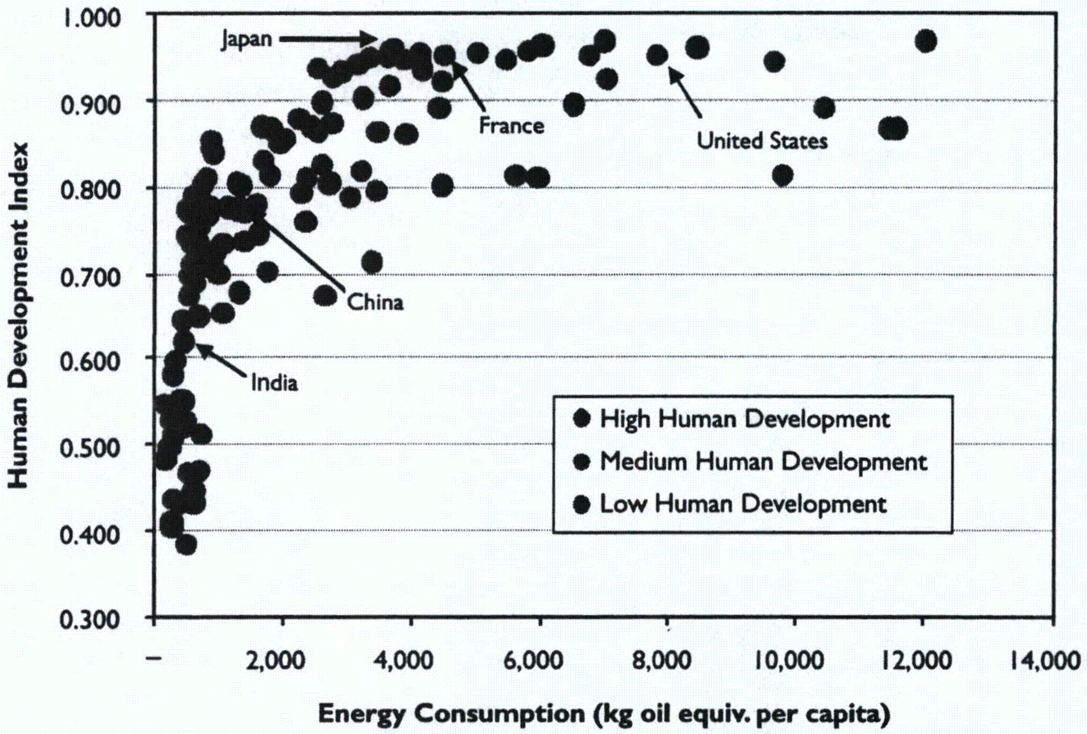
The Human Development Index[2] is a commonly used measure of quality of life. Figure 3 illustrates that a nation's standard of living depends in part on energy consumption. Access to adequate energy is now and will continue to be required to achieve a high quality of life. Economic development, combined with efforts to limit carbon emissions, will likely lead to a

[1] 2007 GHG emissions reported in EPA, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2007* EPA 430-R-09-004, April 15, 2009. Administration emission goals taken from the "Testimony of Peter R. Orszag, Director of the Office of Management and Budget, Before the Committee on the Budget, U.S. House of Representatives" on March 3, 2009.

[2] The index was developed by the United Nations to enable cross-national comparisons of development and is updated in an annual report. The derivation of the index was introduced in United Nations Development Programme, *Human Development Report 1990*, Oxford University Press, 1990.

significant expansion of nuclear power. The U.S., in concert with the international community, must develop the technologies and systems to accomplish such expansion while limiting proliferation risks.

Figure 3. 2005 Human Development Index vs. Energy Consumption (Per Capita Kilograms Oil Equivalent)



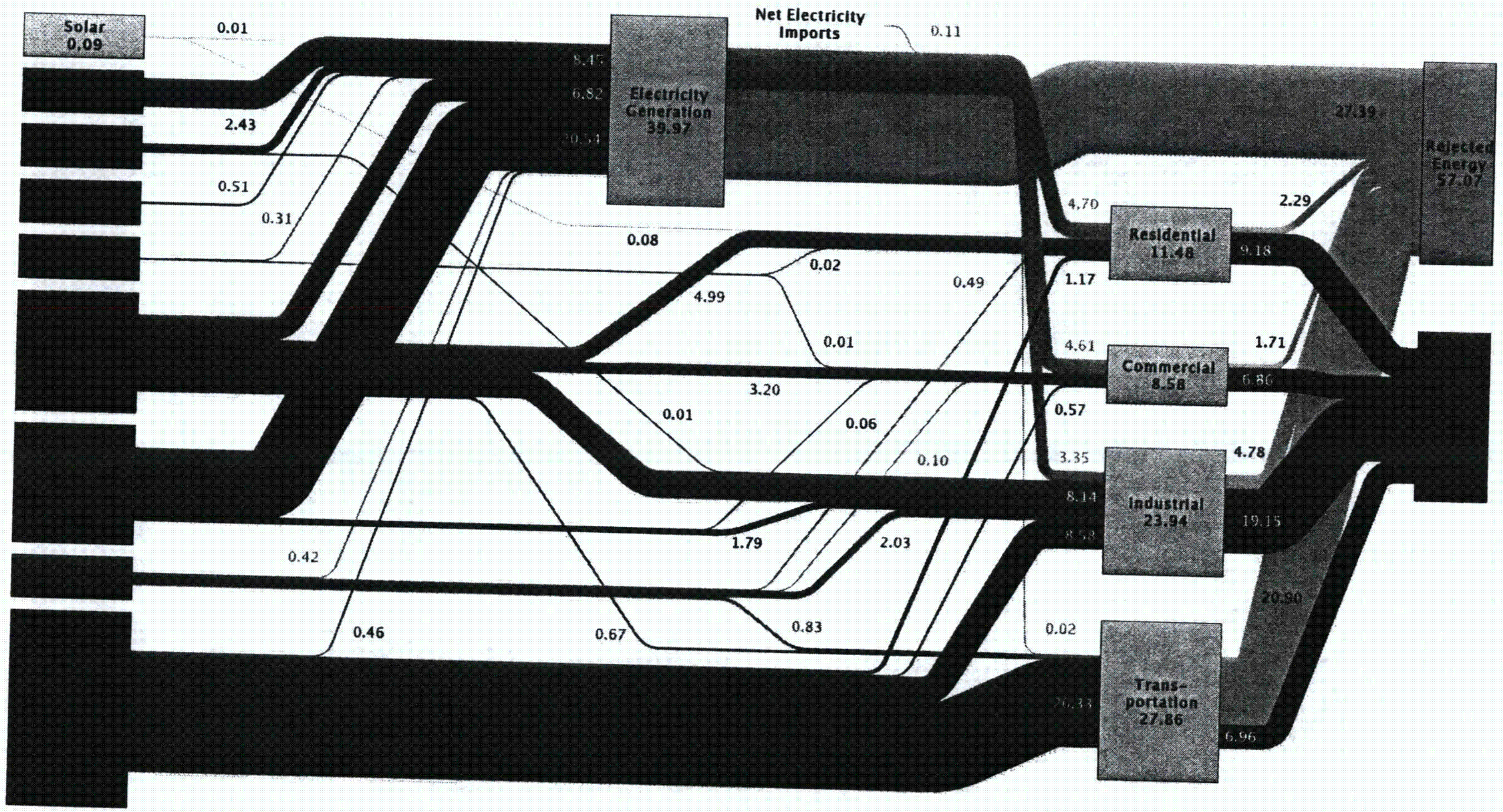
As we move forward, efficiency and conservation will become ever-increasing components of energy policy. However, conservation and energy efficiency alone will not be sufficient to maintain a desirable quality of life.

The United States currently consumes roughly 100 quadrillion British Thermal Units (BTU), or 100 quads, of primary energy.[3] This represents 25% of world's energy consumption in a country that produces 30% of the global gross domestic product (GDP). Figure 4 shows energy consumption in the United States as a function of sectors and energy sources. At present, 40% of the total energy consumed is in the form of electricity, of which about 20 percent is generated by nuclear power. With 6 billion metric tons (MT) of emitted carbon dioxide (CO_2) as a result of fossil fuel usage (see Figure 5), the United States contributes 25 percent of global GHGs emitted.

[3] The data in Figures 5 and 6 are reported by the U.S. DOE Energy Information Agency "An Updated Annual Energy Outlook 2009 Reference Case," 2009.

Figure 4. U.S. Primary Energy Use in 2008

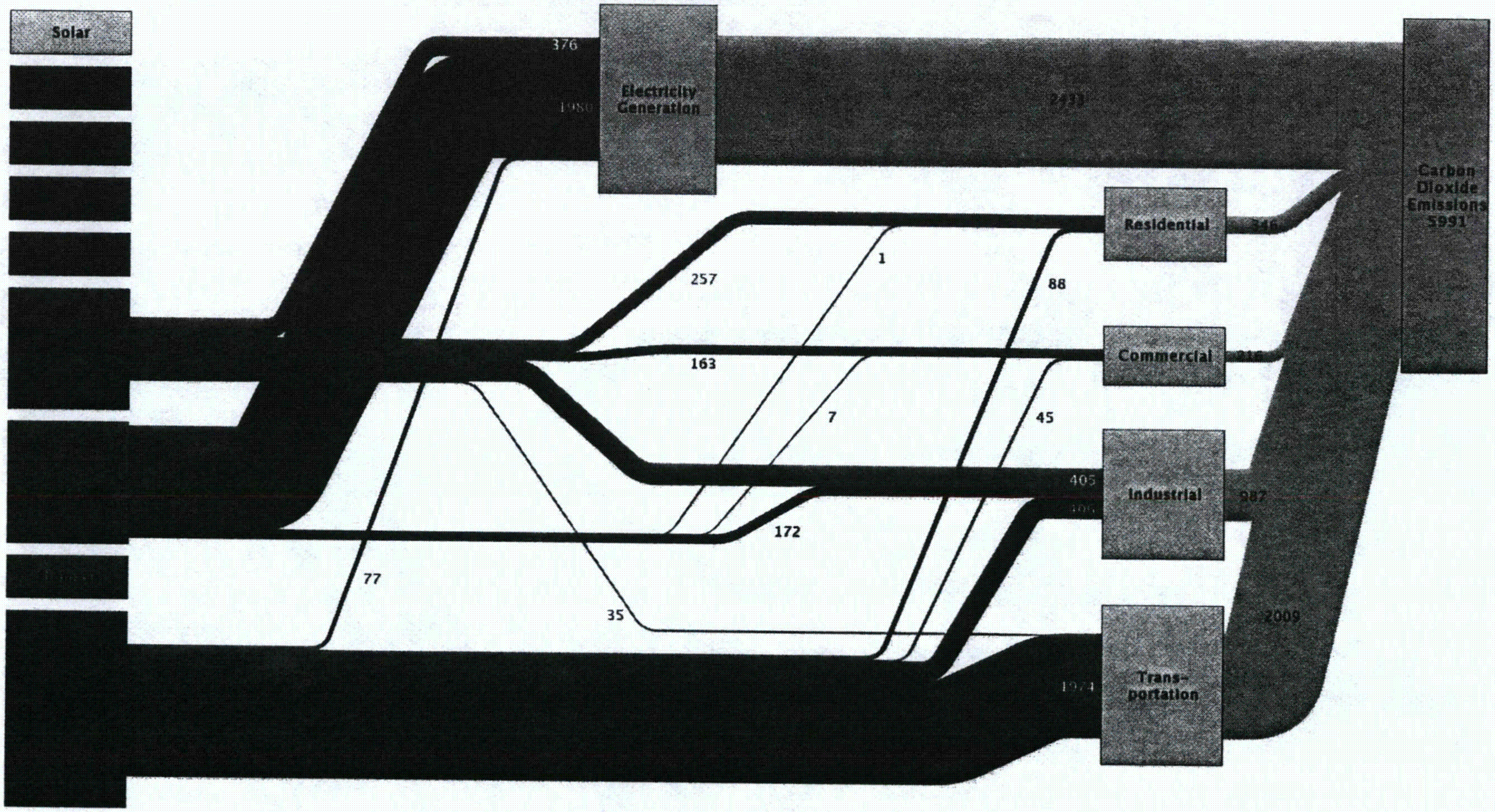
Estimated U.S. Energy Use in 2008: ~99.2 Quads



Source: LLNL 2009. Data is based on DOE/EIA-0384(2008), June 2009. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Distributed electricity represents only retail electricity sales and does not include self-generation. EIA reports flows for non-thermal resources (i.e., hydro, wind and solar) in BTU-equivalent values by assuming a typical fossil fuel plant "heat rate." The efficiency of electricity production is calculated as the total retail electricity delivered divided by the primary energy input into electricity generation. End use efficiency is estimated as 80% for the residential, commercial and industrial sectors, and as 25% for the transportation sector. Totals may not equal sum of components due to independent rounding. LLNL-MI-410527

Figure 5. U.S. Carbon Dioxide Emissions in 2007

Estimated U.S. Carbon Dioxide Emissions in 2007:
~5991 Million Metric Tons



Source: LLNL 2009. Data is based on DOE/EIA-0384(2008), June 2009. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Carbon embodied in industrial and commercial products such as plastics is not shown. The flow of petroleum to electricity production includes both petroleum fuels and the plastics component of municipal solid waste. The combustion of biologically derived fuels is assumed to have zero net carbon emissions – lifecycle emissions associated with biofuels are accounted for in the Industrial and Commercial sectors. Totals may not equal sum of components due to independent rounding. LLNL-MI-411167

The Administration's clean energy and climate change objectives are ambitious and achievable. Successful achievement of these objectives will require solutions to technical challenges associated with various energy sectors, including:

- *Electricity Sector GHG Production* – As seen in Figures 4 and 5, the U.S. electricity production sector annually consumes 40 quadrillion BTU of primary energy, producing 4,150 million MWh of electricity, and emitting 2,400 million MT of CO_2. The average carbon intensity of the U.S. electric-generating sector is 0.58 MT–CO_2/MWh of electricity produced. While far from the world's highest carbon intensity (China produces 0.87 MT-CO_2/MWh of electricity), U.S. electric-generating-sector carbon intensity is far higher than some industrialized countries. For instance, France emits only 0.09 MT–CO_2/MWh of electricity produced. There is clearly both the need for, and the real potential for, significant improvement in U.S. electric-generating-sector carbon intensity and GHG emissions.
- *Transportation Sector Energy Use and GHG Emissions* – The transportation sector is currently responsible for 33% of GHG emissions (Figure 5). In addition to more energy-efficient internal combustion engines, electrification of the transportation sector using new low-carbon electricity-generation technologies will assist in reducing these emissions. Successful electrification of the transportation sector is also dependent on improvements in battery technology to enable high-density energy storage to meet vehicle service range requirements.
- *Industrial Sector Energy Use and GHG Emissions* – Industrial use of energy is responsible for 16 percent of the country's GHG emissions (Figure 5). About half of these emissions come from chemical facilities and oil refineries. The development of GHG-free technologies that can generate and deliver significant thermal and chemical energy to industry is needed.

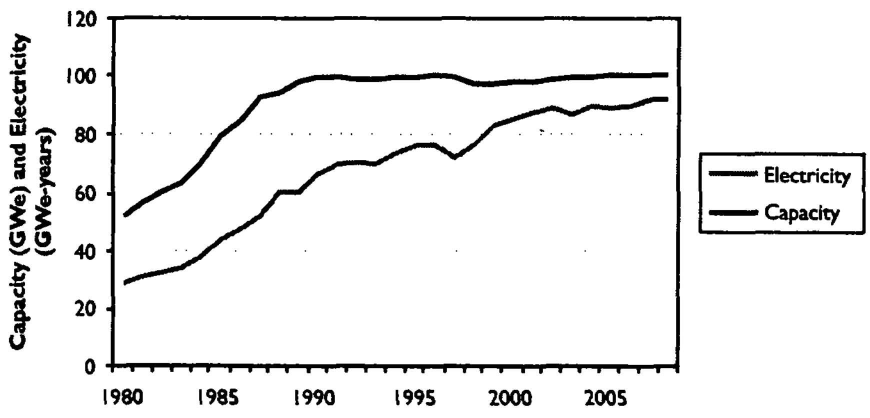
> The driver for the new energy policy is to continue to generate energy, mostly from domestic sources, at an affordable price. The policy must meet increasing demand, with considerably reduced GHG emissions, and without stifling GDP growth.

2.2 The Value and Need for an "Energy Portfolio" Approach

Given the issues noted in Section 2.1, an effective energy policy will almost certainly rely on the development and use of a portfolio of domestic clean energy sources. This is true not only because of resource limits at various points in the energy supply chain but also because all energy sources face economic, technical, and societal risks to their successful deployment.[4] R. Socolow and S. Pacala, in "A Plan To Keep Carbon In Check,"[5] have demonstrated the potential for energy portfolio approaches to enhance U.S. energy security and reduce the threat of global warming. The following section discusses the role of nuclear energy as an element of the U.S. energy portfolio.

2.3 Nuclear Energy as an Element of the Future U.S. Energy Portfolio

Figure 6. U.S. Nuclear Energy History, 1980 – 2008



(EIA, *Annual Energy Review 2008*)

In 2007, the 104 light-water reactors (LWRs) currently operating in the United States generated 806 billion kilowatt-hours (kW-hrs), equivalent to 92 gigawatt-years (GWe-yrs). As shown in Figure 6, even though the generating capacity of the nuclear fleet has been essentially flat for almost twenty years, the production of nuclear electricity continued to grow largely as a result of increased capacity factors. The fleet's average capacity factor improved from 56.3% in 1980 to 91.9% in 2008.[6] This improvement was driven by reactor operators and the efforts of the Electric Power Research Institute (EPRI), spurred by NE-sponsored R&D into high-burnup fuels that allowed utilities to shift from 12-month operating cycles to 18- or 24-month operating cycles that reduced downtime. Additionally, some growth can be attributed to power uprates that increased capacity at existing plants.

While in operation, nuclear power plants do not emit GHGs. Every MWh of electricity produced with nuclear energy avoids the emission of approximately 1.0 MT of CO_2 if the same amount of energy had been generated with conventional coal-fired technologies or approximately 0.6 MT of CO_2 if the energy had been produced with natural gas. Since the per capita electricity consumption in the United States is approximately 14 MWh of electricity per year per person, nuclear energy offers the prospect of avoiding what could otherwise be an annual personal carbon footprint from electricity production of up to 14 MT of CO_2. In addition, nuclear power

[4] R. Socolow and S. Pacala, "Stabilization Wedges: Solving the Climate Problem for the Next 50 Years with Current Technologies." *Science*, August 13, 2004: 968-972.

[5] *Scientific American*, September 2006

[6] EIA, *Annual Energy Review* 2008, Table 9.2.

is dependable. It is available day or night, when the wind is blowing and when it is not. After more than three decades of outstanding safety performance, the public acceptance of nuclear energy has turned in favor of its deployment.[7] However, continued and increased use of nuclear energy faces several key challenges:

- *Capital Cost* – The current fleet of nuclear power plants produces electricity at a very low cost (approximately 2–3 cents/kilowatt-hour) because these plants have already repaid the initial construction investments. However, the capital cost of a large new plant is high and can challenge the ability of electric utilities to deploy new nuclear reactors. Thus, it is important to reduce the capital cost by innovative designs. The introduction of smaller reactors might reduce capital costs by taking advantage of series fabrication in centralized plants and may reduce financial risk by requiring a smaller up-front investment.
- *Waste Management* – At present, no permanent solution to high-level nuclear waste management has been deployed in the United States. Innovative solutions will be required to assure that nuclear waste is properly managed. The Administration has initiated the Blue Ribbon Commission on America's Nuclear Future to conduct a review of policies for managing the back end of the nuclear fuel cycle, including all alternatives for the storage, processing, and disposal of civilian and defense used nuclear fuel and nuclear waste. The results will inform the Government's process to establish a policy for used fuel and waste management. Ultimately, while the need for permanent waste disposal can never be eliminated, transition to nuclear energy technologies that significantly reduce the production of long-lived radioactive waste – rather than deal with it after it is produced – is a desirable goal.
- *Proliferation Risk* – There is considerable interest in the global expansion of nuclear energy. However, such expansion raises concerns about the proliferation of nuclear weapons, including nuclear explosive devices, stemming from access to enrichment and reprocessing activities that might produce weapons-usable materials. Development of innovative technologies and international policies are essential to prevent nuclear proliferation by nation-states as well as nuclear terrorism by rogue entities. Furthermore, a more robust capability to evaluate and compare proliferation and terrorism risks is needed. In addition, it is in the U.S. interest to engage nations contemplating civil nuclear power for the first time in order to help them develop an indigenous infrastructure designed to deploy the technology in a safe and secure manner.
- *Safety and Reliability* – As existing plants continue to operate and new plants and new types of plants are constructed, it is vital that the excellent safety and reliability record of nuclear energy in the United States be maintained. It is also important that the U.S. share its experience with other countries and work with them to ensure safe operation of their plants.

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[7] Ref. http://www.gallup.com/poll/117025/Support-Nuclear-Energy-Inches-New-High.aspx.

3. MISSION AND GOALS OF THE OFFICE OF NUCLEAR ENERGY

The analysis presented in Section 2 supports the conclusion that increased greenhouse gas-free electricity production is necessary to achieve the transition to a clean-energy economy.

3.1 The Office of Nuclear Energy Mission

The primary mission of NE is to advance nuclear power as a resource capable of meeting the nation's energy, environmental, and national security needs by resolving technical, cost, safety, security, and proliferation resistance, through R&D and demonstrations, as appropriate. Progress in these areas should promote the deployment of fission power systems in a socially acceptable, environmentally sustainable, and economically attractive manner.

Four specific research and development objectives for nuclear energy development outline NE's approach to delivering progress in the areas noted above. The objectives are:

- *R&D Objective 1* – Develop technologies and other solutions that can improve the reliability, sustain the safety, and extend the life of current reactors.
- *R&D Objective 2* – Develop improvements in the affordability of new reactors to enable nuclear energy to help meet the Administration's energy security and climate change goals.
- *R&D Objective 3* – Develop sustainable nuclear fuel cycles.
- *R&D Objective 4* – Understand and minimize the risks of nuclear proliferation and terrorism.

The four objectives are discussed more fully in the following sections.

3.2 Nuclear Energy R&D Objectives and the Role of NE in Achieving Them

This section presents a description of the four R&D objectives and NE's role in making progress in these areas.

3.2.1 R&D Objective 1: Develop Technologies and Other Solutions that Can Improve the Reliability, Sustain the Safety, and Extend the Life of Current Reactors

The existing U.S. nuclear fleet has a remarkable safety and performance record, and today these reactors account for 70 percent of the low GHG-emitting domestic electricity production. Extending the operating lifetimes of current plants beyond sixty years and, where possible, making further improvements in their productivity will generate near-term benefits. Industry has a significant financial incentive to extend the life of existing plants, and as such, activities will be cost shared. Federal R&D investments are appropriate to answer fundamental scientific questions and, where private investment is insufficient, to help make progress on broadly applicable technology issues that can generate public benefits.

The DOE role in this R&D objective is to work with industry and, where appropriate, the Nuclear Regulatory Commission (NRC) to support and conduct the long-term research needed to inform major component refurbishment and replacement strategies, performance enhancements, plant license extensions, and age-related regulatory oversight decisions. The DOE R&D role will focus on aging phenomena and issues that require long-term research and are generic to reactor type.

3.2.2 R&D Objective 2: Develop Improvements in the Affordability of New Reactors to Enable Nuclear Energy to Help Meet the Administration's Energy Security and Climate Change Goals

If nuclear energy is to be a strong component of the nation's future energy portfolio, barriers to the deployment of new nuclear plants must be overcome. Impediments to new plant deployment, even for those designs based on familiar light-water reactor technology, include the substantial capital cost of new plants and the uncertainties in the time required to license and construct them. More advanced plant designs, such as small modular reactors (SMRs) and high-temperature reactors (HTRs), will have additional barriers for deployment. These reactors have characteristics that could make them more attractive than today's technology. SMRs, for example, have the potential to achieve lower proliferation risk and more simplified construction than other designs. The development of next-generation reactors could present lower capital costs and improved efficiencies. These reactors may be based upon new designs that take advantage of the advances in high performance computing while leveraging capabilities afforded by improved structural materials. Industry's role in overcoming the barriers in this area is substantial. DOE supports R&D ranging from fundamental nuclear phenomena to the development of advanced fuels that could improve the economic and safety performance of these advanced reactors. Nuclear power can reduce GHG emissions from electricity production and possibly in co-generation by displacing fossil fuels in the generation of process heat for applications including refining and the production of fertilizers and other chemical products.

3.2.3 R&D Objective 3: Develop Sustainable Nuclear Fuel Cycles

Sustainable fuel cycle options are those that improve uranium resource utilization, maximize energy generation, minimize waste generation, improve safety, and complement institutional measures in limiting proliferation risk. The key challenge for the government in this R&D objective is to develop a suite of options that will enable future decision makers to make informed choices about how best to manage the used fuel from reactors. DOE will conduct R&D in this area to investigate the technical challenges involved with three potential strategies for used fuel management.

- *Once-Through* – Develop fuels for use in reactors that would increase the efficient use of uranium resources and reduce the amount of used fuel for direct disposal for each MWh of electricity produced. Additionally, evaluate the inclusion of non-uranium materials (*e.g.*, thorium) in reactor fuel options that may reduce the long-lived radiotoxic elements in the used fuel that would go into a repository.
- *Modified Open Cycle* – Investigate fuel forms and reactors that would increase utilization of the fuel resource and reduce the quantity of long-lived radiotoxic elements in the used fuel to be disposed (per MWh), with limited separations steps using technologies that substantially lower proliferation risk.
- *Full Recycling* – Develop techniques that will enable the long-lived actinide elements to be repeatedly recycled rather than be disposed. The ultimate goal is to develop a cost-effective and low proliferation risk approach that would dramatically decrease the long-term danger posed by the waste, reducing uncertainties associated with its disposal.

DOE will work to develop the best approaches within each of these tracks to inform waste management strategies and decision making.

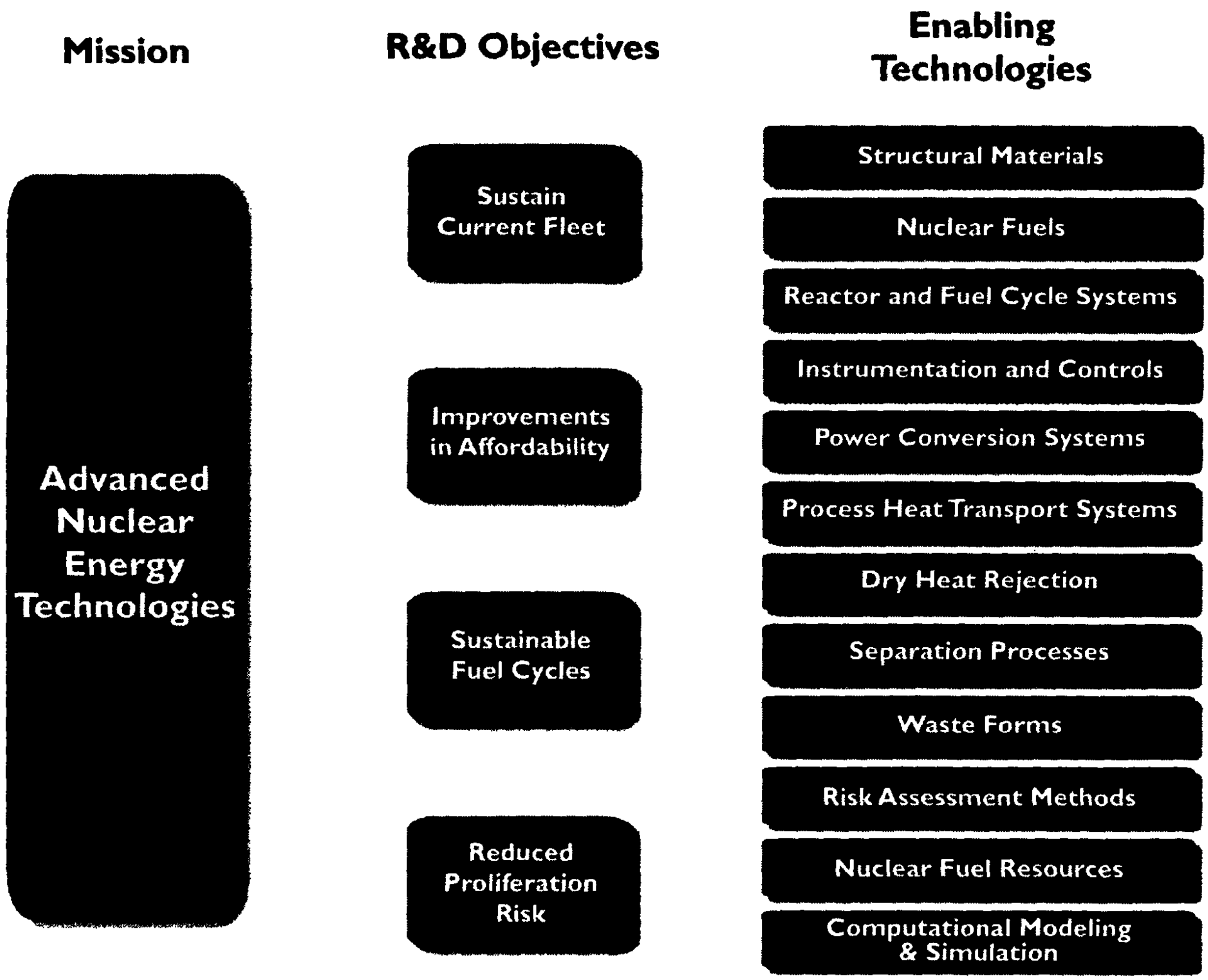
3.2.4 R&D Objective 4: Understand and Minimize the Risks of Nuclear Proliferation and Terrorism

It is important to assure that access to the benefits of nuclear power can be enabled while limiting nuclear proliferation and security risks. This goal requires an integrated approach that incorporates simultaneous development of nuclear fuel cycle technology, safeguards and security technologies and systems, new proliferation risk assessment tools, and non-proliferation frameworks and protocols. These activities must be informed by robust assessments that identify potential approaches for limiting risks of specific technologies and nuclear fuel cycle system options. NE will work with other organizations such as the National Nuclear Security Administration (NNSA), the Department of State, the NRC, and others in further defining, implementing and executing this integrated approach. Aspects of this research may help to inform the exploration of concepts such as international fuel service arrangements.

4. AN INTEGRATED NUCLEAR ENERGY ROADMAP

This section presents an objective-focused roadmap to advance nuclear energy technologies. As depicted in Figure 7, the activities described here ultimately "unpack" to a suite of science and technology development activities, many of which will support more than one R&D objective.

Figure 7. NE Mission, R&D Objectives, and Technologies



The approach incorporates a portfolio of long-term R&D objectives and a balanced focus on evolutionary, innovative, and high-risk–high-payoff R&D in many diverse areas. The organization and coordination of the science and technology thrusts ("Enabling Technologies" in

Figure 7) will be a focus of program and strategic planning follow-on implementation plants, but is briefly addressed in Section 5.2 of this document.

In laying out the activities in each of the R&D objectives described below, we must remain goal-oriented to avoid falling into the trap of doing a great deal of work that, while interesting, fails to address the challenges to the deployment of nuclear energy. The following sections highlight areas in which NE may undertake future R&D. These R&D activities have been considered with the end in mind to ensure that the linkage between research and solution is clear. To that end, in depicting the timelines of activity for the R&D objectives below, the charts show a distinction between near-term milestones toward which the NE R&D plan is designed to progress, represented as triangles, and longer-term potential outcomes that provide a framework for the milestones, which are shown as ovals. The milestone charts attempt to depict the stages of development so as not to leave a sense that new technologies can be immediately deployed at a commercial level. Not every milestone or potential outcome outlined in these charts represent actions that are within DOE's roles and responsibilities, and research paths will include many decision points that require choosing the most promising options for continued R&D. Especially as technology matures, industry has a role and a responsibility to share the costs of making progress. It is ultimately industry's decision which commercial technologies will be deployed. The federal role falls more squarely in the realm of R&D.

These long-term milestones and potential outcomes are not set in stone, and in some cases the following sections outline multiple competing paths within an objective, knowing that ultimately only one direction will be chosen. In all cases, the activities, milestones, and plans outlined in this document will be reconsidered and revised periodically to ensure that NE R&D is consistent with priorities and reflects what we have learned from these efforts. Activities will be reviewed and modified as necessary through the established budgetary and decision-making processes.

Although some smaller component or process "demonstration" activities are mentioned, these are largely field tests and other actions to provide proof or validation of system elements. They are not large-scale demonstrations like the Next Generation Nuclear Plant (NGNP). Any decisions to embark on such large-scale demonstrations will be the result of decision-making processes that include the relevant stakeholders in the Executive Branch and Congress and will be made in accordance with NEPA and DOE Order 413 requirements. This R&D will enable these stakeholders to understand the potential tradeoffs embodied in these decisions.

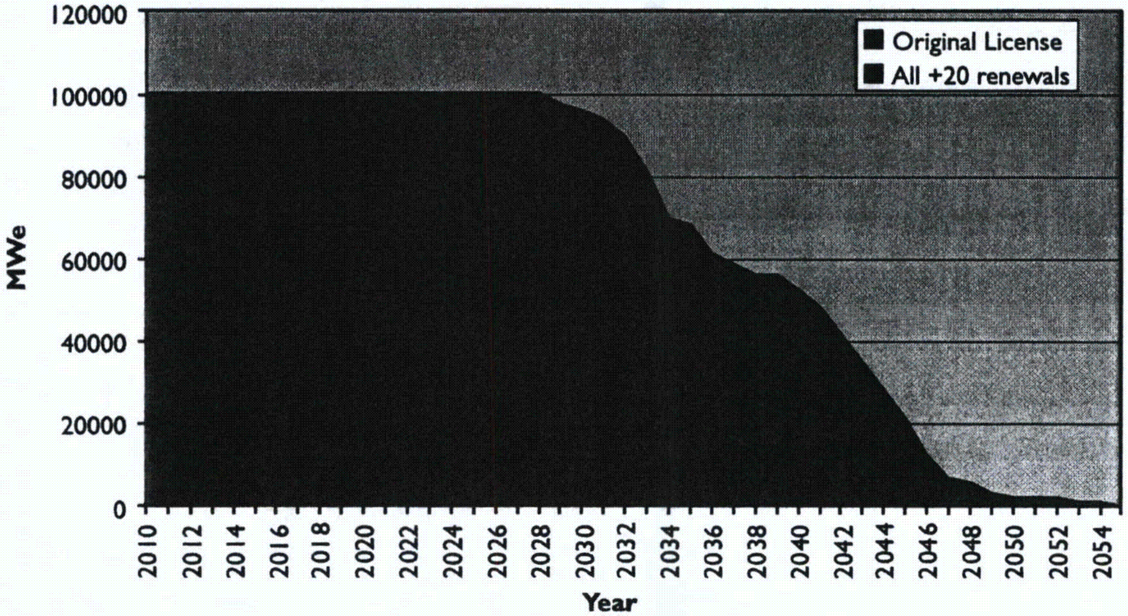
4.1 R&D Objective 1: Develop Technologies and Other Solutions that Can Improve the Reliability, Sustain the Safety, and Extend the Life of Current Reactors

The current fleet of 104 nuclear power plants has reliably and economically contributed almost 20 percent of electricity generated in the United States over the past two decades. However, by

2030, even those current nuclear power plants that have received 20-year extensions from the NRC authorizing 60 years of life will begin reaching the end of their licensed periods of operation. Figure 8 shows projected nuclear energy contribution to domestic generating capacity from those plants that have already received 20-year license extensions. If current plants do not operate beyond 60 years, the total fraction of generated electricity from nuclear power could begin to decline, even with the addition of new nuclear-generating capacity.

Replacing the current fleet would require hundreds of billions of dollars. Replacement of this 100 GWe-generating capacity with traditional fossil plants would lead to significant increases in CO_2 emissions. Extending operating licenses beyond 60 to perhaps 80 years would enable existing plants to continue providing safe, clean and economic electricity without significant GHG emissions. The objective of this R&D objective is to provide a comprehensive technical basis for extending the life of today's LWRs that could be used to inform licensing and managing the long-term safe and economical operation.

Figure 8. Nuclear Capacity With and Without License Extensions



4.1.1 Challenges Facing the Current Fleet

The following are the major challenges facing the current fleet:

- Aging and degradation of system structures and components, such as reactor core internals, reactor pressure vessels, concrete, buried pipes, and cables.
- Fuel reliability and performance issues.
- Obsolete analog instrumentation and control technologies.

- Design and safety analysis tools based on 1980s vintage knowledge bases and computational capabilities.

Industry's economic incentive to meet these challenges in order to continue the safe and reliable operation of existing plants is tremendous. As such, federal activities undertaken in this area will be cost-shared with industry. Industry, working through EPRI or through the various owners' groups, will engage some of these problems directly. Federal R&D investments are appropriate to answer fundamental scientific questions and where private investment is insufficient, to help make progress on broadly-applicable technology issues that can generate public benefits. The government holds a great deal of theoretical, computational, and experimental expertise in nuclear R&D that is not available in industry. The benefits of assisting industry with R&D on life-extension apply not only to current plants but also to the next generation of reactor technologies still in development.

4.1.2 R&D Topics for Life Extension and Performance Improvement

The overall focus of the R&D activities will be to improve a power plant operator's ability to manage the effects of the aging of passive components and increase operational efficiency and economics. In selecting projects for federal investment, it is vital that due consideration be given not only to how each of the R&D activities support achievement of safety and economic sustainability for existing LWRs, but also to how the R&D results will be more broadly applicable to the next generation of reactor technologies. These activities should also be integrated with outside sources of information and parallel R&D programs in industry, the NRC, universities, and other laboratories, both domestic and international. Close coordination with the NRC as appropriate is needed to assure that R&D programs focus on issues relevant to licensing.

The following are R&D topics where NE will focus its efforts to help provide solutions to the challenges listed above, thereby helping enable reactor life extension beyond 60 years with improved performance. Progress on this long-term and high-risk–high-reward R&D, which supports the current nuclear power plant fleet, will provide the scientific underpinnings for plant owners to make billion-dollar investment decisions to prolong the economic lifetime of these assets. R&D findings will also inform improvements in the lifetime of future-generation reactor designs.

- *Nuclear Materials Aging and Degradation* – Develop a scientific basis for understanding and predicting long-term environmental degradation behavior of materials in nuclear power plants. Provide data and methods to assess performance of systems, structures, and components essential to safe and sustained nuclear power plant operation.
- *Advanced LWR Nuclear Fuel Development* – Improve the scientific knowledge basis for understanding and predicting fundamental nuclear fuel and cladding performance in nuclear power plants. Apply this information to the development of high-performance, high-burnup fuels with improved safety, cladding, integrity, and economics.

- *Advanced Instrumentation, Information, and Control (II&C) System Technologies* – Research to address long-term aging and obsolescence of existing instrumentation and control technologies and to develop and test new technologies. Establishing a strategy to implement long-term modernization of II&C systems will be the focus of federal R&D, while industry will focus on the more immediate benefits of adapting existing digital technologies to current plants. NE will work with industry to develop advanced condition-monitoring technologies for reliable plant operation, improved understanding of physical methods of degradation, and the means to detect and characterize these processes.
- *Risk-Informed Safety Margin Characterization (RISMC)* – Bring together risk-informed, performance-based methodologies with fundamental scientific understanding of critical phenomenological conditions and deterministic predictions of nuclear plant performance to provide an integrated characterization of public safety margins in aging nuclear power plants. Such an approach will better characterize safety margins and should improve the reliability and efficiency of plant operations. RISMC will also be applicable to future generations of nuclear power plants.
- *Efficiency Improvement* – Improve the efficiency of the current fleet while maintaining excellent safety performance is one of the primary objectives of life extension. Power uprates have contributed to improving the current fleet's economic performance. This activity focuses on developing methodologies and scientific bases to enable more extended power uprates.
- *Advanced Modeling and Simulation Tools* – Conduct R&D needed to create a new set of modeling and simulation capabilities that will be used to better understand the safety performance of the aging reactor fleet. These tools will be fully three-dimensional, high-resolution, modeling integrated systems based on first-principle physics. To accomplish this, the modeling and simulation capabilities will have to be run on modern, highly parallel processing computer architectures.

The sustainability of light water reactors will benefit enormously from advanced modeling and simulation capabilities. The NE Modeling and Simulation Hub will integrate existing nuclear energy modeling and simulation capabilities with relevant capabilities developed by the Office of Science, the NNSA, and others. The results will leapfrog current technology to provide a multi-physics, multi-scale predictive capability that is a revolutionary improvement over conventional codes. A key challenge will be to adapt advanced computer science tools to an applications environment. The hub is intended to create a new state-of-the-art in an engineering-oriented multi-physics computational environment that can be used by a wide range of practitioners to conduct ultra-high fidelity predictive calculations of reactor performance.

4.1.3 Key Activities

The following chart outlines potential milestones and future national industry aims for this objective. It presents a distinction between near-term milestones toward which the NE R&D plan is designed to progress, represented as triangles, and longer-term potential outcomes that provide a framework for the milestones, shown as ovals. The milestone charts attempt to depict the stages of development so as not to leave a sense that new technologies can be immediately deployed at a commercial level. Not every milestone or potential outcome outlined in these charts represents actions that are within DOE's roles and responsibilities, and research paths will include many decision points that require choosing the most promising options for continued R&D. All DOE R&D activities will be evaluated and revisited regularly and modified as necessary through the budget process to ensure the portfolio reflects past progress and current priorities.

Although some smaller component or process "demonstration" activities are mentioned, these are largely field tests and other actions to provide proof or validation of system elements. They are not costly, large-scale demonstrations like NGNP. Any consideration to embark on such large-scale demonstrations will be the result of decision-making and budget development processes.

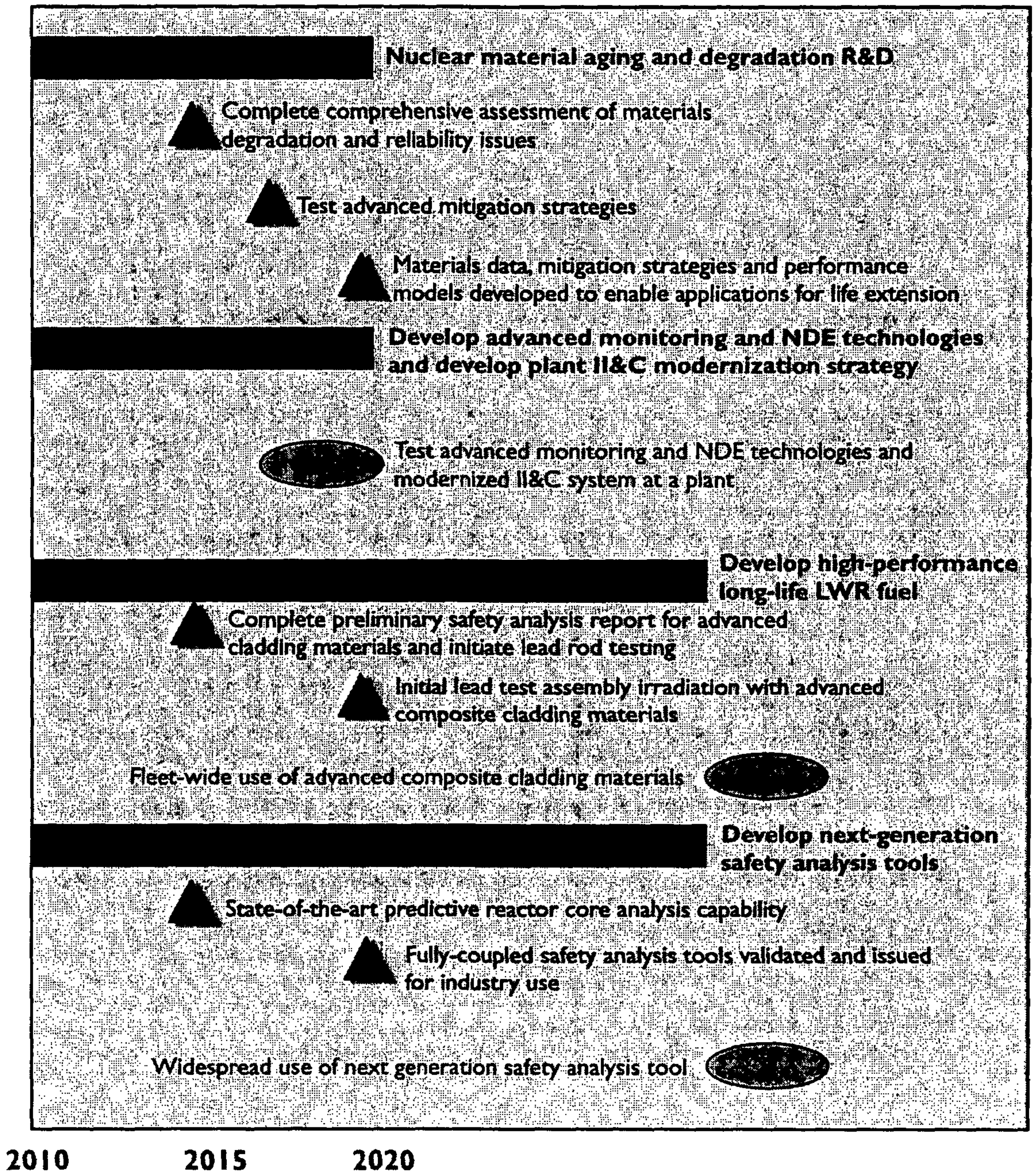
4.2 R&D Objective 2: Develop Improvements in the Affordability of New Reactors to Enable Nuclear Energy to Help Meet the Administration's Energy Security and Climate Change Goals

The previous 30-year U.S. hiatus in new nuclear plant orders presents a number of immediate hurdles for the construction of new plant designs. Utility investors are still wary of the new regulatory framework, which will not be fully exercised until the first new plant begins operation. There are also concerns regarding the large capital costs of plants and associated difficulties in financing their construction.

NE's objective is to assist in the revitalization of the U.S. industry through R&D. By advancing technologies through R&D, NE can help accelerate deployment of new plants in the short term, support development of advanced concepts for the medium term, and promote design of revolutionary systems for the long term. Work will be done in partnership with industry to the maximum extent possible. Elements of NE's strategy in this area include:

- Assist industry to improve light water reactors using existing technologies and designs.
- Explore advanced LWR designs with improved performance.
- Research and develop small modular reactors that have the potential to achieve lower proliferation risks and more simplified construction than other designs.

Figure 9. Key Activities for R&D Objective 1



- In the longer term, support R&D of advanced reactor technologies that offer lower costs and waste generation.
- Investigate revolutionary reactor concepts that promise to significantly reduce costs and improve performance of nuclear energy.
- Support R&D of nuclear energy's potential to displace fossil fuels in the production of process heat.

Implementing this strategy will require that DOE work in partnership with the nuclear industry and, to the degree appropriate, the NRC.

4.2.1 Challenges Facing New Reactor Deployments

There are several new plant designs, often referred to as Gen III+, that have been certified or are being reviewed by the NRC for immediate deployment in the United States. Potential owners of these Gen III+ plants must overcome serious financial hurdles. All near-term options for new plants are large LWR designs that are optimized for baseload electricity production. Smaller reactors that could be deployed in modules might help reduce the up-front capital costs associated with large plants by allowing utilities to incrementally "step up" to larger electrical capacities while generating revenue and repaying initial debts. New reactor designs beyond Gen III+ may also be deployed. In many cases, new technologies will be needed to enable these new designs, and innovative features will need to be fully demonstrated. Certain aspects of the regulatory framework need to accommodate these new technologies and design features, especially for designs that differ significantly from the large LWR plants in operation today. Economic competitiveness will remain the major hurdle for all novel concepts, including smaller reactors and reactors for non-electric applications.

During the 30-year hiatus from new plant orders in the United States, some nations have continued to grow their nuclear industries. As a result, some other countries have advanced the state-of-the art in manufacturing of nuclear plant components and have made progress in applying more efficient construction techniques. The domestic industry can learn from these international experiences.

4.2.2 R&D Topics for Enabling New Builds

In the United States, it is the responsibility of industry to design, construct, and operate commercial nuclear power plants. However, DOE has statutory authority under the Atomic Energy Act to promote and support nuclear energy technologies for commercial applications. In general, appropriate government roles include researching high-potential technologies beyond the investment horizon of industry and also reducing the technical risks of new technologies. In the case of new commercial reactor designs, potential areas of NE involvement could include:

- Enabling new technologies to be inserted into emerging and future designs by providing access to unique laboratory resources for new technology development and, where appropriate, demonstration.
- Working through the laboratories and universities to provide unique expertise and facilities to industry for R&D in the areas of:
    - Innovative concepts and advanced technologies.
    - Fundamental phenomena and performance data.
    - Advanced modeling and simulation capabilities.

- New technology testing and, if appropriate, demonstration.
- Advanced manufacturing methods.

Representative R&D activities that support each of the roles stated above are presented below. The level of DOE investment relative to industry investment will vary across the spectrum of these activities, with a generally increasing trend in DOE investment for longer-term activities. Finally, there is potential to leverage and amplify effective U.S. R&D through collaborations with other nations through multilateral and bilateral agreements including the Generation IV International Forum, which is investigating multiple advanced reactor concepts. DOE is also a participant in OECD/NEA and IAEA initiatives that bear directly on the development and deployment of new reactor systems.

4.2.2.1 Accelerate Advancements in LWR Designs

Given the maturity of the Gen III+ LWR designs, R&D needs are necessarily limited, as the design of these plants is well underway or already complete, some of them are being built overseas, and many have been ordered in the United States and elsewhere. Nevertheless the R&D topics identified jointly with industry for R&D Objective 1 are all applicable to this task.

R&D of more advanced LWR concepts, including novel materials, fuels, and innovative system architectures, is a legitimate role for DOE and its laboratories in partnership with industry. This R&D will help address long-term trends in the capital cost of large LWR plants. Much of this research is also expected to be applicable to non-LWR technologies.

4.2.2.2 Accelerate the Development of SMR Designs

Several U.S.-based companies are seeking to bring new SMR designs to market, including some with potential for deployment within the next decade. Many of these designs use well-established light-water coolant technology to the fullest extent possible to shorten the timeline for deployment. As such, R&D needs for these technologies are minimal. However, these designs may include new features, such as the use of an integral primary system reactor (IPSR) design and components that are not currently used in commercial plants, such as helical-coil steam generators. DOE will hold workshops with LWR SMR vendors and suppliers, potential utility customers, national laboratory and university researchers, DOE, NRC, and other stakeholders to identify potential priorities to enable their commercialization and development. The Administration will evaluate potential priorities in the context of the appropriate federal role to identify the most cost-effective, efficient, and appropriate mechanisms to support further development.

SMR designs that are not based on LWR technology have the potential to offer added functionality and affordability. In this area, NE will support a range of R&D activities, such as basic physics and materials research and testing, state-of-the-art computer modeling and simulation of reactor systems and components, probabilistic risk analyses of innovative safety designs and features, and other development activities that are necessary to establish the concept's feasibility for future deployment. For SMRs that are based on concepts with lower levels of technical maturity, the Department will first seek to establish the R&D activities necessary to prove and advance innovative reactor technologies and concepts. The Department will support R&D activities to develop and prove the proposed design concepts. Emphasis will be on advanced reactor technologies that offer simplified operation and maintenance for distributed power and load-following applications and increased proliferation resistance and security.

Activities will focus on showing that SMRs provide an innovative reactor technology that is capable of achieving electricity generation and performance objectives that meet market demands and are comparable, in both safety and economics, to the current large baseload nuclear power plants.

NE may also support the development of new/revised nuclear industry codes and standards necessary to support licensing and commercialization of innovative designs and, consistent with NRC guidance and regulations, identify activities for DOE funding to enable SMR licensing for deployment in the United States.

4.2.2.3 Develop Advanced Reactor Technologies

Future-generation reactor systems will employ advanced technologies and designs to improve performance beyond what is currently attainable. Moving beyond LWR technology, for example, may enable reactors to operate at higher temperatures and improved efficiencies resulting in improved economics. Advanced materials may make reactors easier to construct while also enabling better performance. Improved designs utilizing these advances could reduce the capital costs associated with the current set of reactors being considered. Two prominent examples of advanced reactor technologies worthy of further investigation include:

- The high temperature gas-cooled reactor (HTGR), a graphite moderated thermal-spectrum reactor operated at high temperature for efficient generation of electricity and heat delivery for non-electric applications.
- Fast-spectrum reactors that could provide options for future fuel cycle management and could also be used for electricity generation (see R&D Objective 3).

The U.S. is also a member of the Generation IV International Forum, which is investigating additional advanced reactor systems that employ comparatively less mature technologies while offering significant potential for performance, safety, and economic advances.

Key areas of R&D for future systems could include:

- High-performance materials compatible with the proposed coolant types and capable of extended service at elevated temperatures.

- New fuels and cladding capable of irradiation to high burnup.
- Advanced heat delivery and energy conversion systems for increased efficiency of electricity production.
- Advanced modeling and simulation tools that can reduce uncertainties in predicted performance, improve characterization of uncertainties, and streamline the design of new reactor technologies.
- Systems design for revolutionary new reactor concepts.

4.2.2.4 Develop Technologies Consistent with Both Electric and Non-Electric Applications

An additional potential benefit from nuclear power could be realized through new plant designs that would be used to displace GHG-emitting fuels in the industrial sector while also generating electricity. Some industrial process heat applications require temperatures substantially above the 300–325°C outlet temperature of today's LWRs. Petroleum refining, for example, requires temperatures in the range of 250-500°C while steam reforming of natural gas requires process heat in the 500-900°C range. Achieving higher output temperatures requires switching to a new coolant technology such as gas, liquid metal, or molten salt. With these coolants, it may be possible to achieve outlet temperatures ranging from over 500°C for liquid metal coolants to over 900°C for helium or molten salt coolants. Achieving these temperatures, however, will require the development and qualification of fuels, materials and instrumentation, particularly at the higher end of the temperature range. Also, the use of coolants other than water will require the development of a variety of plant components and systems such as electromagnetic pumps for liquid metal coolants, compact heat exchangers for gas coolants, and chemical purification systems for molten salt coolants. These coolants will also require the development of new licensing requirements and codes and standards. While the economic market for dedicated process heat from nuclear power may be limited, reactors that could produce electricity as well as industrial process heat may have broader applications.

Key areas of R&D for future systems could include:

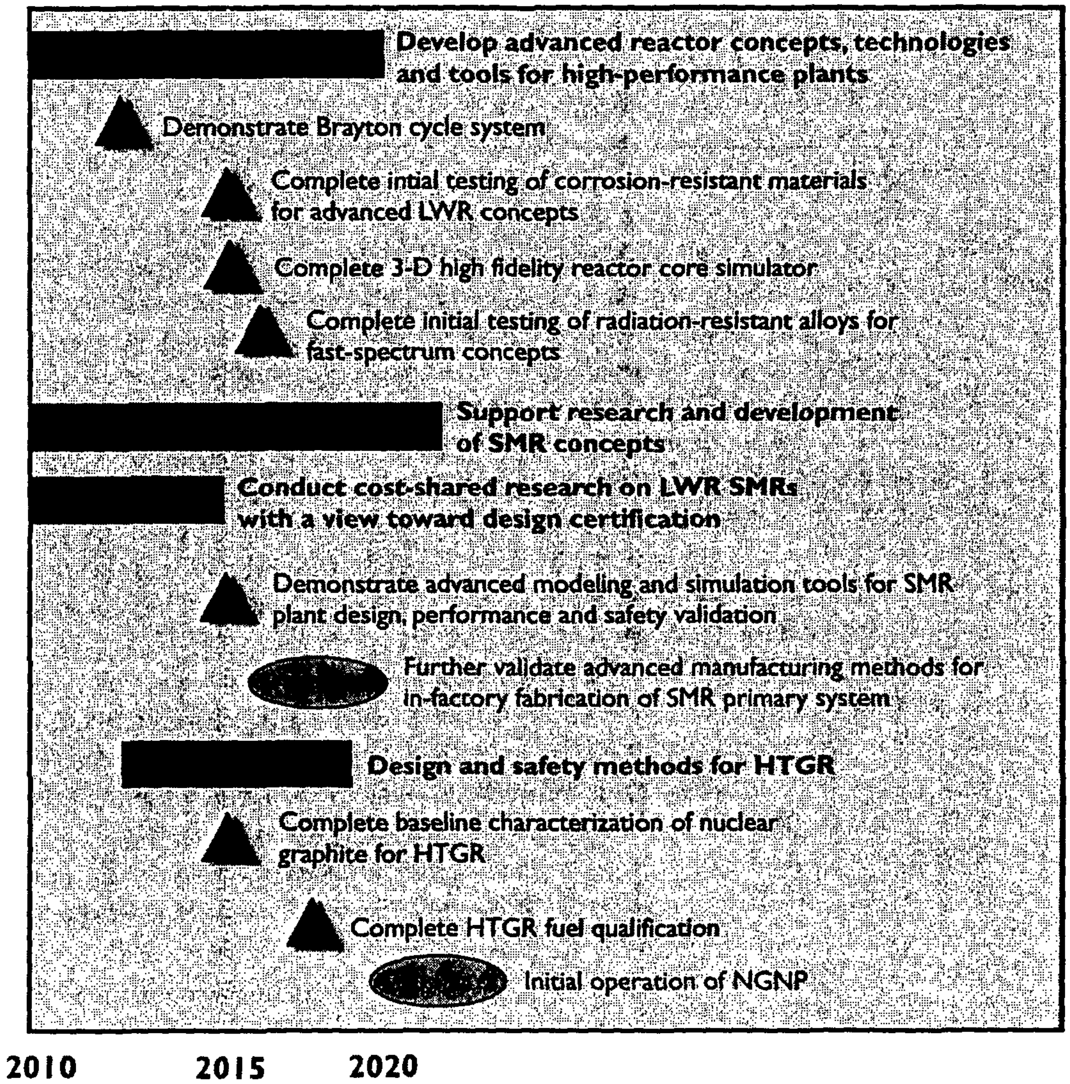
- *Develop interfacing heat transport systems* – Supply process heat with minimal losses to industrial users within several kilometers of the reactor.
- *Develop modeling and simulation capabilities* – These tools would improve understanding of interactions between the kinetics of the various reactor types and the kinetics of the chemical plants or refineries, which they would serve. Modeling may also be used to understand the long-term performance of catalysts and solid-oxide cells at an atomistic level.

4.2.3 Key Activities

The following chart outlines potential milestones and future national industry aims for this objective. It presents a distinction between near-term milestones toward which the NE R&D plan is designed to progress, represented as triangles, and longer-term potential outcomes that provide a framework for the milestones, shown as ovals. The milestone charts attempt to depict the stages of development so as not to leave a sense that new technologies can be immediately deployed at a commercial level. Not every milestone or potential outcome outlined in these charts represents actions that are within DOE's roles and responsibilities, and research paths will include many decision points that require choosing the most promising options for continued R&D. All DOE R&D activities will be evaluated and revisited regularly and modified as necessary through the budget process to ensure the portfolio reflects past progress and current priorities.

Although some smaller component or process "demonstration" activities are mentioned, these are largely field tests and other actions to provide proof or validation of system elements. They are not costly, large-scale demonstrations like NGNP. Any consideration to embark on such large-scale demonstrations will be the result of decision-making and budget development processes.

Figure 10. Key Activities for R&D Objective 2

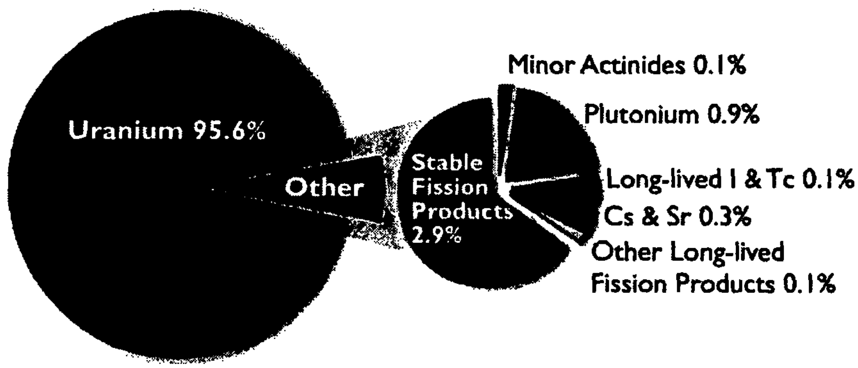


4.3 R&D Objective 3: Develop Sustainable Nuclear Fuel Cycles

Sustainable fuel cycle options are those that improve uranium resource utilization, maximize energy generation, minimize waste generation, improve safety, and limit proliferation risk. The principal challenge for the government in this objective is to develop a suite of options that will enable future decision makers to make informed choices about how best to manage the used fuel from reactors. The Administration has established the Blue Ribbon Commission on America's Nuclear Future to inform this waste management decision-making process. The Commission will review policies for managing the back end of the fuel cycle including alternatives for the storage, processing, and disposal of civilian and defense used nuclear fuel and nuclear waste. All research and development activities and plans outlined here will be revisited and revised as needed to reflect the Commission's findings and associated Administration decisions.

An expansion of nuclear power in the United States will result in a growth of the used nuclear fuel inventories. The Nuclear Waste Policy Act of 1982 gave the U.S. government the mission to safely manage the used fuel from these nuclear power plants. Research and development of sustainable nuclear fuel cycles and waste management activities is important to support the expansion of nuclear energy. Some of the attributes of the sustainable fuel cycle, including waste management and disposal technologies, include the responsible use of natural resources, preservation of the environment for future generations, safety, security, public acceptance, and cost effectiveness.

Figure 11. Constituents of Used LWR Fuel



The constituents of current used nuclear fuel (UNF) after discharge from LWRs are shown in Figure 11. As this figure shows, the vast majority of the material in the used fuel is uranium that is generally unchanged from the fuel that went into the reactor to produce energy. Uranium is considered an element in the category called "actinides," along with the "transuranic" elements of plutonium and the "minor" actinides: neptunium, americium, and curium, principally. These elements generally are long-lived and must be isolated from the environment for tens or hundreds of thousands of years. Actinides are also of interest because uranium and plutonium could be recycled to produce more energy in reactors, as could the minor actinides in fast-spectrum reactors. The remaining class of elements in the used fuel is fission products, many of which are stable and pose little concern. The short-lived fission products – primarily cesium and strontium – generate most of the hazard for the first hundreds of years of disposal. There are also fission products, notably iodine and technetium, that last for hundreds of thousands of years and must be isolated from the environment.

NE will research and develop nuclear fuel and waste management technologies that will enable a safe, secure, and economic fuel cycle. The NE R&D strategy will be to investigate the technical challenges that would be encountered in each of three potential methods and perform R&D within each of these tracks:

- *Once-Through* – Nuclear fuel makes a single pass through a reactor after which the used fuel is removed, stored for some period of time, and then directly disposed in a geologic repository for long-term isolation from the environment. The used fuel will not undergo any sort of treatment to alter the waste form prior to disposal in this approach, eliminating the need for separations technologies that may pose proliferation concerns. Less than one percent of the mined uranium is utilized in the present once-through fuel cycle.

- *Modified Open Cycle* – The goal of this approach is to develop fuel for use in reactors that can increase utilization of the fuel resource and reduce the quantity of actinides that would be disposed in used fuel. This strategy is "modified" in that some limited separations and fuel processing technologies are applied to the used LWR fuel to create fuels that enable the extraction of much more energy from the same mass of material and accomplish waste management goals.
- *Full Recycle* – In a full recycle strategy, all of the actinides important for waste management are recycled in thermal- or fast-spectrum systems to reduce the radiotoxicity of the waste placed in a geologic repository while more fully utilizing uranium resources. In a full recycle system, only those elements that are considered to be waste (primarily the fission products) are intended for disposal, not used fuel. Implementing this system will require extensive use of separation technologies and the likely deployment of new reactors or other systems capable of transmuting actinides.

The R&D approach will be to understand what can be accomplished in each of these strategies and then to develop the promising technologies to maximize their potential. One element that crosscuts all potential approaches is disposal and R&D activities will include a focus on those technologies. Additionally, storage will be an important part of any strategy, and R&D will be needed to assess the performance of storage technologies with higher-burnup used LWR fuels, as well as any potential new fuels that may be deployed in the future.

The discussion above is primarily focused on the uranium fuel cycle that is the norm throughout the world. An alternative that could be considered would be the use of thorium to replace at least part of the uranium in the system. Thorium could be used as part of a once-through, modified open, or full recycle fuel cycle. The appeal of thorium is two-fold. First, thorium is more abundant in nature than uranium and can be used to extend or replace uranium in the fuel cycle. Second, the use of thorium enables reduced production of transuranic elements that end up in used fuel. However, there are still technical and economic challenges facing thorium-based fuels. Thus some R&D to address related challenges may be considered. Significant R&D in the use of thorium has been performed previously in the United States and is currently being considered in other parts of the world (particularly in India).

Unlike R&D Objectives 1 and 2, management of UNF and development of fuel cycle technologies are primarily the government's responsibilities because the government is legally responsible for UNF. Thus, the necessary research, development, and demonstration, if appropriate, will be led primarily by the government. However, early and continuous industrial involvement is important because any technologies that are developed will ultimately be implemented by the commercial entities.

4.3.1 Major Challenges Associated with Fuel Cycle Options

Each of the potential fuel cycle strategies faces challenges, some of which may be shared with other approaches. Similarly, the R&D needed to overcome these challenges may support more than one strategy.

- *Once-Through* – Improving the sustainability of a once-through approach to used fuel management begins with increasing the burnup of the fuel – the amount of energy that can be extracted from fuel in the reactor – which may also have the effect of consuming more actinides in the fuel, leaving less to be disposed. Increasing the burnup of a fuel will require ensuring that both the fuel itself and the structural material designed to keep it in place in the reactor will be able to withstand extended irradiation in the reactor and maintain its integrity when being stored after removal. Deploying advanced fuels will require that they first undergo a qualification process that can take a great deal of time, as researchers must irradiate and conduct examinations on test samples to assure their performance. Also, fuels that are notably different from those currently used in LWR's may drive changes in the fuel processing infrastructure that has evolved to meet current needs. To the extent that the deployed once-through fuel cycle is built upon enriched uranium fuels, the proliferation concerns associated with enrichment technologies will need to be addressed.
- *Modified Open Cycle* – A modified open cycle faces some of the same challenges as the once-through, along with some encountered in a full recycle approach. The modified open cycle introduces the possibility of a used fuel separations step to enable more options for producing fuels. This flexibility enables the inclusion of transuranic elements – notably plutonium – at concentrations capable of supporting ultra-high burnup, along with the attendant difficulties of developing these fuels. The challenges of developing high-burnup fuels discussed in the previous paragraph are applicable to this strategy. The use of separations technology to prepare the ultra-high-burnup fuel introduces difficulties in separations as well as managing proliferation concerns. A key element of this fuel cycle is the likely need to introduce advanced reactors that can utilize these new fuels. The overarching challenge in making a modified open cycle worthwhile is to determine if the improvement in fuel resource utilization and in the waste to be disposed is sufficient to justify the additional complication, potential proliferation concerns, and expense this approach would entail.
- *Full Recycle* – In a full recycle approach, used fuel is not directly disposed in a repository; rather, those elements of the used fuel that are deemed appropriate for recycling are reintroduced into reactors or other systems while the remaining elements are stabilized in a waste form and disposed. This strategy offers the potential of waste forms that pose far less long-term concern, although the approach would require overcoming not only technical challenges but also economic, proliferation, and public perception concerns. This system would rely on multiple separations processes that must minimize process losses and

waste generation while addressing proliferation concerns. Furthermore, fuels must be developed that will allow for the inclusion of all of those elements that are to be recycled in concentrations that vary over time. This is a central tradeoff in the full recycle approach: the more elements that are recycled, the better the waste form will be; however, more separation of elements in the fuel increases the technical and other challenges. Elements that are recycled must be capable of transmutation in a system – likely, but not necessarily, a fast reactor – to eventually eliminate them. In order for a full recycle strategy to be considered, the waste benefits and improved resource utilization produced by such a system must outweigh the complication, expense and potential proliferation concerns associated with it.

4.3.2 R&D for Sustainable Fuel Cycle Options

There are major R&D needs to understand how best to overcome the challenges posed by each of the fuel cycle approaches being considered. The potential R&D efforts that DOE would undertake would have a long-term view and would be science-based. It would take considerable time before the issues in the modified open and the full recycle alternatives would be overcome. Many R&D areas will be applicable to multiple strategies. Prior to beginning major R&D work in these areas, analyses will be performed to gauge the likely value of the efforts.

- *Fuel Resource Exploration and Mining* – The availability of fuel resources for each potential fuel cycle and reactor deployment scenario must be understood. Extended use of nuclear power may drive improvements in defining resource availability and on fuel resource exploration and mining. Primarily, this is work that the private sector would undertake, and how and when this would occur would depend on price and other market conditions. This is most relevant for a once-through approach, but even modified open cycles and full recycle systems may require comparable levels of natural sources of fuel for the foreseeable future. Most appropriate for federal involvement in this area would be R&D to support investigation of long-term, "game-changing" approaches such as recovering uranium from seawater.
- *Used Fuel Disposition* – All radioactive wastes generated by existing and future fuel cycles will need to be safely stored, transported, and disposed. This R&D will identify options for performing these functions, including research into disposal in a variety of geologic environments. This R&D will consider used fuel and high-level waste inventories arising from the current reactor fleet and any additional new builds, including the potential for changing used fuel characteristics from enhanced operations (*e.g.*, increased fuel burnup) and the projected inventories from advanced reactor and fuel cycle systems (*e.g.*, HTRs and SMRs). This research is important to all of the potential fuel cycle approaches.
- *Reduce Transuranic Production In Reactors* – One thrust in developing sustainable fuel cycles will be the exploration of nuclear fuels and reactors that significantly reduce the long-lived actinide content of the used fuel per MWh of energy produced. Exploration of

avenues both to reduce actinide production in present and near-term LWRs and to develop future non-LWR systems that produce lower actinide inventories in their used fuel is important. This research area is central to developing the high burnup fuels that will improve the attractiveness of a once-through or modified open fuel cycle.

- *Separation and Partitioning* – The development of processes to recycle used fuel is needed, as well as an evaluation of the feasibility and risks associated with recycling. The objective is to use a predictive approach to evaluate separation chemistry and processes to achieve the desired performance in terms of product purity, environmental impact, and losses. Though not applicable in a once-through system, this topic would be germane to a modified open cycle approach and central to a full recycle strategy.
- *Waste Forms* – It is necessary to develop understanding of waste form behavior over time to help inform decisions on recycle and disposal options. This understanding must extend over a broad range of potential waste chemistry and disposal environments so waste forms can be adapted and implemented when specific repository conditions are known. This R&D area may be somewhat relevant to strategies that rely on the direct disposal of certain used fuels (such as disposal of high-temperature gas reactor fuels) but the development of improved waste forms is a key component in enabling a full recycle strategy to achieve its promise.
- *Fuel Forms* – The science-based approach will combine theory, experiments, and multi-scale modeling and simulation aimed at a fundamental understanding of the fuel fabrication processes and fuel and clad performance under irradiation. The objective is to use a predictive approach to design future fuels and cladding to enable the development of ultra-high-burnup fuels in a modified open cycle and to demonstrate the inclusion of recovered actinides in transmutation fuels under a full recycle approach. In the early phases of the program, the major fuel fabrication activities include development of innovative processes to enhance the process efficiency and to improve the control of fuel microstructure for enhanced performance, including tailored fuel forms designed to limit excess actinides across the complex.
- *Material Reuse* – The research will focus primarily on recovered uranium for reuse in reactors to obviate the need to dispose of this material once separated from the rest of the used fuel. The critical areas that require process or equipment modifications will be identified, and technologies will be developed to enable the reuse (and in some cases the re-enrichment) of recycled uranium. Efforts will also investigate the potential recycling and reuse of other constituents of used fuel, such as the zirconium cladding, that are potentially useful but not currently being considered by industry because of uncertainties about material characteristics.
- *Transmutation Systems* – Transmutation is a process to change the characteristics of waste by turning recycled elements into elements with more desirable disposal characteristics. While the focus of most recent work has been on fast-spectrum transmutation reactors, thermal-spectrum transmutation can offer some waste management benefits. R&D would

focus on broadly applicable issues including areas such as materials and energy conversion. In addition, studies may be conducted to review the technical and economic aspects of external neutron source-driven transmutation systems to inform whether future investigation in this approach is warranted.

4.3.3 Key Activities

NE's science-based R&D program will provide a more complete understanding of the underlying science supporting the development of advanced fuel cycle and waste management technologies and, therefore, help provide a sound basis for future decision making. The program will also conduct scientific research and technology development to enable storage, transportation, and disposal of used nuclear fuel and all radioactive wastes generated by existing and future nuclear fuel cycles. Over the next decade, the R&D program will mainly be geared to ensuring that the needed breakthroughs and advancements are available and ready when needed. Examples of such technologies would include ultra-deep-burn LWR, HTR, or fast reactor fuel; reactor technologies to support optimized once-through fuel cycles; and advanced fast reactor concepts to support closed fuel cycles. These technologies would encompass all of the known and anticipated advances that could be expected to be available in areas including materials, design methods, components, and energy conversion.

In keeping with Secretary Chu's vision of using science to provide technological breakthroughs to solve America's grand challenges, the program will include long-term, high-risk–high-payoff R&D. This part of the program will seek revolutionary and transformational breakthroughs in systems, materials and components of the fuel cycle that can better meet the program's objectives. Examples of this could include novel reactor concepts such as molten-salt fuel reactors or thorium fuel cycles. Thus while evolutionary advancements are being made, revolutionary advancements will also be pursued such that, if successful, they could replace all or part of existing or near-term technologies. The roadmap includes milestones for selection of technologies as the program matures. Each approach has a set of reference technologies associated with these milestones:

- *Once-Through* – Develop higher-burnup fuel for LWRs.
- *Modified Open Cycle* – Develop ultra-high-burnup fuel for high-temperature gas-cooled reactors using transuranic elements from used LWR fuel. It is assumed that the NGNP or a comparable reactor will be available for fuel testing. Alternative approaches may require access to a fast-spectrum test reactor and nuclear fuel research capabilities.
- *Full Recycle* – Develop technologies to allow repeated recycling of transuranic elements in fast-spectrum reactors. The initial fuel for the fast reactors will come from separated used LWR fuel with successive reloads made from used fast reactor fuel. Access to a fast-spectrum test reactor will be essential for this research, as will nuclear fuel research capabilities.

The following chart outlines potential milestones and future national industry aims for this objective. It presents a distinction between near-term milestones toward which the NE R&D plan is designed to progress, represented as triangles, and longer-term potential outcomes that provide a framework for the milestones, shown as ovals. The milestone charts attempt to depict the stages of development so as not to leave a sense that new technologies can be immediately deployed at a commercial level. Not every milestone or potential outcome outlined in these charts represents actions that are within DOE's roles and responsibilities, and research paths will include many decision points that require choosing the most promising options for continued R&D. All DOE R&D activities will be evaluated and revisited regularly and modified as necessary through the budget process to ensure the portfolio reflects past progress and current priorities.

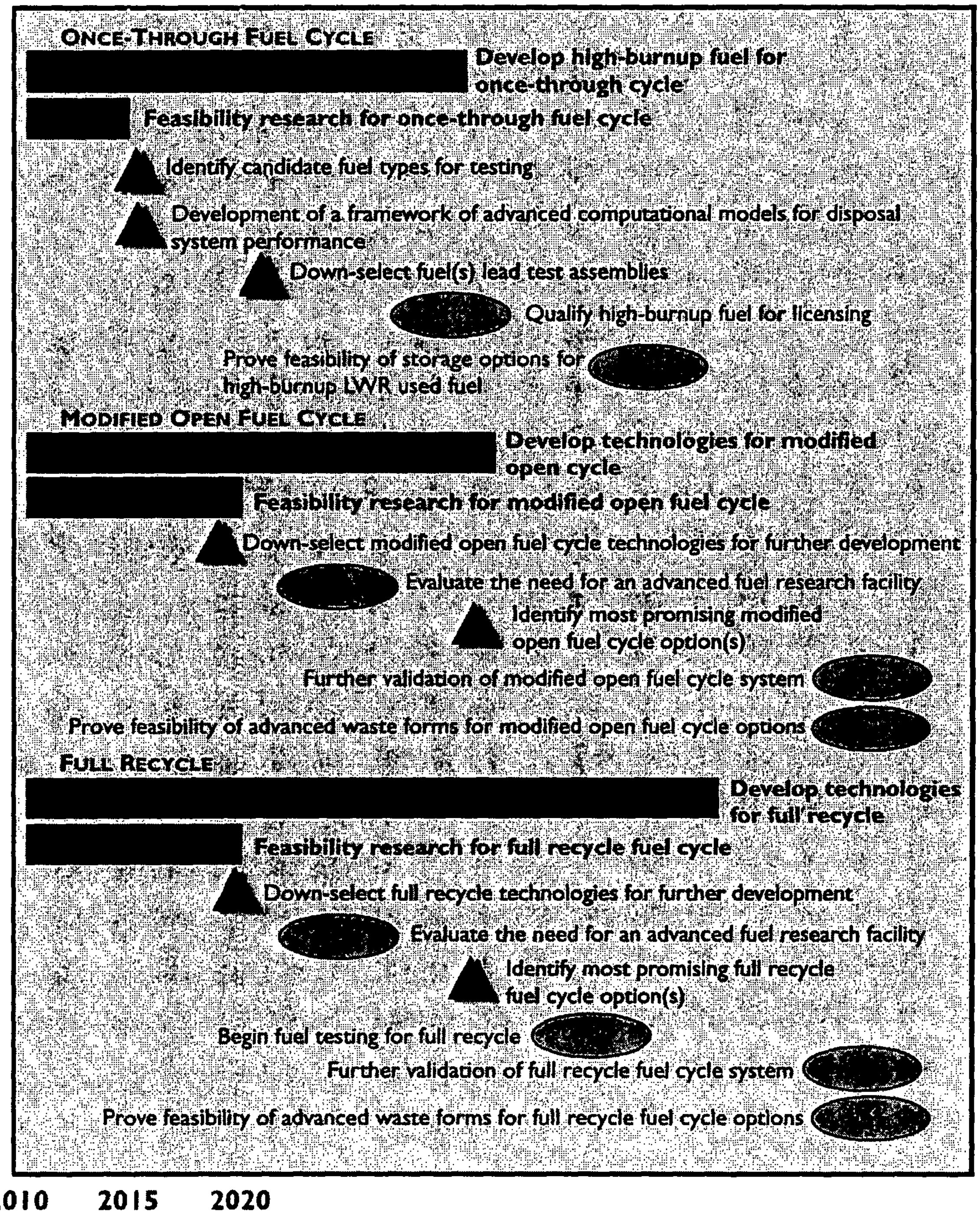
Although some smaller component or process "demonstration" activities are mentioned, these are largely field tests and other actions to provide proof or validation of system elements. They are not costly, large-scale demonstrations like NGNP. Any consideration to embark on such large-scale demonstrations will be the result of decision-making and budget development processes.

4.4 R&D Objective 4: Understanding and Minimizing the Risks of Nuclear Proliferation and Terrorism

The final R&D objective for nuclear energy is to enable secure nuclear energy expansion by developing and demonstrating options that limit proliferation and physical security risks associated with nuclear power while also achieving economic, public health and safety, and environmental goals. These risks include not only the possibility that nations may attempt to use nuclear technologies in pursuit of a nuclear weapon, but also the concern that terrorists might seek to steal material that could be used in a nuclear explosive device. This requires NE advocacy for, and participation in, an integrated program to develop technologies, frameworks, and policy options for the future nuclear enterprise, cutting across all aspects of the fuel cycle.

The United States has extensive experience protecting nuclear materials, from the weapons program that has produced significant quantities of plutonium-239 and highly enriched uranium, to 104 commercial reactors in the U.S. today that handle, use, and store nuclear materials. Internationally, the U.S. has also contributed extensively to the development of technologies now used in the application of international safeguards to monitor used fuel recycling activities in England, France, and Japan. Going forward, safeguards and physical security will become even more integral components in the domestic and global expansion of nuclear power, including the development of future fuel cycle and reactor technologies that further increase the barriers against proliferation and nuclear terrorism.

Figure 12. Key Activities for R&D Objective 3



An integrated U.S. safeguards program provides an opportunity to design improved safeguards and physical security directly into the planning and deployment of new energy systems and fuel cycle facilities. Incorporating safeguards and physical security into the early design phase for new facilities will allow the international community to monitor and verify nuclear material more effectively and efficiently.

DOE has three programs that are collaborating to address safeguards and nonproliferation challenges. The NE Fuel Cycle R&D Materials Protection, Accounting, and Control for Transmutation (MPACT) campaign develops advanced nuclear material management technologies and methods in support of the future domestic U.S. nuclear fuel cycle. The Next Generation Safeguards Initiative (NGSI) within the NNSA Office of Nonproliferation and International Security is designed to leverage U.S personnel, technology, and R&D to add new capacity and significantly strengthen international nuclear safeguards. The third program, the NNSA Office of Nonproliferation Research and Development's Global Nuclear Safeguards R&D Program, whose mission is to support long-term nonproliferation R&D, rounds out the U.S. safeguards R&D efforts for nuclear energy. The work described in this section reflects NE's aspect of the integrated safeguards and nonproliferation work being performed within DOE. This work will be performed in direct collaboration or close coordination with NNSA activities.

In addition to addressing technical safeguards R&D needs, successful integration of these programs would develop revolutionary new tools for proliferation risk assessments and subsequent optimization of advanced nuclear energy systems from nonproliferation and physical security perspectives. The ultimate goal of this crosscutting effort would be to develop and use new analytical tools that could revolutionize our ability to compare proliferation and physical security risk of nuclear energy system options, including aspects of policy and human behavior as well as technical attributes.

As civilian nuclear power expands across the globe, it becomes more important that high standards of safety and security be implemented around the world. Looking only at how the R&D can improve nuclear technologies without considering who is to use these technologies, and the national and international frameworks under which they are operating, will provide an overly narrow perspective of proliferation risks. NE, in cooperation with other DOE offices and national agencies and in partnership and collaboration with other nations, must implement collaborative programs with civilian nuclear power programs in both experienced and inexperienced states in order to minimize proliferation and physical security risks, enhance reactor safety, maximize resource utilization through cooperative R&D, and encourage methods to minimize the dispersion of enrichment and reprocessing facilities worldwide.

4.4.1 Challenges

A key challenge facing the expanded use of nuclear energy and associated fuel cycles is minimizing the potential for the misuse of the technology and materials for weapons purposes. International treaties such as the Nuclear Nonproliferation Treaty, combined with transparency in the use of technology and materials, provide the basic building blocks to assure the peaceful use of nuclear energy. Fuel cycle infrastructure built upon these tenets while enabling the economic provision of fuel cycle services can help prevent the spread of sensitive nuclear technology and materials.

Today's key challenges are to take the wealth of knowledge and experience that exists within the international safeguards and physical security communities and to deploy advanced, affordable techniques to immediately detect the diversion of nuclear materials or the modification of systems. The key technical challenges that must be addressed include:

- Incorporation of nuclear safeguards and physical security technology into designs for fuel cycle facilities, advanced fast reactors, and associated nuclear materials storage and transportation systems.
- Development of proliferation risk assessment methodologies and tools that allow for an integrated view of fuel cycle options to be studied, optimized, and compared.
- Development of advanced containment and surveillance, smart safeguards information management systems, nuclear facility use-control systems, and next-generation nondestructive analysis and process-monitoring systems.
- R&D of advanced material tracking methodologies, process-control technologies, and plant engineering.
- Remote sensing, environmental sampling, and forensic verification methods.

Addressing these challenges will enable the use and expansion of nuclear energy for peaceful purposes to proceed in a safe and secure manner.

4.4.2 R&D for Understanding and Minimizing the Risks of Nuclear Proliferation and Terrorism

Some potential R&D areas for Objective 4 are:

- *Proliferation Risk Assessments* – Any fuel cycle technologies deployed in the U.S. must be considered in light of how other nations might choose to incorporate them into their own nuclear enterprises. Towards this end, it is important for NE to develop a means of understanding how these new technologies would be viewed by other countries in the context of their national goals. This research effort would develop the tools and approaches for understanding, limiting, and managing the risks of nation-state proliferation and physical security for fuel cycle options. NE will focus on assessments required to inform domestic fuel cycle technology and system option development. These analyses would complement those assessments performed by NNSA to evaluate nation-state proliferation and the international nonproliferation regime. Taken in conjunction, these comprehensive proliferation risk assessments will provide important information for discussions and decisions regarding fuel cycle options. These assessments will:
  - Exploit science-based approaches, to the extent possible, for analyzing difficult-to-quantify proliferation risk factors or indicators (e.g., capabilities, motivations, and intentions); address issues identified in several National Academy of Sciences studies

related to risk assessment; and leverage current state-of-the-art academic social science research in this field.

- Integrate the diverse decision factors (including economics, public health and safety, environmental benefits, and proliferation and terrorism risk reduction) for different fuel cycle options to understand the tradeoffs and potential synergies between these decision criteria.
- Apply these tools to study nuclear energy system options, and display the results in a useful format for decision makers.

- *Safeguards and Physical Security Technologies and Systems* – The NE focus is on the development of safeguards technologies and integrated systems for current and potential future domestic fuel cycle options. These technologies and systems contribute significantly to limiting proliferation and physical security risks while also achieving economic, public health and safety, and environmental goals. This requires that these activities be performed in an integrated program with the fuel cycle technology development activities. Opportunities exist to collaborate with other organizations (e.g. NNSA, the Department of Homeland Security, the Department of Defense) and will be utilized. NNSA will be responsible for evaluating the nation-state proliferation risks of deploying new fuel cycle technologies – particularly recycling technologies – outside of the United States.
  - <u>Advanced Instrumentation</u> – Many advanced fuel cycle processes, such as advanced aqueous reprocessing, electrochemical separations, and recycle fuel fabrication pose new challenges for safeguards and nuclear material management. The safeguards state-of-the-art will be advanced through a developmental program to improve the precision, speed, sampling methods, and scope of nuclear process monitoring and accountancy measurements, and innovative approaches for containment and surveillance. This effort supports the development of advanced safeguards instrumentation such as active interrogation methods based on neutron and photon drivers and advanced passive detectors, such as ultra-high resolution spectrometer and neutron multiplicity counting. Additionally, existing nuclear data is evaluated for the identification of gaps or needed improvements.
  - <u>Advanced Concepts and Integration</u> – Early integration of safeguards concepts into nuclear facility design is optimal to meet U.S. and international standards with minimum impact on operations. This requires development of a framework to codify the safeguards-by-design concept, applicable for both international safeguards and physical security for U.S. fuel cycle facilities. It also includes the evaluation of material attractiveness of relevant fuel cycle materials. A monitoring and control system must be developed that is secure and can rapidly authenticate and investigate summary and raw data to unequivocally distinguish process deviations, maintenance problems, and calibration and component failures from actual diversion events.
  - <u>Modeling and Simulation</u> – Development of modeling and simulation tools to enable new technology development, elucidation of high-impact R&D priorities, and approaches that optimize effectiveness and efficiency of the overall system will be

essential for the integration of new safeguards technologies and techniques into nuclear energy systems.

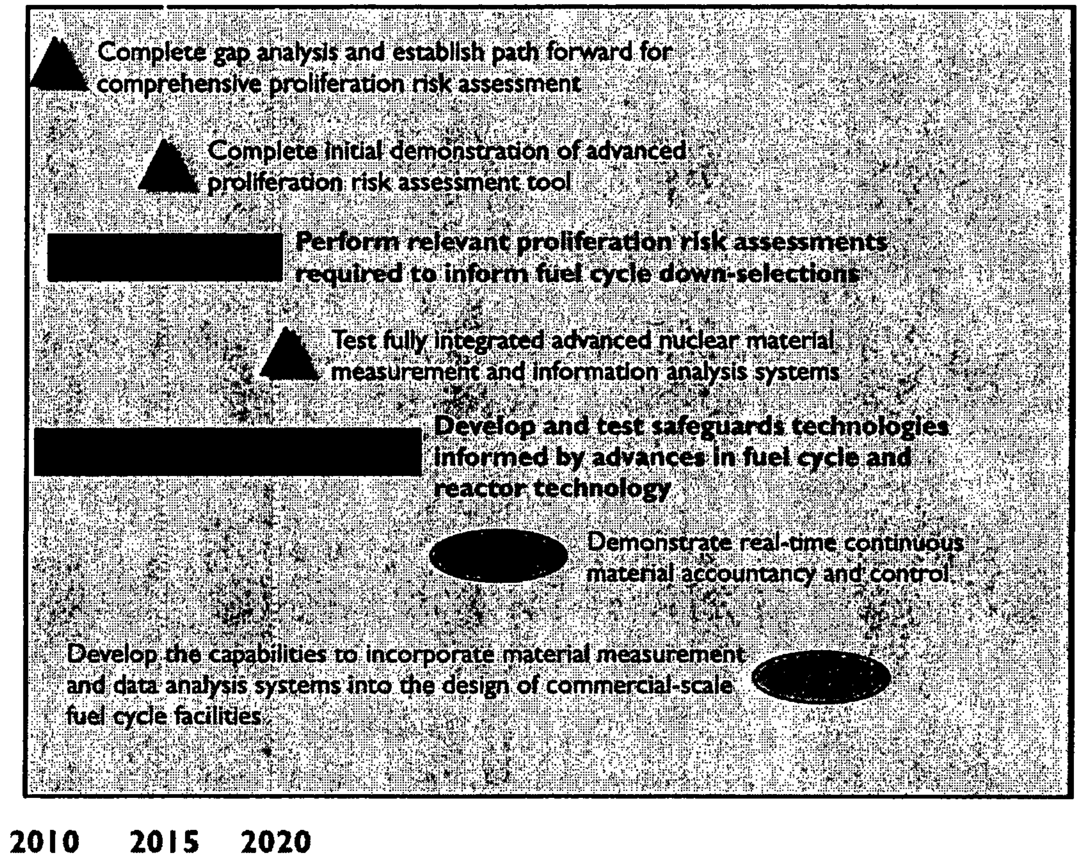
- *Nuclear Energy Technologies and Systems* – This element includes developing and assessing a sufficiently wide and innovative range of options (in concert with R&D Objectives 1–3) to achieve Objective 4. This includes, for example, options that enable decreasing the attractiveness and accessibility of used fuel and intermediate materials, transmuting materials of potential concern, optimizing safeguards and physical security systems approaches, and minimizing the number of needed enrichment and recycle facilities. In conjunction with NNSA, NE will lead the development of these options and implement mechanisms that tightly link and inform both this R&D and other elements of R&D Objective 4.

4.4.3 Key Activities and Milestones

The following chart outlines potential milestones and future national industry aims for this objective. It presents a distinction between near-term milestones toward which the NE R&D plan is designed to progress, represented as triangles, and longer-term potential outcomes that provide a framework for the milestones, shown as ovals. The milestone charts attempt to depict the stages of development so as not to leave a sense that new technologies can be immediately deployed at a commercial level. Not every milestone or potential outcome outlined in these charts represents actions that are within DOE's roles and responsibilities, and research paths will include many decision points that require choosing the most promising options for continued R&D. All DOE R&D activities will be evaluated and revisited regularly and modified as necessary through the budget process to ensure the portfolio reflects past progress and current priorities.

Although some smaller component or process "demonstration" activities are mentioned, these are largely field tests and other actions to provide proof or validation of system elements. They are not costly, large-scale demonstrations like NGNP. Any consideration to embark on such large-scale demonstrations will be the result of decision-making and budget development processes.

Figure 13. Key Activities for R&D Objective 4



5. R&D APPROACH

Section 4 of this roadmap presents NE's four R&D objectives. These objectives show the connection between how nuclear energy will contribute to meeting the nation's energy goals and the R&D that needs to be performed to enable that contribution. This section describes the approach that will be taken to perform this R&D, provides brief descriptions of the key areas of technological development that will be undertaken, presents a brief description of the facilities needed to perform this research, and describes the interfaces with stakeholders that will be required for success.

5.1 Solution-Driven, Goal-Oriented, Science-Based Approach to Nuclear Energy Development

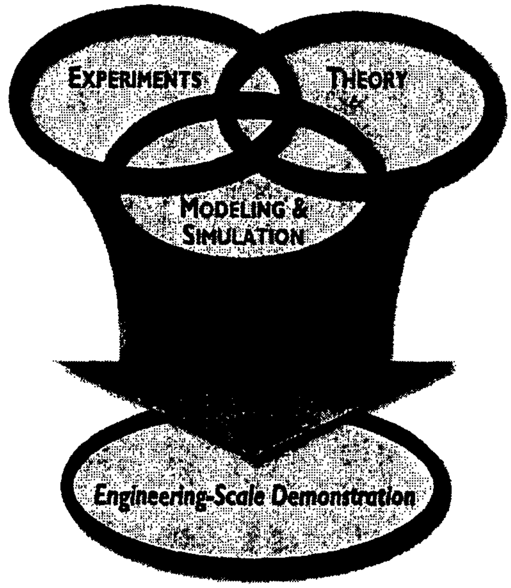
Nuclear power systems were initially developed during the latter half of the 20th century. Their development was greatly facilitated by the nation's ability and willingness to conduct large-scale experiments. The federal government constructed 52 reactors at what is now Idaho National Laboratory, another 14 at Oak Ridge National Laboratory, and a few more at other national laboratory sites. By today's standards, even large experiments and technology demonstrations were relatively affordable. While relying heavily on the Edisonian approach in the 1950s and 1960s, the nuclear energy community was a rapid adopter of high-end computational modeling and simulation during the 1970s and 1980s. During this period, nuclear power plant designers and regulators developed and deployed many of the most demanding simulation models and tools on the most advanced computational platforms then available. Still, the United States embraced a regulatory process that relied, and still relies, heavily on the use of experiments to confirm the ultimate safety of nuclear power systems. Building upon the scientific advances of the last two decades, our understanding of fundamental nuclear science, improvements in computational platforms, and other tools can now enable a new generation of nuclear power plant designers, fabricators, regulators, and operators to develop technological advancements with less of a reliance on large-scale experimentation. The developmental approach employed in this roadmap embodies four elements, as depicted in Figure 14:

Experiments – These are generally small-scale experiments aimed at observation of isolated phenomena or measurements of fundamental properties. However, targeted integral experiments also will be needed in some cases.

Theory – Based either on first principles or observations made during phenomenological testing, theories are developed to explain fundamental physical phenomena.

Modeling and Simulation – A range of mathematical models for diverse phenomena at much different time and spatial scales are developed and then integrated to predict the overall behavior of the system. Key objectives of the modeling and simulation effort are to reduce the number of prototypes and large-scale experiments needed before demonstration and deployment and to quantify uncertainties and design and operational parameters.

Figure 14. Major Elements of Science-Based Research, Development & Demonstration



Demonstrations – While the state of knowledge can be significantly advanced through the combination of experiments, theory, and modeling and simulation, there may be instances where it is appropriate to work with the private sector to further develop and validate laboratory findings. Demonstrations can be a useful element in proving viability of new technologies, but their high cost must be considered in the context of a variety of other factors. There must be sufficient industry commitment for deployment of commercial technologies before such demonstrations would be considered. Any potential future demonstration activities will be evaluated on a case-by-case basis through the established decision-making procedures of the Department and budget formulation.

5.2 Enabling Technologies

A set of enabling technologies has been identified that support progress on multiple objectives. Where NE has an R&D role in these technology areas, coordination of NE's activities across these technologies must be implemented. For example, the NE "owner" of the fuel cycle objective in such a case will be responsible for coordination of all nuclear fuel work across objectives.

- *Structural Materials* – Advanced radiation and corrosion-resistant materials with extension to high-temperature applications benefit many of the R&D objectives, especially when conducted using a science-based development approach without relying heavily on empirical experiments. Thus, a synergistic R&D program can be developed to support all the objectives.
- *Nuclear Fuels* – The development of improved and advanced nuclear fuels is clearly a major objective for both existing LWRs and the entire spectrum of advanced nuclear energy systems discussed throughout this document. The short list of potentially needed

fuels include high-burnup LWR, fast reactor, and gas-reactor fuels; coated-particle fuels; fast-spectrum and thermal-spectrum transmutation fuels and targets; thorium fuels; and molten-salt fuels. A tightly coordinated and well integrated nuclear fuels R&D program must be developed to support all of the R&D objectives.

- *Reactor Systems* – The development of advanced reactor concepts and supporting technologies is a core function of NE. Advanced technologies and reactor concepts are needed to improve the economics of electricity production. Multiple advanced reactor concepts (LWR, small modular, gas-cooled, liquid metal-cooled, molten salt-cooled, etc.) may play a role in our nuclear future. The development of a robust advanced reactor system concept definition capability will be an important element of NE strategy development.
- *Instrumentation and Control* – The development and implementation of digital instrumentation and control systems will benefit current reactors as well as future reactors. Advanced instrumentation and control systems will also benefit future fuel cycle facilities. Safeguards technology development also relies on advanced instrumentation and plant control systems through safeguards-by-design.
- *Power Conversion Systems* – Advanced power conversion systems will lead to increased efficiency for the future reactors and facilitate the use of nuclear power in markets requiring process heat.
- *Process Heat Transport Systems* – The development of process heat transport systems that can be combined with multiple reactor technologies will enable the use of nuclear power to deliver needed process heat to the industrial sector.
- *Dry-Heat-Rejection Systems* – Advanced dry-heat-rejection systems will improve the environmental friendliness of the nuclear power plants and enable the deployment of nuclear energy in areas where water constraints might otherwise preclude its use.
- *Separations Processes* – This report has noted the wide variety of fuel cycle options that may be needed in the future to address U.S. energy security, economic, and sustainability goals. Our future ability to sustainably and economically recycle LWR fuels, fast reactor fuels, gas-cooled reactor fuels, molten salt fuels, *etc.* will depend, in part, on our ability to separate key elements from the waste that will not be disposed in a repository.
- *Waste Forms* – The ability to engineer, produce, and manage fuel cycle waste forms that are chemically and structurally stable over relevant periods of time from decades to hundreds of thousands of years (depending on the radioisotope) is critical to achieving a sustainable fuel cycle and must be closely integrated with both radiochemical research and repository systems research.
- *Risk Assessment Methods* – Advanced methods for risk assessment based on mechanistic modeling of system behavior will benefit the safety assessments of the new nuclear energy systems and fuel cycle technologies. State-of-the-art computational and experimental

techniques will benefit not only novel reactor concepts but other nuclear facilities needed for the fuel cycle.

- *Advanced Modeling and Simulation* – The science-based approach relies heavily on fundamental experiments combined with associated theories for predictive capabilities. However, a comprehensive use of the science-based approach for predictive tools with multiple interrelated phenomenologies requires advances in computational sciences where phenomena at different time and length scales can be bridged into an engineering code using modern computational platforms.

5.3 R&D Facilities and Infrastructure

Ultimately all design and safety tools for nuclear systems must be validated with underpinning experimental data. Without such a foundation in reality, licensing these systems would be virtually impossible. Experiments also provide essential waypoints for guiding the development of technology. Having such an experimental capability requires that nuclear energy R&D maintain access to a broad range of facilities from small-scale laboratories potentially up to full prototype demonstrations. Hot cells and test reactors are at the top end of the hierarchy, followed by smaller-scale radiological facilities, specialty engineering facilities, and non-radiological small laboratories.

Nuclear energy R&D employs a multi-pronged approach to having these capabilities available when needed. The core capabilities rely on DOE-owned irradiation, examination, chemical processing and waste form development facilities. These are supplemented by university capabilities ranging from research reactors to materials science laboratories. Future infrastructure requirements will be considered through the established budget development processes as needs arise.

The high cost of creating and maintaining physical infrastructure for nuclear R&D, including the necessary safety and security infrastructure, requires creativity and periodic realignment of infrastructure planning with programmatic direction. NE successfully employs a solid approach to maintaining infrastructure. The approach concentrates the high-risk nuclear facilities at the remote Idaho site, maintains unique capabilities at other sites if required, supports vital university infrastructure, negotiates equitable capability exchanges with trusted international partners, refurbishes and reequips essential facilities if required, addresses maintenance backlogs to ensure safe operation, and makes efficient use of modeling, simulation, and single-effect experiments.

5.4 Interfaces and Coordination

In order to achieve the objectives under each R&D objective, NE must closely coordinate its activities with other agencies, the nuclear industry, and international partners.

Other Department of Energy Offices –The use of a "science-based" approach to develop innovative nuclear energy systems and components requires a strong collaboration between NE and the Office of Science (SC) to employ the tools developed for science in engineering applications. Such tools include advanced experimental techniques, a fundamental understanding of materials behavior, and advanced computational sciences. R&D on storage and disposal of nuclear waste will be performed in coordination with the Office of Environmental Management (EM) and the Office of Naval Reactors (NR), as there are salient similarities in the disposition challenges facing each.

NNSA – Technology development for safeguards is a crosscutting tool that is applicable for both domestic and international uses. NNSA and NE are implementing a coordinated effort to address the safeguards R&D needs for domestic and international applications. These collaborative efforts address the assessment of proliferation risks, accountancy, and control (domestic) and verification (international) by contributing new safeguards technologies; recruiting a new generation of safeguards specialists into the U.S. national laboratories, universities, and industry; and informing the development of safe and secure nuclear facilities. NNSA will be responsible for evaluating the international nation state proliferation risks of deploying new fuel cycle technologies, particularly recycling technologies, outside of the United States.

NRC – Appropriate collaboration between DOE and the NRC will help assure that nuclear energy remains a viable option for the United States. The development of science-based tools to inform licensing paradigms is one key goal of this collaboration.

Nuclear Industry – The decision to deploy nuclear energy systems is made by industry and the private sector in market-based economies. However, it is important that industry is engaged during the definition and execution of the R&D phase and that industry participate in joint demonstration activities if such demonstration is deemed necessary and appropriate to facilitate commercialization and deployment of the resulting technologies and systems. As technologies are developed, cost-sharing with industry is an integral part of NE's agenda. DOE will proceed in a manner that recognizes the importance of maintaining a strong and viable nuclear industry.

International Community –Strong participation and leadership by the United States in international nuclear R&D, safety and nonproliferation programs is essential. Nuclear energy worldwide must be deployed with safety and security of paramount importance. In addition, several countries have established strong nuclear R&D programs and specialized expertise from which the United States can benefit, such as the leadership position of Russia, France, and Japan in fast reactor technology. Collaborations in nuclear technology R&D will be implemented through bilateral and multilateral agreements and through international organizations such as the Generation IV International Forum.

In order for nuclear power to continue to be a viable energy option in any country, including the United States, nuclear safety, security, and safeguards must be maintained at the highest levels on a global scale. DOE will help to achieve consensus criteria for safe reactor operation through international organizations, such as the World Association of Nuclear Operators, and seek to enhance safety standards for nuclear power, promote appropriate infrastructure at the national and international levels, and minimize proliferation risks from the expansion of nuclear power through its participation with the IAEA and related organizations.

6. SUMMARY AND CONCLUSIONS

This document presents an integrated strategy and R&D framework for the DOE Office of Nuclear Energy. In order to meet the Administration's goals of energy security and greenhouse gas reductions, nuclear energy must play an important role in the national energy portfolio. NE's derived missions in support of these national goals are to enable the development and deployment of fission power systems for the production of electricity and process heat. Four research and development objectives have been identified, which will guide NE's program and strategic planning. Progress in these areas will help ensure that nuclear energy continues to be among the suite of available U.S. energy options throughout the 21st century. These objectives are:

- *R&D Objective 1* – Develop technology and other solutions that can improve the reliability, sustain the safety, and extend the life of current reactors.
- *R&D Objective 2* – Develop improvements in the affordability of new reactors to enable nuclear energy to help meet the Administration's energy security and climate change goals.
- *R&D Objective 3* – Develop sustainable nuclear fuel cycles.
- *R&D Objective 4* – Understand and minimize the risks of nuclear proliferation and terrorism.

The White House

Office of the Press Secretary

For Immediate Release January 25, 2011

Remarks by the President in State of Union Address

United States Capitol, Washington, D.C.

9:12 P.M. EST

THE PRESIDENT: Mr. Speaker, Mr. Vice President, members of Congress, distinguished guests, and fellow Americans:

Tonight I want to begin by congratulating the men and women of the 112th Congress, as well as your new Speaker, John Boehner. (Applause.) And as we mark this occasion, we're also mindful of the empty chair in this chamber, and we pray for the health of our colleague -- and our friend — Gabby Giffords. (Applause.)

It's no secret that those of us here tonight have had our differences over the last two years. The debates have been contentious; we have fought fiercely for our beliefs. And that's a good thing. That's what a robust democracy demands. That's what helps set us apart as a nation.

But there's a reason the tragedy in Tucson gave us pause. Amid all the noise and passion and rancor of our public debate, Tucson reminded us that no matter who we are or where we come from, each of us is a part of something greater — something more consequential than party or political preference.

We are part of the American family. We believe that in a country where every race and faith and point of view can be found, we are still bound together as one people; that we share common hopes and a common creed; that the dreams of a little girl in Tucson are not so different than those of our own children, and that they all deserve the chance to be fulfilled.

That, too, is what sets us apart as a nation. (Applause.)

Now, by itself, this simple recognition won't usher in a new era of cooperation. What comes of this moment is up to us. What comes of this moment will be determined not by whether we can sit together tonight, but whether we can work together tomorrow. (Applause.)

I believe we can. And I believe we must. That's what the people who sent us here expect of us. With their votes, they've determined that governing will now be a shared responsibility between parties. New laws will only pass with support from Democrats and Republicans. We will move forward together, or not at all — for the challenges we face are bigger than party, and bigger than politics.

At stake right now is not who wins the next election — after all, we just had an election. At stake is whether new jobs and industries take root in this country, or somewhere else. It's whether the hard work and industry of our people is rewarded. It's whether we sustain the leadership that has made America not just a place on a map, but the light to the world.

We are poised for progress. Two years after the worst recession most of us have ever known, the stock market has come roaring back. Corporate profits are up. The economy is growing again.

But we have never measured progress by these yardsticks alone. We measure progress by the success of our people. By the jobs they can find and the quality of life those jobs offer. By the prospects of a small business owner who dreams of turning a good idea into a thriving enterprise. By the opportunities for a better life that we pass on to our children.

That's the project the American people want us to work on. Together. (Applause.)

We did that in December. Thanks to the tax cuts we passed, Americans' paychecks are a little bigger today. Every business can write off the full cost of new investments that they make this year. And these steps, taken by Democrats and Republicans, will grow the economy and add to the more than one million private sector jobs created last year.

But we have to do more. These steps we've taken over the last two years may have broken the back of this recession, but to win the future, we'll need to take on challenges that have been decades in the making.

Many people watching tonight can probably remember a time when finding a good job meant showing up at a nearby factory or a business downtown. You didn't always need a degree, and your competition was pretty much limited to your neighbors. If you worked hard, chances are you'd have a job for life, with a decent paycheck and good benefits and the occasional promotion. Maybe you'd even have the pride of seeing your kids work at the same company.

That world has changed. And for many, the change has been painful. I've seen it in the shuttered windows of once booming factories, and the vacant storefronts on once busy Main Streets. I've heard it in the frustrations of Americans who've seen their paychecks dwindle or their jobs disappear — proud men and women who feel like the rules have been changed in the middle of the game.

They're right. The rules have changed. In a single generation, revolutions in technology have transformed the way we live, work and do business. Steel mills that once needed 1,000 workers can now do the same work with 100. Today, just about any company can set up shop, hire workers, and sell their products wherever there's an Internet connection.

Meanwhile, nations like China and India realized that with some changes of their own, they could compete in this new world. And so they started educating their children earlier and longer, with greater emphasis on math and science. They're investing in research and new technologies. Just recently, China became the home to the world's largest private solar research facility, and the world's fastest computer.

So, yes, the world has changed. The competition for jobs is real. But this shouldn't discourage us. It should challenge us. Remember -- for all the hits we've taken these last few years, for all the naysayers predicting our decline, America still has the largest, most prosperous economy in the world. (Applause.) No workers -- no workers are more productive than ours. No country has more successful companies, or grants more patents to inventors and entrepreneurs. We're the home to the world's best colleges and universities, where more students come to study than any place on Earth.

What's more, we are the first nation to be founded for the sake of an idea — the idea that each of us deserves the chance to shape our own destiny. That's why centuries of pioneers and immigrants have risked everything to come here. It's why our students don't just memorize equations, but answer questions like "What do you think of that idea? What would you change about the world? What do you want to be when you grow up?"

The future is ours to win. But to get there, we can't just stand still. As Robert Kennedy told us, "The future is not a gift. It is an achievement." Sustaining the American Dream has never been about standing pat. It has required each generation to sacrifice, and struggle, and meet the demands of a new age.

And now it's our turn. We know what it takes to compete for the jobs and industries of our time. We need to out-innovate, out-educate, and out-build the rest of the world. (Applause.) We have to make America the best place on Earth to do business. We need to take responsibility for our deficit and reform our government. That's how our people will prosper. That's how we'll win the future. (Applause.) And tonight, I'd like to talk about how we get there.

The first step in winning the future is encouraging American innovation. None of us can predict with certainty what the next big industry will be or where the new jobs will come from. Thirty years ago, we couldn't know that something called the Internet would lead to an economic revolution. What we can do -- what America does better than anyone else -- is spark the creativity and imagination of our people. We're the nation that put cars in driveways and computers in offices; the nation of Edison and the Wright brothers; of Google and Facebook. In America, innovation doesn't just change our lives. It is how we make our living. (Applause.)

Our free enterprise system is what drives innovation. But because it's not always profitable for companies to invest in basic research, throughout our history, our government has provided cutting-edge scientists and inventors with the support that they need. That's what planted the seeds for the Internet. That's what helped make possible things like computer chips and GPS. Just think of all the good jobs -- from manufacturing to retail -- that have come from these breakthroughs.

Half a century ago, when the Soviets beat us into space with the launch of a satellite called Sputnik, we had no idea how we would beat them to the moon. The science wasn't even there yet. NASA didn't exist. But after investing in better research and education, we didn't just surpass the Soviets; we unleashed a wave of innovation that created new industries and millions of new jobs.

This is our generation's Sputnik moment. Two years ago, I said that we needed to reach a level of research and development we haven't seen since the height of the Space Race. And in a few weeks, I will be sending a budget to Congress that helps us meet that goal. We'll invest in biomedical research, information technology, and especially clean energy technology — (applause) -- an investment that will strengthen our security, protect our planet, and create countless new jobs for our people.

Already, we're seeing the promise of renewable energy. Robert and Gary Allen are brothers who run a small Michigan roofing company. After September 11th, they volunteered their best roofers to help repair the Pentagon.

But half of their factory went unused, and the recession hit them hard. Today, with the help of a government loan, that empty space is being used to manufacture solar shingles that are being sold all across the country. In Robert's words, "We reinvented ourselves."

That's what Americans have done for over 200 years: reinvented ourselves. And to spur on more success stories like the Allen Brothers, we've begun to reinvent our energy policy. We're not just handing out money. We're issuing a challenge. We're telling America's scientists and engineers that if they assemble teams of the best minds in their fields, and focus on the hardest problems in clean energy, we'll fund the Apollo projects of our time.

At the California Institute of Technology, they're developing a way to turn sunlight and water into fuel for our cars. At Oak Ridge National Laboratory, they're using supercomputers to get a lot more power out of our nuclear facilities. With more research and incentives, we can break our dependence on oil with biofuels, and become the first country to have a million electric vehicles on the road by 2015. (Applause.)

We need to get behind this innovation. And to help pay for it, I'm asking Congress to eliminate the billions in taxpayer dollars we currently give to oil companies. (Applause.) I don't know if -- I don't know if you've noticed, but they're doing just fine on their own. (Laughter.) So instead of subsidizing yesterday's energy, let's invest in tomorrow's.

Now, clean energy breakthroughs will only translate into clean energy jobs if businesses know there will be a market for what they're selling. So tonight, I challenge you to join me in setting a new goal: By 2035, 80 percent of America's electricity will come from clean energy sources. (Applause.)

Some folks want wind and solar. Others want nuclear, clean coal and natural gas. To meet this goal, we will need them all -- and I urge Democrats and Republicans to work together to make it happen. (Applause.)

Maintaining our leadership in research and technology is crucial to America's success. But if we want to win the future — if we want innovation to produce jobs in America and not overseas — then we also have to win the race to educate our kids.

Think about it. Over the next 10 years, nearly half of all new jobs will require education that goes beyond a high school education. And yet, as many as a quarter of our students aren't even finishing high school. The quality of our math and science education lags behind many other nations. America has fallen to ninth in the proportion of young people with a college degree. And so the question is whether all of us — as citizens, and as parents — are willing to do what's necessary to give every child a chance to succeed.

That responsibility begins not in our classrooms, but in our homes and communities. It's family that first instills the love of learning in a child. Only parents can make sure the TV is turned off and homework gets done. We need to teach our kids that it's not just the winner of the Super Bowl who deserves to be celebrated, but the winner of the science fair. (Applause.) We need to teach them that success is not a function of fame or PR, but of hard work and discipline.

Our schools share this responsibility. When a child walks into a classroom, it should be a place of high expectations and high performance. But too many schools don't meet this test. That's why instead of just pouring money into a system that's not working, we launched a competition called Race to the Top. To all 50 states, we said, "If you show us the most innovative plans to improve teacher quality and student achievement, we'll show you the money."

Race to the Top is the most meaningful reform of our public schools in a generation. For less than 1 percent of what we spend on education each year, it has led over 40 states to raise their standards for teaching and learning. And these standards were developed, by the way, not by Washington, but by Republican and Democratic governors throughout the country. And Race to the Top should be the approach we follow this year as we replace No Child Left Behind with a law that's more flexible and focused on what's best for our kids. (Applause.)

You see, we know what's possible from our children when reform isn't just a top-down mandate, but the work of local teachers and principals, school boards and communities. Take a school like Bruce Randolph in Denver. Three years ago, it was rated one of the worst schools in Colorado -- located on turf between two rival gangs. But last May, 97 percent of the seniors received their diploma. Most will be the first in their families to go to college. And after the first year of the school's transformation, the principal who made it possible wiped away tears when a student said, "Thank you, Ms. Waters, for showing that we are smart and we can make it." (Applause.) That's what good schools can do, and we want good schools all across the country.

Let's also remember that after parents, the biggest impact on a child's success comes from the man or woman at the front of the classroom. In South Korea, teachers are known as "nation builders." Here in America, it's time we treated the people who educate our children with the same level of respect. (Applause.) We want to reward good teachers and stop making excuses for bad ones. (Applause.) And over the next 10 years, with so many baby boomers retiring from our classrooms, we want to prepare 100,000 new teachers in the fields of science and technology and engineering and math. (Applause.)

In fact, to every young person listening tonight who's contemplating their career choice: If you want to make a difference in the life of our nation; if you want to make a difference in the life of a child -- become a teacher. Your country needs you. (Applause.)

Of course, the education race doesn't end with a high school diploma. To compete, higher education must be within the reach of every American. (Applause.) That's why we've ended the unwarranted taxpayer subsidies that went to banks, and used the savings to make college affordable for millions of students. (Applause.) And this year, I ask Congress to go further, and make permanent our tuition tax credit — worth $10,000 for four years of college. It's the right thing to do. (Applause.)

Because people need to be able to train for new jobs and careers in today's fast-changing economy, we're also revitalizing America's community colleges. Last month, I saw the promise of these schools at Forsyth Tech in North Carolina. Many of the students there used to work in the surrounding factories that have since left town. One mother of two, a woman named Kathy Proctor, had worked in the furniture industry since she was 18 years old. And she told me she's earning her degree in biotechnology now, at 55 years old, not just because the furniture jobs are gone, but because she wants to inspire her children to pursue their dreams, too. As Kathy said, "I hope it tells them to never give up."

If we take these steps — if we raise expectations for every child, and give them the best possible chance at an education, from the day they are born until the last job they take — we will reach the goal that I set two years ago: By the end of the decade, America will once again have the highest proportion of college graduates in the world. (Applause.)

One last point about education. Today, there are hundreds of thousands of students excelling in our schools who are not American citizens. Some are the children of undocumented workers, who had nothing to do with the actions of their parents. They grew up as Americans and pledge allegiance to our flag, and yet they live every day with the threat of deportation. Others come here from abroad to study in our colleges and universities. But as soon as they obtain advanced degrees, we send them back home to compete against us. It makes no sense.

Now, I strongly believe that we should take on, once and for all, the issue of illegal immigration. And I am prepared to work with Republicans and Democrats to protect our borders, enforce our laws and address the millions of undocumented workers who are now living in the shadows. (Applause.) I know that debate will be difficult. I know it will take time. But tonight, let's agree to make that effort. And let's stop expelling talented, responsible young people who could be staffing our research labs or starting a new business, who could be further enriching this nation. (Applause.)

The third step in winning the future is rebuilding America. To attract new businesses to our shores, we need the fastest, most reliable ways to move people, goods, and information -- from high-speed rail to high-speed Internet. (Applause.)

Our infrastructure used to be the best, but our lead has slipped. South Korean homes now have greater Internet access than we do. Countries in Europe and Russia invest more in their roads and railways than we do. China is building faster trains and newer airports. Meanwhile, when our own engineers graded our nation's infrastructure, they gave us a "D."

We have to do better. America is the nation that built the transcontinental railroad, brought electricity to rural communities, constructed the Interstate Highway System. The jobs created by these projects didn't just come from laying down track or pavement. They came from businesses that opened near a town's new train station or the new off-ramp.

So over the last two years, we've begun rebuilding for the 21st century, a project that has meant thousands of good jobs for the hard-hit construction industry. And tonight, I'm proposing that we redouble those efforts. (Applause.)

We'll put more Americans to work repairing crumbling roads and bridges. We'll make sure this is fully paid for, attract private investment, and pick projects based [on] what's best for the economy, not politicians.

Within 25 years, our goal is to give 80 percent of Americans access to high-speed rail. (Applause.) This could allow you to go places in half the time it takes to travel by car. For some trips, it will be faster than flying — without the pat-down. (Laughter and applause.) As we speak, routes in California and the Midwest are already underway.

Within the next five years, we'll make it possible for businesses to deploy the next generation of high-speed wireless coverage to 98 percent of all Americans. This isn't just about – (applause) -- this isn't about faster Internet or fewer dropped calls. It's about connecting every part of America to the digital age. It's about a rural community in Iowa or Alabama where farmers and small business owners will be able to sell their products all over the world. It's about a firefighter who can download the design of a burning building onto a handheld device; a student who can take classes with a digital textbook; or a patient who can have face-to-face video chats with her doctor.

All these investments — in innovation, education, and infrastructure — will make America a better place to do business and create jobs. But to help our companies compete, we also have to knock down barriers that stand in the way of their success.

For example, over the years, a parade of lobbyists has rigged the tax code to benefit particular companies and industries. Those with accountants or lawyers to work the system can end up paying no taxes at all. But all the rest are hit with one of the highest corporate tax rates in the world. It makes no sense, and it has to change. (Applause.)

So tonight, I'm asking Democrats and Republicans to simplify the system. Get rid of the loopholes. Level the playing field. And use the savings to lower the corporate tax rate for the first time in 25 years — without adding to our deficit. It can be done. (Applause.)

To help businesses sell more products abroad, we set a goal of doubling our exports by 2014 — because the more we export, the more jobs we create here at home. Already, our exports are up. Recently, we signed agreements with India and China that will support more than 250,000 jobs here in the United States. And last month, we finalized a trade agreement with South Korea that will support at least 70,000 American jobs. This agreement has unprecedented support from business and labor, Democrats and Republicans -- and I ask this Congress to pass it as soon as possible. (Applause.)

Now, before I took office, I made it clear that we would enforce our trade agreements, and that I would only sign deals that keep faith with American workers and promote American jobs. That's what we did with Korea, and that's what I intend to do as we pursue agreements with Panama and Colombia and continue our Asia Pacific and global trade talks. (Applause.)

To reduce barriers to growth and investment, I've ordered a review of government regulations. When we find rules that put an unnecessary burden on businesses, we will fix them. (Applause.) But I will not hesitate to create or enforce common-sense safeguards to protect the American people. (Applause.) That's what we've done in this country for more than a century. It's why our food is safe to eat, our water is safe to drink, and our air is safe to breathe. It's why we have speed limits and child labor laws. It's why last year, we put in place consumer protections against hidden fees and penalties by credit card companies and new rules to prevent another financial crisis. (Applause.) And it's why we passed reform that finally prevents the health insurance industry from exploiting patients. (Applause.)

Now, I have heard rumors that a few of you still have concerns about our new health care law. (Laughter.) So let me be the first to say that anything can be improved. If you have ideas about how to improve this law by making care better or more affordable, I am eager to work with you. We can start right now by correcting a flaw in the legislation that has placed an unnecessary bookkeeping burden on small businesses. (Applause.)

What I'm not willing to do -- what I'm not willing to do is go back to the days when insurance companies could deny someone coverage because of a preexisting condition. (Applause.)

I'm not willing to tell James Howard, a brain cancer patient from Texas, that his treatment might not be covered. I'm not willing to tell Jim Houser, a small business man from Oregon, that he has to go back to paying $5,000 more to cover his employees. As we speak, this law is making prescription drugs cheaper for seniors and giving uninsured students a chance to stay on their patients' -- parents' coverage. (Applause.)

So I say to this chamber tonight, instead of re-fighting the battles of the last two years, let's fix what needs fixing and let's move forward. (Applause.)

Now, the final critical step in winning the future is to make sure we aren't buried under a mountain of debt.

We are living with a legacy of deficit spending that began almost a decade ago. And in the wake of the financial crisis, some of that was necessary to keep credit flowing, save jobs, and put money in people's pockets.

But now that the worst of the recession is over, we have to confront the fact that our government spends more than it takes in. That is not sustainable. Every day, families sacrifice to live within their means. They deserve a government that does the same.

So tonight, I am proposing that starting this year, we freeze annual domestic spending for the next five years. (Applause.) Now, this would reduce the deficit by more than $400 billion over the next decade, and will bring discretionary spending to the lowest share of our economy since Dwight Eisenhower was President.

This freeze will require painful cuts. Already, we've frozen the salaries of hardworking federal employees for the next two years. I've proposed cuts to things I care deeply about, like community action programs. The Secretary of Defense has also agreed to cut tens of billions of dollars in spending that he and his generals believe our military can do without. (Applause.)

I recognize that some in this chamber have already proposed deeper cuts, and I'm willing to eliminate whatever we can honestly afford to do without. But let's make sure that we're not doing it on the backs of our most vulnerable citizens. (Applause.) And let's make sure that what we're cutting is really excess weight. Cutting the deficit by gutting our investments in innovation and education is like lightening an overloaded airplane by removing its engine. It may make you feel like you're flying high at first, but it won't take long before you feel the impact. (Laughter.)

Now, most of the cuts and savings I've proposed only address annual domestic spending, which represents a little more than 12 percent of our budget. To make further progress, we have to stop pretending that cutting this kind of spending alone will be enough. It won't. (Applause.)

The bipartisan fiscal commission I created last year made this crystal clear. I don't agree with all their proposals, but they made important progress. And their conclusion is that the only way to tackle our deficit is to cut excessive spending wherever we find it — in domestic spending, defense spending, health care spending, and spending through tax breaks and loopholes. (Applause.)

This means further reducing health care costs, including programs like Medicare and Medicaid, which are the single biggest contributor to our long-term deficit. The health insurance law we passed last year will slow these rising costs, which is part of the reason that nonpartisan economists have said that repealing the health care law would add a quarter of a trillion dollars to our deficit. Still, I'm willing to look at other ideas to bring down costs, including one that Republicans suggested last year -- medical malpractice reform to rein in frivolous lawsuits. (Applause.)

To put us on solid ground, we should also find a bipartisan solution to strengthen Social Security for future generations. (Applause.) We must do it without putting at risk current retirees, the most vulnerable, or people with disabilities; without slashing benefits for future generations; and without subjecting Americans' guaranteed retirement income to the whims of the stock market. (Applause.)

And if we truly care about our deficit, we simply can't afford a permanent extension of the tax cuts for the wealthiest 2 percent of Americans. (Applause.) Before we take money away from our schools or scholarships away from our students, we should ask millionaires to give up their tax break. It's not a matter of punishing their success. It's about promoting America's success. (Applause.)

In fact, the best thing we could do on taxes for all Americans is to simplify the individual tax code. (Applause.) This will be a tough job, but members of both parties have expressed an interest in doing this, and I am prepared to join them. (Applause.)

So now is the time to act. Now is the time for both sides and both houses of Congress — Democrats and Republicans — to forge a principled compromise that gets the job done. If we make the hard choices now to rein in our deficits, we can make the investments we need to win the future.

Let me take this one step further. We shouldn't just give our people a government that's more affordable. We should give them a government that's more competent and more efficient. We can't win the future with a government of the past. (Applause.)

We live and do business in the Information Age, but the last major reorganization of the government happened in the age of black-and-white TV. There are 12 different agencies that deal with exports. There are at least five different agencies that deal with housing policy. Then there's my favorite example: The Interior Department is in charge of salmon while they're in fresh water, but the Commerce Department handles them when they're in saltwater. (Laughter.) I hear it gets even more complicated once they're smoked. (Laughter and applause.)

Now, we've made great strides over the last two years in using technology and getting rid of waste. Veterans can now download their electronic medical records with a click of the mouse. We're selling acres of federal office space that hasn't been used in years, and we'll cut through red tape to get rid of more. But we need to think bigger. In the coming months, my administration will develop a proposal to merge, consolidate, and reorganize the federal government in a way that best serves the goal of a more competitive America. I will submit that proposal to Congress for a vote — and we will push to get it passed. (Applause.)

In the coming year, we'll also work to rebuild people's faith in the institution of government. Because you deserve to know exactly how and where your tax dollars are being spent, you'll be able to go to a website and get that information for the very first time in history. Because you deserve to know when your elected officials are meeting with lobbyists, I ask Congress to do what the White House has already done -- put that information online. And because the American people deserve to know that special interests aren't larding up legislation with pet projects, both parties in Congress should know this: If a bill comes to my desk with earmarks inside, I will veto it. I will veto it. (Applause.)

The 21st century government that's open and competent. A government that lives within its means. An economy that's driven by new skills and new ideas. Our success in this new and changing world will require reform, responsibility, and innovation. It will also require us to approach that world with a new level of engagement in our foreign affairs.

Just as jobs and businesses can now race across borders, so can new threats and new challenges. No single wall separates East and West. No one rival superpower is aligned against us.

And so we must defeat determined enemies, wherever they are, and build coalitions that cut across lines of region and race and religion. And America's moral example must always shine for all who yearn for freedom and justice and dignity. And because we've begun this work, tonight we can say that American leadership has been renewed and America's standing has been restored.

Look to Iraq, where nearly 100,000 of our brave men and women have left with their heads held high. (Applause.) American combat patrols have ended, violence is down, and a new government has been formed.

This year, our civilians will forge a lasting partnership with the Iraqi people, while we finish the job of bringing our troops out of Iraq. America's commitment has been kept. The Iraq war is coming to an end. (Applause.)

Of course, as we speak, al Qaeda and their affiliates continue to plan attacks against us. Thanks to our intelligence and law enforcement professionals, we're disrupting plots and securing our cities and skies. And as extremists try to inspire acts of violence within our borders, we are responding with the strength of our communities, with respect for the rule of law, and with the conviction that American Muslims are a part of our American family. (Applause.)

We've also taken the fight to al Qaeda and their allies abroad. In Afghanistan, our troops have taken Taliban strongholds and trained Afghan security forces. Our purpose is clear: By preventing the Taliban from reestablishing a stranglehold over the Afghan people, we will deny al Qaeda the safe haven that served as a launching pad for 9/11.

Thanks to our heroic troops and civilians, fewer Afghans are under the control of the insurgency. There will be tough fighting ahead, and the Afghan government will need to deliver better governance. But we are strengthening the capacity of the Afghan people and building an enduring partnership with them. This year, we will work with nearly 50 countries to begin a transition to an Afghan lead. And this July, we will begin to bring our troops home. (Applause.)

In Pakistan, al Qaeda's leadership is under more pressure than at any point since 2001. Their leaders and operatives are being removed from the battlefield. Their safe havens are shrinking. And we've sent a message from the Afghan border to the Arabian Peninsula to all parts of the globe: We will not relent, we will not waver, and we will defeat you. (Applause.)

American leadership can also be seen in the effort to secure the worst weapons of war. Because Republicans and Democrats approved the New START treaty, far fewer nuclear weapons and launchers will be deployed. Because we rallied the world, nuclear materials are being locked down on every continent so they never fall into the hands of terrorists. (Applause.)

Because of a diplomatic effort to insist that Iran meet its obligations, the Iranian government now faces tougher sanctions, tighter sanctions than ever before. And on the Korean Peninsula, we stand with our ally South Korea, and insist that North Korea keeps its commitment to abandon nuclear weapons. (Applause.)

This is just a part of how we're shaping a world that favors peace and prosperity. With our European allies, we revitalized NATO and increased our cooperation on everything from counterterrorism to missile defense. We've reset our relationship with Russia, strengthened Asian alliances, built new partnerships with nations like India.

This March, I will travel to Brazil, Chile, and El Salvador to forge new alliances across the Americas. Around the globe, we're standing with those who take responsibility — helping farmers grow more food, supporting doctors who care for the sick, and combating the corruption that can rot a society and rob people of opportunity.

Recent events have shown us that what sets us apart must not just be our power — it must also be the purpose behind it. In south Sudan — with our assistance — the people were finally able to vote for independence after years of war. (Applause.) Thousands lined up before dawn. People danced in the streets. One man who lost four of his brothers at war summed up the scene around him: "This was a battlefield for most of my life," he said. "Now we want to be free." (Applause.)

And we saw that same desire to be free in Tunisia, where the will of the people proved more powerful than the writ of a dictator. And tonight, let us be clear: The United States of America stands with the people of Tunisia, and supports the democratic aspirations of all people. (Applause.)

We must never forget that the things we've struggled for, and fought for, live in the hearts of people everywhere. And we must always remember that the Americans who have borne the greatest burden in this struggle are the men and women who serve our country. (Applause.)

Tonight, let us speak with one voice in reaffirming that our nation is united in support of our troops and their families. Let us serve them as well as they've served us – by giving them the equipment they need, by providing them with the care and benefits that they have earned, and by enlisting our veterans in the great task of building our own nation.

Our troops come from every corner of this country — they're black, white, Latino, Asian, Native American. They are Christian and Hindu, Jewish and Muslim. And, yes, we know that some of them are gay. Starting this year, no American will be forbidden from serving the country they love because of who they love. (Applause.) And with that change, I call on all our college campuses to open their doors to our military recruiters and ROTC. It is time to leave behind the divisive battles of the past. It is time to move forward as one nation. (Applause.)

We should have no illusions about the work ahead of us. Reforming our schools, changing the way we use energy, reducing our deficit — none of this will be easy. All of it will take time. And it will be harder because we will argue about everything. The costs. The details. The letter of every law.

Of course, some countries don't have this problem. If the central government wants a railroad, they build a railroad, no matter how many homes get bulldozed. If they don't want a bad story in the newspaper, it doesn't get written.

And yet, as contentious and frustrating and messy as our democracy can sometimes be, I know there isn't a person here who would trade places with any other nation on Earth. (Applause.)

We may have differences in policy, but we all believe in the rights enshrined in our Constitution. We may have different opinions, but we believe in the same promise that says this is a place where you can make it if you try. We may have different backgrounds, but we believe in the same dream that says this is a country where anything is possible. No matter who you are. No matter where you come from.

That dream is why I can stand here before you tonight. That dream is why a working-class kid from Scranton can sit behind me. (Laughter and applause.) That dream is why someone who began by sweeping the floors of his father's Cincinnati bar can preside as Speaker of the House in the greatest nation on Earth. (Applause.)

That dream -- that American Dream -- is what drove the Allen Brothers to reinvent their roofing company for a new era. It's what drove those students at Forsyth Tech to learn a new skill and work towards the future. And that dream is the story of a small business owner named Brandon Fisher.

Brandon started a company in Berlin, Pennsylvania, that specializes in a new kind of drilling technology. And one day last summer, he saw the news that halfway across the world, 33 men were trapped in a Chilean mine, and no one knew how to save them.

But Brandon thought his company could help. And so he designed a rescue that would come to be known as Plan B. His employees worked around the clock to manufacture the necessary drilling equipment. And Brandon left for Chile.

Along with others, he began drilling a 2,000-foot hole into the ground, working three- or four-hour -- three or four days at a time without any sleep. Thirty-seven days later, Plan B succeeded, and the miners were rescued. (Applause.) But because he didn't want all of the attention, Brandon wasn't there when the miners emerged. He'd already gone back home, back to work on his next project.

And later, one of his employees said of the rescue, "We proved that Center Rock is a little company, but we do big things." (Applause.)

We do big things.

From the earliest days of our founding, America has been the story of ordinary people who dare to dream. That's how we win the future.

We're a nation that says, "I might not have a lot of money, but I have this great idea for a new company." "I might not come from a family of college graduates, but I will be the first to get my degree." "I might not know those people in trouble, but I think I can help them, and I need to try." "I'm not sure how we'll reach that better place beyond the horizon, but I know we'll get there. I know we will."

We do big things. (Applause.)

The idea of America endures. Our destiny remains our choice. And tonight, more than two centuries later, it's because of our people that our future is hopeful, our journey goes forward, and the state of our union is strong.

Thank you. God bless you, and may God bless the United States of America. (Applause.)

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INL/EXT-11-20792

Objective 1: Extend Life, Improve Performance, and Maintain Safety of the Current Fleet

Implementation Plan

January 2011

The INL is a U.S. Department of Energy National Laboratory
operated by Battelle Energy Alliance

INL/EXT-11-20792

Objective 1: Extend Life, Improve Performance and Maintain Safety of the Current Fleet

Implementation Plan

January 2011

Idaho National Laboratory
Idaho Falls, Idaho 83415

http://www.inl.gov

Prepared for the
U.S. Department of Energy
Office of Nuclear Energy
Under DOE Idaho Operations Office
Contract DE-AC07-05ID14517

INL/EXT-11-20792

Objective 1: Extend Life, Improve Performance, and Maintain Safety of the Current Fleet

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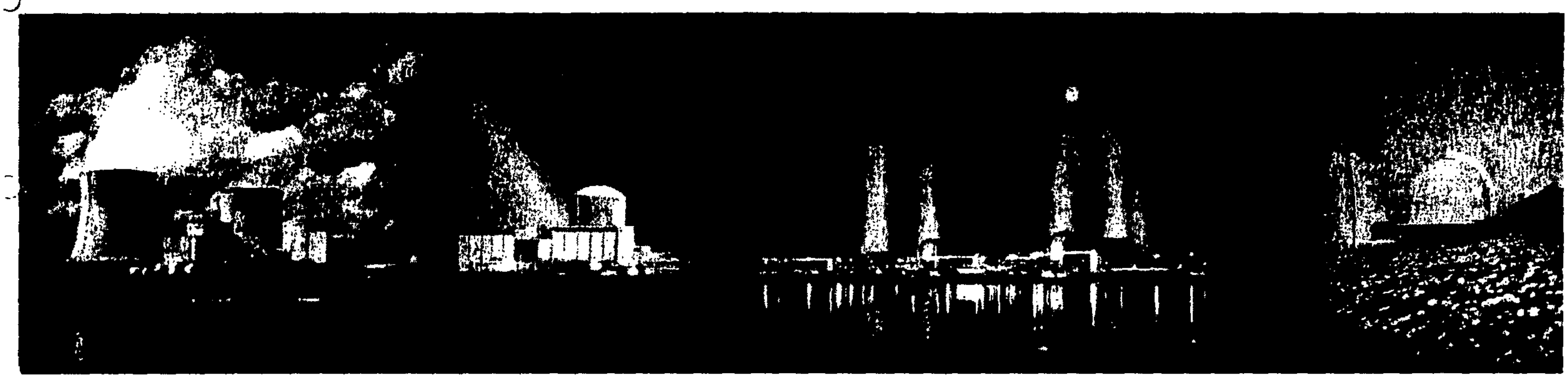


January 2011

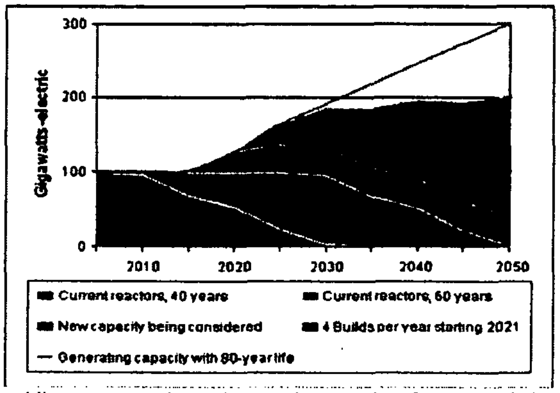
U.S. Department of Energy

Office of Nuclear Energy

EXECUTIVE SUMMARY

Nuclear power has reliably and economically contributed almost 20% of electrical generation in the United States over the past two decades. It remains the single largest contributor (more than 70%) of non-greenhouse-gas-emitting electric power generation in the United States.

By the year 2030, domestic demand for electrical energy is expected to grow to levels of 16 to 36% higher than 2007 levels. At the same time, most currently operating nuclear power plants will begin reaching the end of their 60-year operating licenses. Figure E-1 shows projected nuclear energy contribution to the domestic generating capacity. If current operating nuclear power plants do not operate beyond 60 years, the total fraction of generated electrical energy from nuclear power will begin to decline—even with the expected addition of new nuclear generating capacity. The oldest commercial plants in the United States reached their 40th anniversary in 2009.



The red line represents the total generating capacity of current and planned nuclear power plants, assuming extended operation to 80 years.
The unshaded area below the line represents lost capacity if the current nuclear power plant fleet is decommissioned after 60 years.

Figure E-1. Projected nuclear power generation.

The U.S. Department of Energy (DOE) Office of Nuclear Energy's Research and Development Roadmap has organized its activities in accordance with four objectives that ensure nuclear energy remains a compelling and viable energy option for the United States. The objectives are as follows: (1) develop technologies and other solutions that can improve the reliability, sustain the safety, and extend the life of the current reactors; (2) develop improvements in the affordability of new reactors to enable nuclear energy to help meet the Administration's energy security and climate change goals; (3) develop sustainable nuclear fuel cycles; and (4) understand and minimize risks of nuclear proliferation and terrorism.

The Light Water Reactor Sustainability (LWRS) Program is the primary programmatic activity that addresses Objective 1. This document describes how Objective 1 and the LWRS Program will be implemented.

The existing U.S. nuclear fleet has a remarkable safety and performance record and today accounts for 70% of the low greenhouse gas emitting domestic electricity production. Extending the operating lifetimes of current plants beyond 60 years and, where possible, making further improvements in their productivity will generate early benefits from research, development, and demonstration investments in nuclear power. DOE's role in Objective 1 is to partner with industry and the Nuclear Regulatory Commission in appropriate ways to support and conduct the long-term research needed to inform major component refurbishment and replacement strategies, performance enhancements, plant license extensions, and age-related regulatory oversight decisions. The DOE research, development, and demonstration role will focus on aging phenomena and issues that require long-term research and are generic to reactor type. Cost-shared demonstration activities will be conducted when appropriate.

The following five research and development pathways have been identified to address Objective 1:

(1) ***Nuclear Materials Aging and Degradation.*** Research to develop the scientific basis for understanding and predicting long-term environmental degradation behavior of materials in nuclear power plants. Provide data and methods to assess performance of systems, structures, and components essential to safe and sustained nuclear power plant operation.

(2) ***Advanced Light Water Reactor Nuclear Fuel Development.*** Improve scientific knowledge basis for understanding and predicting fundamental nuclear fuel and cladding performance in nuclear power plants. Apply this information to development of high-performance, high burn-up fuels with improved safety, cladding integrity, and improved nuclear fuel cycle economics.

(3) ***Advanced Instrumentation, Information, and Control Systems Technologies.*** Address long-term aging and obsolescence of instrumentation and control technologies and develop and test new information and control technologies. Develop advanced condition monitoring technologies for more automated and reliable plant operation.

(4) ***Risk-Informed Safety Margin Characterization.*** Bring together risk-informed, performance-based methodologies with scientific understanding of critical phenomenological conditions and deterministic predictions of nuclear power plant performance, leading to an integrated characterization of public safety margins in an optimization of nuclear safety, plant performance, and long-term asset management.

(5) ***Economics and Efficiency Improvement.*** Improve economics and efficiency of the current fleet of reactors while maintaining excellent safety performance. Develop methodologies and scientific basis to enable additional extended power uprates. Improve thermal efficiency by developing advanced cooling technologies to minimize water usage. Study the feasibility of expanding the current fleet into nonelectric applications.

The sustainability of light water reactors will benefit enormously from advanced modeling and simulation capabilities. The DOE Energy Innovation Modeling and Simulation Hub, Consortium for Advanced Simulation of LWRs will integrate existing nuclear energy modeling and simulation capabilities with relevant capabilities developed by the DOE Office of Science, the National Nuclear Security Administration, and others to leapfrog current technology to provide a multiphysics, multiscale predictive capability that is a revolutionary improvement over conventional codes. A key challenge will be to adapt advanced computer science tools to an applications environment. The hub is intended to create a new state-of-the-art in an engineering-oriented, multiphysics computational environment that can be used by a wide range of practitioners to conduct ultra-high fidelity predictive calculations of reactor performance.

With the 60-year licenses beginning to expire between the years 2029 and 2049, utilities are likely to initiate planning for baseload replacement power by 2014 or earlier. Research for addressing nuclear power plant aging questions must start now and is likely to extend through 2029. The LWRS Program represents the timely collaborative research needed to retain the existing safe operation of nuclear power plant infrastructure in the United States as long as it can operate safely.

CONTENTS

FIGURES

ACRONYMS

CASL	Consortium for Advanced Simulation of LWRs
DOE	U.S. Department of Energy
DOE-NE	U.S. Department of Energy Office of Nuclear Energy
EPRI	Electric Power Research Institute
FY	fiscal year
II&C	instrumentation, information, and control(s)
INL	Idaho National Laboratory
LWR	light water reactor
LWRS	light water reactor sustainability
NRC	U.S. Nuclear Regulatory Commission
PRA	probabilistic risk assessment
R7	RELAP7 – Next generation analysis capability
R&D	research and development
RISMC	Risk-Informed Safety Margin Characterization
SSC	systems, structures, and components
TIO	Technical Integration Office

Objective 1: Extend Life, Improve Performance, and Maintain Safety of the Current Fleet

1. IMPLEMENTATION PLAN

1.1 Introduction

The U.S. Department of Energy (DOE) Office of Nuclear Energy's (NE) Research and Development (R&D) Roadmap has organized its activities according to four objectives that ensure nuclear energy remains a compelling and viable energy option for the United States. The objectives are as follows: (1) develop technologies and other solutions that can improve the reliability, sustain safety, and extend the life of the current reactors; (2) develop improvements in the affordability of new reactors to enable nuclear energy to help meet the Administration's energy security and climate change goals; (3) develop sustainable nuclear fuel cycles; and (4) understand and minimize risks of nuclear proliferation and terrorism.

The Light Water Reactor Sustainability (LWRS) Program is the primary programmatic activity that addresses Objective 1. This document describes how Objective 1 and the LWRS Program will be implemented.

Currently, 104 nuclear power plants are operating in 31 states (Figure 1-1). The existing, operating fleet of U.S. nuclear power plants has consistently maintained outstanding levels of nuclear safety, reliability, and operational performance over the last two decades and operates with an average capacity factor above 90%, far superior to the 71% capacity factor achieved just over a decade ago.[a] This significant improvement in performance has made nuclear power plants considerably more economical to operate. Major improvements were made in all areas of plant performance, including operations, training, equipment maintenance and reliability, technological improvements, and improved understanding of component degradation. More broadly, these improvements reflect effective management practices, advances in technology, and the sharing of safety and operational experience. Today, nuclear production costs are the lowest among major U.S. power-generating options.

The oldest operating nuclear power plant started operation in 1969, and the newest plant started operation in 1996. The first group of nuclear power plants was brought online between 1969 and 1979, and the second group between 1980 and 1996. Almost all operating nuclear power plants have been issued, are applying for, or plan to apply for a 20-year license extension. This license extension will result in a licensed operating plant life of 60 years.

In about the year 2030, unless further licensing renewal occurs, the current fleet of nuclear power plants will reach the end of their 60-year operating license period. Absent additional research to address critical plant-aging issues, these valuable generating stations will be retired and decommissioned. Furthermore, degradation and obsolescence threaten to decrease power production from these nuclear power plants even before the scheduled end of their licensed lifetimes. Over the next three decades, this would result in a loss of 100-GWe of emission-free generating capacity and is comparable to electrical generation of new nuclear power plants that may be built over the same time period, leaving a gap in projections of required emission-free generating capacity. This gap might be filled with higher construction rates of new nuclear power plants or with other technologies. However, continued safe and economical operation of current reactors for an even longer period of commercial operation, beyond the

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[a] U.S. Energy Information Administration, "Monthly Energy Review June 2010," p. 113.

current license renewal lifetime of 60 years, is a potentially low-risk option to fill the gap and to maintain power generation at a fraction of the cost of building new plants.

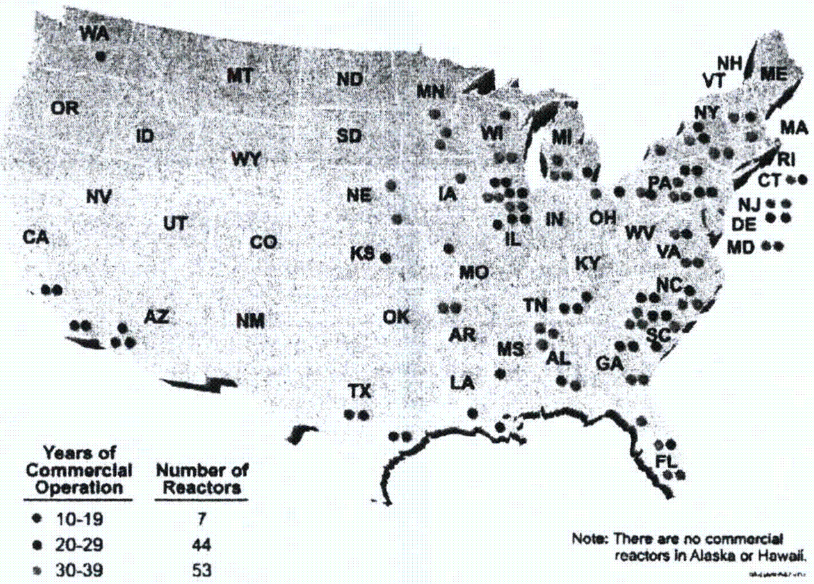


Figure 1-1. National distribution of operating nuclear power plants.

In order to receive a 20-year license extension, a nuclear power plant operator must ensure that the plant will operate safely for the duration of the license extension. The 40-year operating license period established in the Atomic Energy Act was based on antitrust considerations, not technical limitations. The 20-year license extension periods are presently authorized under the governing regulation of 10 CFR Part 54, "Requirements for Renewal of Operating Licenses for Nuclear Power Plants." This rule places no limit on the number of times a plant can be granted a 20-year license renewal as long as the licensing basis is maintained during the renewal term in the same manner and to the same extent as during the original licensing term.

This regulatory process ensures continued safety of all currently operating nuclear power plants during future renewal periods. The license extension process requires a safety review and an environmental review, with multiple opportunities for public involvement. The applicant must demonstrate safety issues through technical documentation and analysis, which the U.S. Nuclear Regulatory Commission (NRC) confirms before granting a license extension. A solid technical understanding of how systems, structures, and components (SSCs) age is necessary for nuclear power plants to demonstrate continued safety. A well-established knowledge base for the current period of licensed operation exists; however, additional research is needed to establish the robust technical basis that will be required for continued operational evaluations beyond 60 years.

The cost to replace the current fleet would require hundreds of billions of dollars. Replacement of this 100-GWe generating capacity with traditional fossil plants would lead to significant increases in carbon dioxide emissions. Extending operating licenses beyond 60 years would enable existing plants to continue to provide safe, clean, and economic electricity without significant greenhouse gas emissions. The goal of Objective 1 is to provide a comprehensive technical basis for licensing and managing the long-term safe and economical operation of the current fleet of nuclear power plants. The LWRS Program is the primary program that addresses Objective 1.

In developing the strategic plan and more specific program plans, it has become apparent that a government/industry cost-sharing arrangement for R&D is desirable for addressing the long-range, policy-driven goals of government and the acceptability and usefulness of derived solutions to industry. The LWRS Program requires the long-term vision and support of national laboratories and universities to address strategic reliability and safety requirements of existing nuclear power plants that could not be addressed by more inherently tactical organizations. The long-term, higher-risk research required to construct a scientific basis to understand the complex effects of plant aging is not likely to be carried out by industry alone.

The following major challenges face the current fleet:

- Aging and degradation of SSCs, such as reactor core internals, reactor pressure vessel, concrete, buried pipes, and cables
- Fuel reliability and performance issues
- Obsolete analog instrumentation and control technologies
- Design and safety analysis tools based on 1980s vintage knowledge bases and computational capabilities.

The economic incentive to meet these challenges in order to continue safe and reliable operation of existing plants is tremendous. Therefore, the LWRS Program will seek to maximize cost sharing with industry. Industry, working through the Electric Power Research Institute (EPRI) or through various owners' groups, will engage some of these challenges directly; however, those requiring significant research, development, and demonstration without a guaranteed or near-term return on investment will not be explored by industry. Federal R&D investments are appropriate where private investment is insufficient to help make progress on broadly applicable technology issues that can generate public benefits. The government holds a great deal of theoretical, computational, and experimental expertise in nuclear R&D that is not readily available in industry. The benefits of R&D on life extension can be applied to current plants as wells as to advanced reactor technologies still in development.

DOE-NE conducts research, development, and demonstrations that will maximize the national benefit of nuclear energy technology. The role for DOE is to work cooperatively with industry to support and conduct the long-term research needed to inform major component refurbishment and replacement strategies, performance enhancements, plant license extensions, and age-related regulatory oversight decisions. DOE will focus on aging phenomena and issues that require long-term research and develop advanced technology that industry can apply across the existing nuclear power plant fleet.

Secretary of Energy Steven Chu has reiterated the Administration's position that nuclear energy is an important part of the energy mix. He has recognized the importance of nuclear energy in meeting this challenge and supports R&D that can help increase the benefits of nuclear energy. Additionally, the benefits of assisting industry with R&D on life extension apply to current plants. Finally, the government holds a great deal of theoretical, computational, and experimental expertise in nuclear R&D that is not duplicated in industry. DOE-NE intends to proceed in a manner that supports a strong and viable nuclear industry in the United States and preserves the ability of that industry to participate in nuclear projects here and abroad.

DOE-NE research is focused on advancing the science-based understanding of aging nuclear power plants to increase safety and economics in the existing nuclear power plant fleet. This research has a focus on activities that industry and vendors cannot achieve because of the broad scope of the research across the industry or the technical coordination and infrastructure do not allow the work to progress. The relatively small national investment will be supported by very large infrastructure improvements by the industry as the technology for safe and economic operation matures.

Over the past several decades, academia and national laboratories have made enormous advances in the area of general materials science and modeling of fundamental structures. Applications of these sciences, although not specifically nuclear in nature, have the potential to bring tremendous advances over the narrowly focused, step-wise improvements the nuclear industry has realized thus far. Additionally, because of their unique resources (such as experimental irradiation and post-irradiation examination facilities), the national laboratory infrastructure is positioned to bridge the nuclear industry, R&D, and demonstration infrastructures. The LWRS Program serves to facilitate use of this knowledge with further R&D that is specific to the current fleet of nuclear power plants in understanding ongoing and complex challenges to long-term operations.

In summary, the electrical energy sector is challenged to supply increasing amounts of electricity in a dependable and economical manner and with reduced carbon dioxide emissions. Nuclear power is an important part of answering the challenge through long-term safe and economical operation of current nuclear power plants and with building new nuclear power plants. While implementing the Nuclear Energy Roadmap's Objective 1, the LWRS Program is designed to provide, in collaboration with industry programs, the sound technical basis for licensing and managing the long-term safe operation of existing operating nuclear power plants.

2. DESCRIPTION

2.1 Vision

Today's commercial nuclear power plant fleet has reliably produced environmentally friendly power in the United States for decades. As these nuclear power plants reach the end of their original 40-year operating license and enter their first 20-year extended license, sound engineering principles used in designing and building them must be applied to demonstrate their continued safety for a possible second license extension. In order to preserve the option of continued safe and economical operation of these nuclear power plants, a technical basis is required for the utility to evaluate investments in life-extending improvements and for the regulator to accept license extension applications. This implementation plan identifies R&D activities for enhancing scientific understanding of aging mechanisms important to the SSCs in nuclear power plants and to develop methods and technologies for managing plant aging and evaluating safety of nuclear power plants for long-term operation.

The LWRS Program vision is captured in the following statements:

Existing operating nuclear power plants will continue to safely provide clean and economic electricity well beyond their first license-extension period, significantly contributing to reduction of United States and global carbon emissions, enhancement of national energy security, and protection of the environment.

There is a comprehensive technical basis for licensing and managing the long-term, safe, economical operation of nuclear power plants. Sustaining the existing operating U.S. fleet also will improve its international engagement and leadership on nuclear safety and security issues.

Extending the life of nuclear power plants is a vital step in meeting the electrical needs of the United States today and in decades to come. By keeping these plants safely in service, the Nation will retain valuable infrastructure and allow additional time to construct new sources of clean, reliable, and secure energy. Until other reliable sources of power are built and placed on the electrical grid, the existing fleet of nuclear power plants is a vital component of the economy.

2.2 Program Goals

The LWRS Program is designed to achieve its vision by addressing long-term operational challenges that face nuclear utilities in the United States. Program goals are to develop scientific understanding, tools, processes, and technical and operational improvements to do the following:

1. Support long-term licensing and operation of the existing operating nuclear power plants to successfully achieve planned lifetime extension up to 60 years and lifetime extension beyond 60 years

2. Support maintenance and enhancement of performance of the existing operating fleet of LWRs to ensure superior safety, high reliability, and economic performance throughout their full lifetime.

2.2.1 Scientific Basis

Nuclear power systems were developed during the latter half of the 20th century. Their development was greatly facilitated by the Nation's ability and willingness to conduct large-scale experiments. Fifty-two test reactors were constructed at what is now the Idaho National Laboratory, another 14 reactors were constructed at the Oak Ridge National Laboratory, and a few others at other national laboratory sites. By today's standards, these large experiments and technology demonstrations were relatively affordable. The nuclear energy community was a rapid adopter of high-end computational modeling and simulation during the 1970s and 1980s. During this period, nuclear power plant designers and regulators developed many of the most demanding simulation models and tools on the most advanced computational platforms available. During the following 20 years, as the pace of nuclear energy deployment in the United States slowed to a halt, continued developments in our understanding of the fundamental science and phenomenology of nuclear power and transformational improvements in computational platforms went largely untapped due to perceived lack of need. This is no longer the case. These tools can now enable a new generation of nuclear power plant designers, fabricators, regulators, and operators to deliver affordable, safe, and environmentally sustainable nuclear power. The current developmental approach embodies the following elements:

- Theory – Based either on first principles or observations made during phenomenological testing, theories are developed to explain fundamental physical phenomena.

- Modeling and Simulation – A range of mathematical models for diverse phenomena at different time and spatial scales are developed and integrated to predict the overall behavior of the system. Key objectives of the modeling and simulation effort are to reduce the number of prototypes and large-scale experiments needed before demonstration and deployment and to quantify uncertainties and design and operational parameters.

- Verification and Validation – Verification and validation are essential parts of the modeling and simulation tools development process to support life-extension decision-making. Verification is done to ensure specifications are complete and mistakes have not been made in implementing the model. It also ensures the model is programmed correctly, algorithms are properly implemented, models do not contain errors, and coding does not contain bugs. Validation ensures the model meets its intended requirements in terms of the methods employed and results obtained. The ultimate goal of validation is to ensure the model addresses the right problem, provides accurate information about the system being modeled, and is accurately used. Validation requires a large amount of data, which are generated and range from small-scale experiments aimed at observation of isolated phenomena or measurements of fundamental properties to targeted integral experiments.

2.3 Implementation Strategy

Three strategies will be implemented in the LWRS Program:

1. Develop the scientific basis to understand, predict, and measure changes in materials and SSCs as they age in environments associated with continued long-term operation of existing LWRs
2. Apply this fundamental knowledge in collaborative public-private and international partnerships, developing and demonstrating methods and technologies that support safe and economical long-term operation of existing LWRs
3. Identify and verify the efficacy of new technology to address obsolescence while enhancing plant performance and safety.

Because of the scale, cost, and time horizons involved in sustaining the current operating fleet of LWRs, achieving the strategic goals of the LWRS Program will require extensive collaboration with industry, NRC, and international R&D institutions. The LWRS Program Technical Integration Office (TIO) was structured to address the technical and management requirements of the program (as discussed in Section 4). The TIO structure also is designed to facilitate interactions with multiple organizations within industry and universities and to maximize the contribution from each partner. In addition, recognizing the need to support education and training of the next generation of scientists and engineers, the following strategic guidelines were established to guide organization and implementation of the program:

- Leverage institutional knowledge and collaborative opportunities between the nuclear industry, national laboratories, universities, and the federal government in developing the basic scientific understanding in predicting key materials and safety margin characterizations
- Using the LWRS Program's vision and goals, build relationships across established relevant research interests, both at international and domestic levels
- Integrate Nuclear Energy University Program projects with selected R&D pathways
- Ensure the LWRS Program is accountable to sponsors, partners, and other stakeholders.

The LWRS Program can be divided into four phases that correspond to the four phases of sustainability (Section 1.2). The following describes the main objectives of each phase and the timeframe applicable to those nuclear power plants with the 60-year license expiring in 2029 and beyond:

- Phase I: Using data and tools, build confidence for the industry to proceed with new applications for extending plant operating licenses beyond 60 years or understand why such extensions are inadvisable (the timeframe for this phase is 2010 to 2015)
- Phase II: Enable the industry to make the decision to invest in plant refurbishments, modernizations, and licenses for extended operation beyond the first license extension (the timeframe for this period is 2015 to 2020)
- Phase III: Apply scientific solutions and continuing technology development to support NRC review and plant capital investment (the timeframe for this period is 2020 to 2030)

- Phase IV: Enable safe and economic operations with the extended operating licenses (the timeframe for this phase is 2030 and beyond).

The implementation schedule (Figure 2-1) is structured to support the following high-level milestones:

- 2010: Ensure long-term, safe operation is an accepted high-priority option for nuclear power generation by industry, DOE, and NRC
- 2015: Build confidence in long-term operation with data and tools
- 2020: Enable industry decision to invest and license for long-term operation
- 2025: Accept advanced tools, methods, and technologies
- 2030: Commence licensed long-term operations.

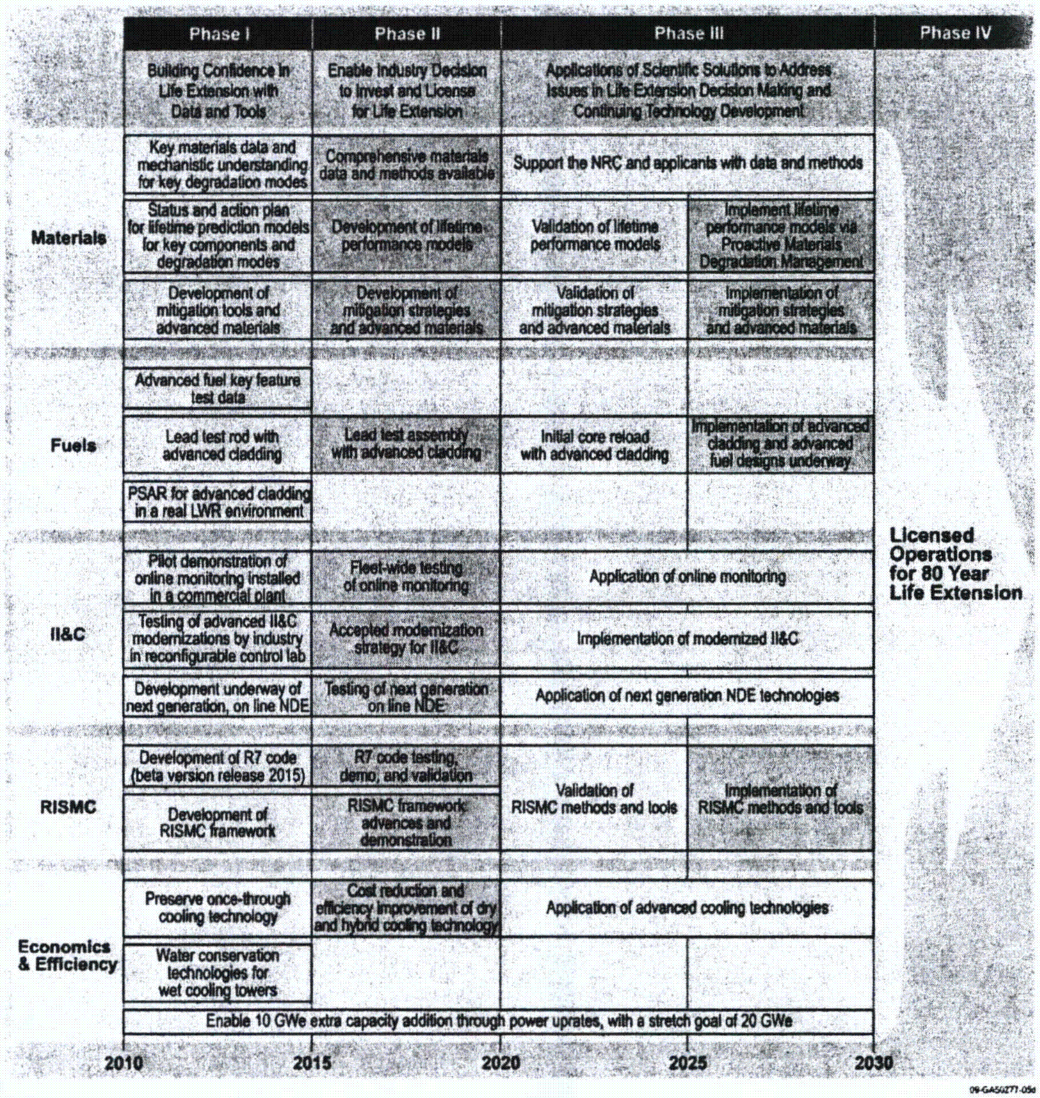


Figure 2-1. Light Water Reactor Sustainability Program implementation schedule.

3. RESEARCH AND DEVELOPMENT PATHWAYS

There are five R&D pathways (i.e., R&D topics) where DOE-NE-supported activities would provide solutions to the challenges encountered and could enable life extension of the reactors beyond 60 years with improved performance. Modest investment in long-term and high-risk/high-reward R&D that supports the current nuclear power plant fleet will provide scientific underpinnings for plant owners to make billion-dollar investment decisions to prolong the economic lifetime of these valuable national strategic assets and improve the lifetime of future generation reactor designs. The following five R&D pathways have been identified to achieve the program vision and address DOE's Objective 1:

1. ***Nuclear Materials Aging and Degradation***. Research to develop the scientific basis for understanding and predicting long-term environmental degradation behavior of materials in nuclear power plants. Provide data and methods to assess performance of SSCs essential to safe and sustained nuclear power plant operation.

2. ***Advanced LWR Nuclear Fuel Development.*** Improve scientific knowledge basis for understanding and predicting fundamental nuclear fuel and cladding performance in nuclear power plants. Apply this information to development of high-performance, high burn-up fuels with improved safety, cladding integrity, and improved nuclear fuel cycle economics.

3. ***Advanced Instrumentation, Information, and Control Systems Technologies.*** Address long-term aging and obsolescence of instrumentation and control technologies and develop and test new information and control technologies. Develop advanced condition monitoring technologies for more automated and reliable plant operation.

4. ***Risk-Informed Safety Margin Characterization.*** Bring together risk-informed, performance-based methodologies with scientific understanding of critical phenomenological conditions and deterministic predictions of nuclear power plant performance, leading to an integrated characterization of public safety margins in an optimization of nuclear safety, plant performance, and long-term asset management.

5. ***Economics and Efficiency Improvement.*** Improve economics and efficiency of the current fleet of nuclear power plants while maintaining excellent safety performance. Develop methodologies and scientific basis to enable additional extended power. Improve thermal efficiency by developing advanced cooling technologies to minimize water usage. Study the feasibility of expanding the current fleet into nonelectric applications.

3.1 Nuclear Materials Aging and Degradation

3.1.1 Background and Introduction

Nuclear reactors present a very harsh environment for components service. Components within a reactor core must tolerate high temperature water, stress, vibration, and an intense neutron field. Degradation of materials in this environment can lead to reduced performance, and in some cases, sudden failure.

Materials degradation in a nuclear power plant is extremely complex due to the various materials, environmental conditions, and stress states. Over 25 different metal alloys can be found within the primary and secondary systems; additional materials exist in concrete, the containment vessel, instrumentation and control equipment, cabling, buried piping, and other support facilities. Dominant forms of degradation may vary greatly between different SSCs in the reactor and can have an important role in the safe and efficient operation of a nuclear power plant. A small sampling of these metals for a pressurized water reactor is shown in Figure 3-1.

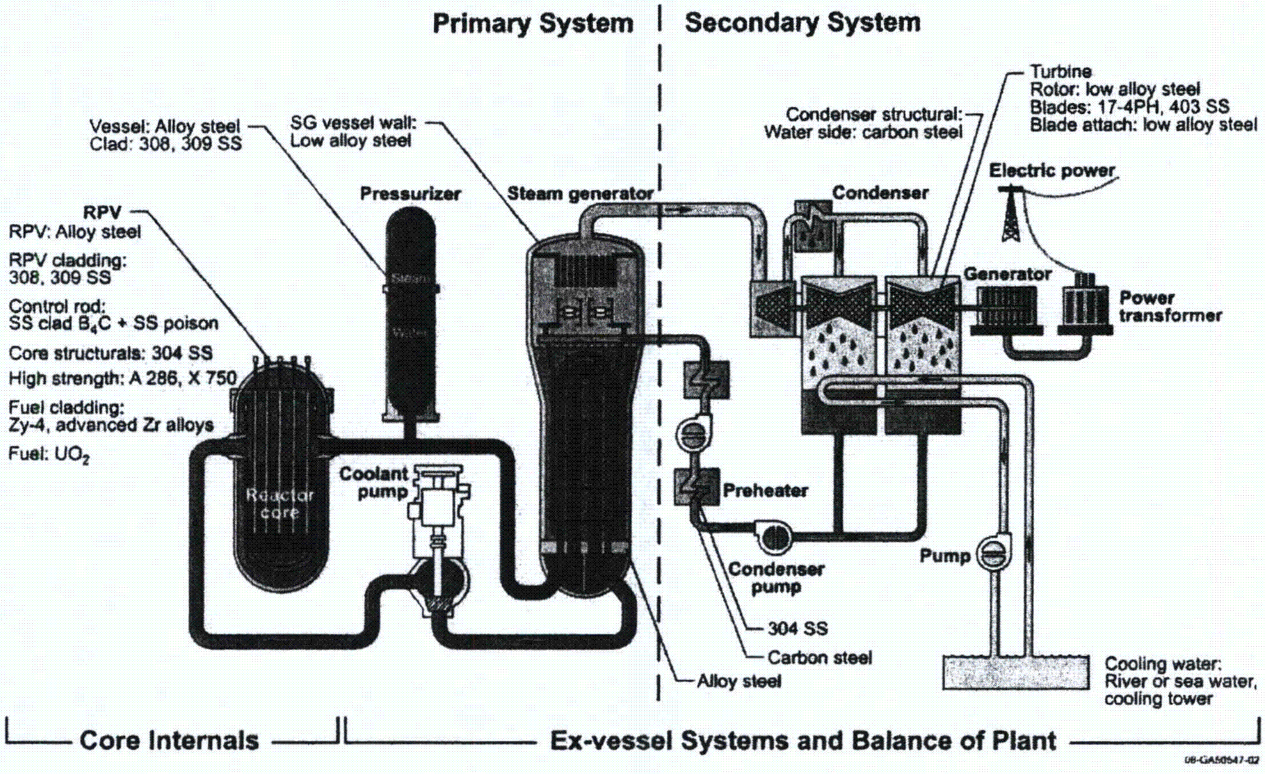


Figure 3-1. Light water reactor metals.

Clearly, materials degradation will impact reactor reliability, availability, and, potentially, safe operation. Routine surveillance and component replacement can mitigate the impact of this degradation; however, failures still occur. With reactor life extensions up to 60 years or beyond and power uprates, many components must tolerate more demanding reactor environments for even longer times. This may increase susceptibility to degradation for different components and may introduce new degradation modes. In many cases, an empirical approach is not practical. In the area of crack-growth mechanisms for Ni-base alloys alone (a single material, degradation mode pair), there are up to 40 variables known to have a measurable effect. Many variables have complex interactions. A purely experimental approach would require greater than a trillion experiments. Application of modern materials science will be required to resolve these issues. In the past two decades, there have been great gains in techniques and methodologies that can be applied to the nuclear materials problems of today. Indeed, modern materials science tools (such as advanced characterization tools and computational tools) must be employed. While specific tools and the science-based approach can be described in detail for each particular degradation mode, many of the diverse topics and needs described earlier can be organized into a few key areas. These could include mechanisms of degradation, mitigation strategies, and modeling and simulation. While all components (except perhaps the reactor pressure vessel) can be replaced, it may not be economically favorable. Therefore, understanding, controlling, and mitigating materials degradation processes and a technical basis for long-range planning for necessary replacements are key priorities for nuclear power plant operation, power uprate considerations, and life extensions.

3.1.2 Vision and Goals

The strategic goals of the Nuclear Materials Aging and Degradation R&D pathway are to develop the scientific basis for understanding and predicting long-term environmental degradation behavior of materials in nuclear power plants and to provide data and methods to assess performance of SSCs essential to safe and sustained nuclear power plant operations.

Specific outputs from this R&D pathway will include improved mechanistic understanding of key degradation modes and sufficient experimental data to provide and validate operational limits and development of advanced mitigation techniques to provide improved performance, reliability, and economics. Mechanistic and operational data also will be used to develop performance models for key material systems and components in later years.

3.1.3 Highlights of Research and Development

The Nuclear Materials Aging and Degradation R&D pathway activities have been organized into five areas: (1) reactor metals, (2) concrete, (3) cables, (4) buried piping, and (5) mitigation strategies. These research areas cover material degradation in SSCs that were designed for service without replacement throughout the life of the plant. Management of long-term operation of these components can be difficult and expensive. As nuclear power plant licensees seek approval for extended operation, the way in which these materials age beyond 60 years will need to be evaluated and their capabilities reassessed in order to ensure that they maintain the required design functions safely and economically. In addition to the five research areas, a Materials Aging and Degradation Assessment also will be conducted to provide a comprehensive assessment of materials degradation.

3.1.3.1 Reactor Metals. Numerous types of metal alloys can be found throughout the primary and secondary systems. Some of these materials, particularly the reactor internals, are exposed to high temperatures, water, and neutron flux. This creates degradation mechanisms that may be unique or environmentally exacerbated. Research programs in this area will provide a foundation upon which a safe regulatory environment can be established for life beyond 60 years. The following eight activities will encompass the reactor metals area: (1) mechanisms of irradiation-assisted stress corrosion cracking in stainless steels, (2) high-fluence effects on reactor pressure vessel steels, (3) crack initiation in Nickel alloys, (4) high-fluence effects on irradiation-assisted stress corrosion cracking of stainless steels, (5) irradiation-assisted stress corrosion cracking of alloy X-750, (6) evaluation of swelling effects in high-fluence core internals, (7) irradiation-induced phase transformations in high-fluence core internals, and (8) surrogate and attenuation effects on reactor pressure vessel steels.

3.1.3.2 Concrete. Currently, there is little or no data on long-term concrete performance in nuclear power plants. Long-term stability and performance of concrete structures within a nuclear power plant is a concern. The objective of this task is to assess the long-term performance of concrete. Research task evaluation and prioritization will be performed on an ongoing basis. Plans for research will continue to be evaluated by collaborators at EPRI and NRC to ensure complementary and cooperative research. In addition, formation of an Extended Service Materials Working Group will provide a valuable resource for additional and diverse input.

3.1.3.3 Cabling. Cable aging is a concern that currently faces the operators of existing nuclear power plants. Utility companies carry out periodic cable inspections using nondestructive examination techniques to measure degradation and determine when replacement is needed. Degradation of these cables is primarily caused by long-term exposure to high temperatures. Additionally, stretches of cables that have been buried underground are frequently exposed to groundwater.

3.1.3.4 ***Buried Piping.*** Maintaining the many miles of buried piping is an area of concern when evaluating the feasibility of continued plant life. While much of the buried pipes comprise either secondary plant or other non-safety-related cooling systems, some buried piping serves a direct safety function. Maintaining the integrity and reliability of all of these systems is necessary for continued plant operation. These systems must be maintained to ensure predictable plant operation and to maintain plant efficiency.

3.1.3.5 ***Mitigation Technologies.*** Mitigation technologies include weld repair, post-irradiation annealing, and water chemistry modifications. Welding is widely used for component repair. Weld-repair techniques must be resistant to long-term degradation mechanisms. Extended lifetimes and increased repair frequency welds must be resistant to corrosion, irradiation, and other forms of degradation. The purpose of this research area is to develop new techniques for weldments, weld analysis, and weld repair. A critical assessment of the most advanced methods and their viability for LWR repair weld applications is needed. Post-irradiation annealing may be a means of reducing irradiation-induced hardening in the reactor pressure vessel. It also may be useful for mitigation of radiation-induced degradation of core internals. Water chemistry modification is another mitigation technology that warrants evaluation.

3.1.4 Integrated Research Activities

This research element includes (1) international collaboration to conduct coordinated research with international institutions such as the Materials Aging Institute in order to provide more collaboration and cost sharing, (2) coordinated irradiation experiments to provide a single integrated effort for irradiation experiments, (3) advanced characterization tools to increase materials testing capability, improve quality, and develop new methods for materials testing, and (4) additional research tasks based on results and assessments of current research activities.

3.1.5 Industry Engagement and Cost Sharing

Coordination with other research efforts will be a national program and will require contributions from many different institutions, including input from EPRI's parallel activities in the Long-Term Operations strategic action plan and NRC's Life Beyond 60 activities. In addition to contributions from EPRI and NRC, participation from utilities and reactor vendors will be required. Given the breadth of the research needs and directions, all technical expertise and research facilities must be employed to support long-term operation of the nuclear power plant fleet.

The activities and results of other research efforts in the past and present must be considered on a continuous basis. Collaborations with other research efforts may provide a significant increase in cost sharing of research and may speed up research for both partners. This approach also reduces unnecessary overlap and duplicate work. Many possible avenues for collaboration exist, including the following:

- **EPRI:** Considerable research efforts on a broad spectrum of nuclear reactor materials issues that are currently under way provide a solid foundation of data, experiences, and knowledge
- **NRC:** Broad research efforts of NRC should be considered carefully during task selection and implementation
- **Boiling water reactor and pressurized water reactor owners groups:** These groups provide a forum for understanding key materials degradation issues for each type of reactor

- **Materials Aging Institute:** The Materials Aging Institute is dedicated to understanding and modeling materials degradation; a specific example might be the issue of environmental-assisted cracking

- **Programs in other industries and sectors:** Research in other fields may be applicable in the LWRS Program; for example, efforts in other fields such as the Advanced Cement-Based Materials Program may provide a valuable starting database on concrete performance for structures

- **Other nuclear facilities:** Degradation of concrete, buried piping, and cabling are not unique to nuclear reactors; other nuclear facilities (such as hot cells and reprocessing facilities) may be a key resource for understanding long-term aging of these materials and systems. The primary focus of the Constellation Pilot Project program centers on the material aging effects. This is a significant program commitment.

- **Other nuclear materials programs:** In addition, research within fast reactor and fusion reactor programs may provide key insights into high-fluence effects on materials because the mechanisms and models of degradation for fast reactor applications can be modified and provide a starting and proven framework for degradation issues in this effort.

Participation and collaboration with all of these partners may yield new opportunities for collaboration. Cost sharing also is being pursued for each task. Cost sharing can take many forms, including direct sharing of expenses, shared materials (or rescued specimens), coordinated plans, and complementary testing.

Requested Fiscal Year (FY) 2011 funding for all the planned FY 2011 tasks is $6.0M, and the stakeholder contributions both direct and in-kind support is $6.4M.

3.1.6 Facility Requirements

The core nuclear and radiological facilities needed to support the research of materials aging and degradation issues already exist. Research into irradiation effects and corrosion issues are expected to be the most difficult and considerable resources already exist within the national laboratory, university, and industry network for these issues. For irradiation effects, two test reactors (i.e., the Advanced Test Reactor and High-Flux Isotope Reactor) and the LWR fleet are available. Post-irradiation testing can be performed at the Idaho National Laboratory's (INL's) hot cell facilities and the Irradiated Materials Examination Lab, Irradiated Fuels Examination Lab, and Low Activation Materials Development and Analysis facilities at the Oak Ridge National Laboratory, which provide complementary techniques and equipment. Assets for corrosion testing exist at four national laboratories (i.e., Pacific Northwest National Laboratory, Argonne National Laboratory, INL, and Oak Ridge National Laboratory), four universities (the University of Michigan, Massachusetts Institute of Technology, University of Wisconsin, and Penn State), and all reactor vendors. Other Office of Science user facilities (such as Shared Research Equipment Facility at Oak Ridge National Laboratory) and INL's Electron Microscopy Laboratory provide world-class electron microscopy and characterization tools. Modification and equipment upgrades and modernization will be required on a case-by-case basis.

3.1.7 Products and Implementation Schedule

The main products from the Nuclear Materials Aging and Degradation R&D pathway are (1) mechanistic understanding of key degradation modes, (2) lifetime performance models, (3) advanced mitigation strategies, and (4) advanced replacement materials. The implementation schedule shown in Figure 3-2 is structured to support the following high-level milestones:

- 2010:
  - Complete the first iteration of reactor material degradation matrix
  - Identify the status and potential magnitude of key degradation modes for materials systems and issues.
- 2015:
  - Develop materials data and mechanistic understanding for key degradation modes in hand:
    - Determination of mechanisms of stress corrosion cracking underway
    - Bounding data for reactor pressure vessel embrittlement
    - Concrete degradation
    - Cabling
  - Develop status and action plan for lifetime prediction models for key components and degradation modes
  - Develop mitigation tools and advanced materials options underway:
    - Validation of post-irradiation annealing
    - Development of advanced replacement materials.
- 2020:
  - Ensure materials data and methods are available to support high confidence of successful long-term operation and predictable service times (replacement times) for major components:
    - Validation of lifetime performance models
    - Development of mitigation strategies.
- 2025: Support applicants and NRC with data and methods for materials degradation issues and limitations via proactive materials degradation management.
- 2030: Implement lifetime performance models, mitigation strategies, and advanced replacement materials.

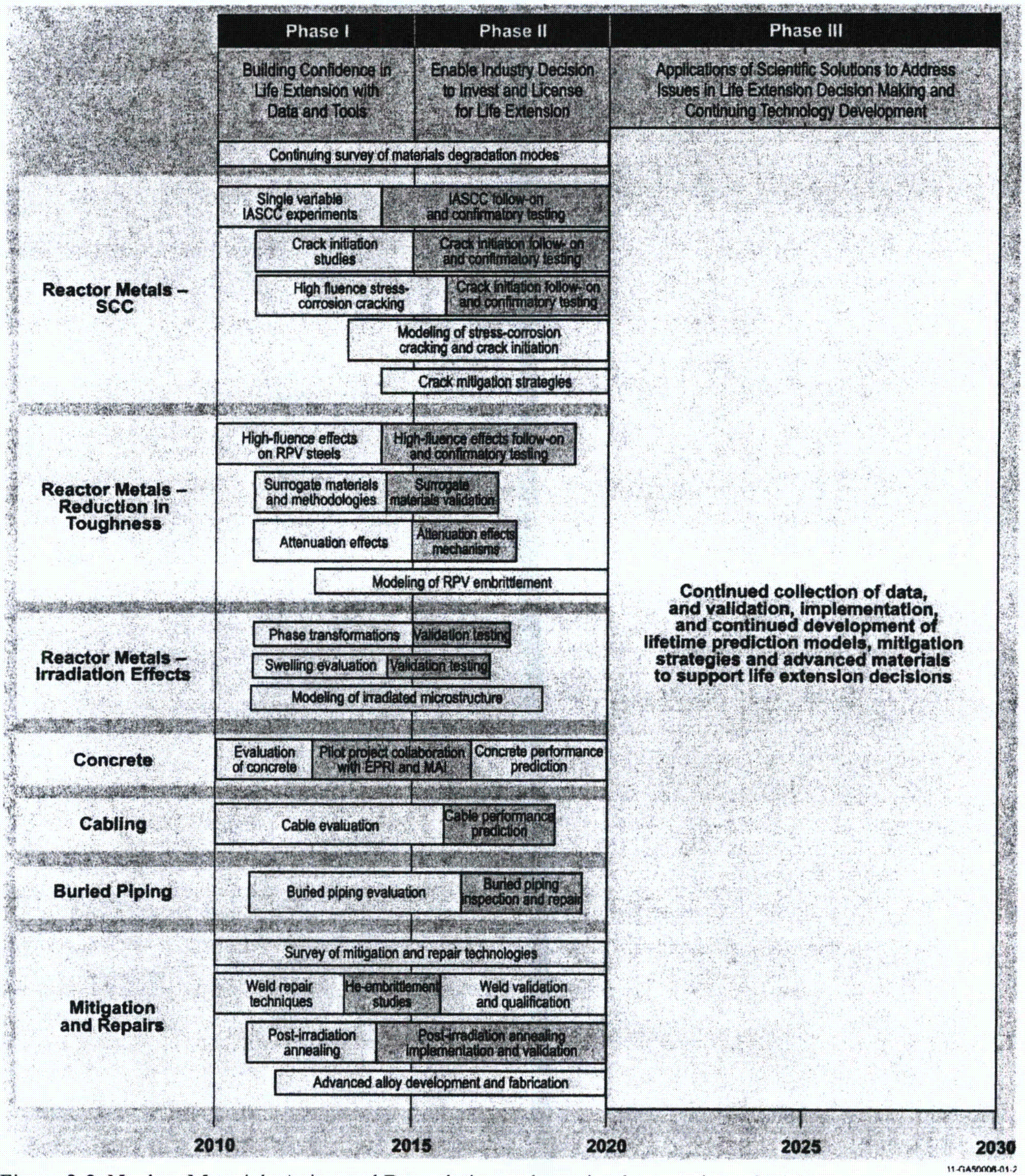


Figure 3-2. Nuclear Materials Aging and Degradation pathway implementation schedule.

3.2 Advanced Light Water Reactor Nuclear Fuel Development

3.2.1 Background and Introduction

Nuclear fuel performance is a significant driver of nuclear power plant operational performance, safety, operating economics, and waste disposal requirements. Over the past two decades, the nuclear power industry has improved plant capacity factors with incremental improvements in fuel reliability and use or burnup. However, these upgrades are reaching their maximum achievable impact within the constraints of existing fuel design, materials, licensing, and enrichment limits. Although the development, testing, and licensing cycle for new fuel designs is typically long (about 10 years from conception through utility acceptance), these improvements are often used with only an empirical understanding of the fundamental phenomena limiting their long-term performance.

Continued development of high-performance nuclear fuels through fundamental research focused on common aging issues can enable nuclear power plant operators to extend plant operating cycles and enhance the safety margins, performance, and productivity of existing nuclear power plants. The Advanced LWR Nuclear Fuel Development R&D pathway performs research on improving reactor core power density, increasing fuel burnups, advanced cladding, and developing enhanced computational models to predict fuel performance. This research is further designed to demonstrate each of these technology advancements while satisfying all safety and regulatory limits through rigorous testing and analysis.

To achieve significant fuel cost and use improvements while remaining within safety boundaries, significant steps beyond incremental improvements in the current generation of nuclear fuel are required. Fundamental improvements are required in the areas of nuclear fuel composition and performance, cladding integrity, and the fuel/cladding interaction to reach the next levels of nuclear fuel development. These technological improvements are likely to take the form of revolutionary cladding materials, enhanced fuel mechanical designs, and alternate isotope fuel compositions. As such, these changes are expected to have substantial beneficial improvements in nuclear power plant economics, operation, and safety.

3.2.2 Vision and Goals

Advanced, high-performance fuels are an essential part of the safe, economic operation of LWRs. New fuels have improved safety margins and economics and are more reliable. Fuel provides head-room for additional power uprates and high burnup limits. The scientific basis for fuel performance is well understood and its response to changing operational conditions and transients is predictable, which supports continuous improvements to reliability and operational flexibility for the nuclear power plant fleet.

Strategic goals are to improve the scientific knowledge basis for understanding and predicting fundamental nuclear fuel and cladding performance in nuclear power plants, and apply this information to development of high-performance, high burnup fuels with improved safety, cladding, integrity, and nuclear fuel cycle economics.

3.2.3 Highlights of Research and Development

The Advanced Nuclear Fuels Development Program element is separated into three R&D tasks: (1) advanced design and concepts, (2) mechanistic understanding of fuel behavior, and (3) advanced tools. These tasks were selected to balance development of new knowledge, verify developed knowledge, and create new advanced fuel technology. The scope of the R&D pathway includes all aspects important to fuel design and performance, including fuel design, exposure effects, and cladding material performance and development. Figure 3-3 shows a typical pressurized water reactor fuel assembly. A boiling water reactor assembly is of different design; however, the fuel rods are quite similar.

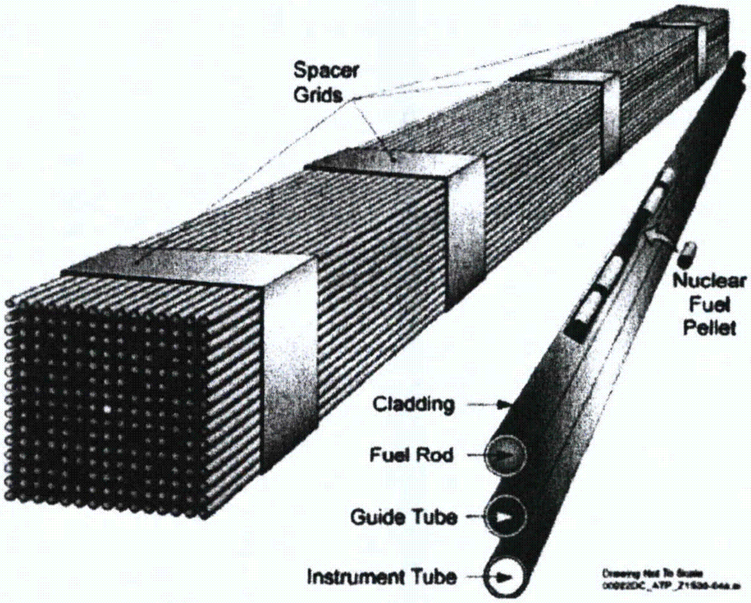


Figure 3-3. Nuclear fuel assembly.

The potential technologies that can be used to achieve the improved nuclear performance include ceramic fuel cladding, nuclear fuel forms, and geometry. Each of these technologies is independently beneficial and can be developed together to maximize the benefit of new materials.

Ceramic fuel cladding may allow for higher strength fuel rods at the high temperatures seen in accident scenarios. Ceramic fuel cladding also has very low chemical reactivity, which will eliminate most corrosion and degradation behavior. Mechanical strength, chemical interactions, effects from radiation, and accident scenarios will need to be studied.

Improved nuclear performance can come from increasing the fissile enrichment content, improved thermal conductivity, and enhanced mechanical strength. The detailed chemistry can be modified to improve thermal conductivity and mechanical strength. Completely new fuel forms may replace the current uranium oxide fuel to achieve significantly different and improved strength and conductivity. These technologies typically require increased enrichment to provide the maximum benefit without compromising current fuel cycle performance. Compatibility with fuel cladding, fuel behavior with increasing use, detailed chemistry effects, behavior during accidents, and the potential requirement for increased enrichment would need to be studied.

Current nuclear fuel pins are cylindrical in shape. Replacing the cylindrical pins with annular or cruciform fuel will increase the surface area to volume ratio. This change can allow higher heat generation rates since more power can be safely removed from the nuclear fuel pin. The higher safe heat rate level will allow increased reactor power without changing the safe operating limits of the reactor. Nuclear fuel behavior, chemistry and corrosion effects, and the accident behavior will need to be studied.

The close coupling of cladding, fuel form, and fuel geometry require sophisticated models and tools to include all performance behavior. Detailed computer simulation is intended to improve predictions of nuclear fuel behavior. This will allow better performance limits, increasing the value of current and future nuclear fuel. A second advantage is to allow an increase in the responsiveness and efficiency of nuclear fuel design.

A significant experimental program is planned to ensure the developed technology is well understood and to develop the intrinsic capability to study new nuclear fuel technology. As the program moves forward and the fuel technology, program infrastructure, and the funding profile mature, additional and supporting technologies also will be developed.

These research areas support each other because development in one area will allow development in the other two areas. This research is designed to demonstrate critical technologies to support nuclear power plant operators in their extended license renewal decision and provide the basis for a new generation of nuclear fuel. The silicon carbide reinforced silicon carbide is a ceramic matrix composite that displays very low chemical reactivity, high hardness, and useful strain before failure and maintains its strength at temperatures that conventional metallic cladding cannot achieve. These material properties offer the opportunity to greatly improve a new generation of nuclear fuel. Maintenance of good structural strength and reduced chemical reaction at elevated temperatures greater than 1,000°C will allow a significant increase in reactor safety. The elimination of exothermic hydrogen reactions seen in zirconium cladding will eliminate a significant nuclear fuel limit, allowing for higher performance and safety. The low chemical reactivity will greatly simplify reactor water chemistry. This will allow optimization of the nuclear power plant water chemistry to protect the vessel internals.

The development of ceramic cladding also demands a much deeper understanding of the fundamental nuclear behavior and material science of the nuclear fuel system. The many design options available to a modern engineered composite allow for many improved performance behaviors. Detailed design of protective glass formation, engineered mechanical properties, and engineered heat transfer properties can be used to optimize fuel cladding performance.

The behavior of ridged ceramic matrix composite cladding and ceramic uranium oxide fuel requires a detailed understanding of nuclear fuel changes at many scales under irradiation. This understanding can be applied to additional or alternate fuel technologies to improve the understanding of safety and performance of nuclear fuel. The insights developed in understanding ceramic matrix composite silicon carbide cladding will be used to address current nuclear fuel issues. The increased understanding will be transferable to other technologies, metallic fuels, annular pellets, cruciform pellets, or higher conductivity fuel, as necessary.

The need for greater understanding of nuclear fuel behavior in a short time also demands a coordinated testing program. The testing program will be used to study new material behavior between ceramic clad and fuel. Testing will define currently unknown behavior to provide information for advanced modeling, pellet clad interaction axial slip, ceramic-ceramic pellet clad interaction, and failure modes of the new fuel. The irradiation program also will provide the basis for a definition of performance properties required to make the licensing case for vendors as the technology matures. The required testing will improve both the physical and knowledge-based infrastructure required for LWR testing. The need for transient testing will require the development of new reactor-based infrastructure. The design, manufacturing, and development of prototype fuel provide a more efficient LWR fuel development process, regardless of the technology focus.

The benefits provided by the current single technology approach include timely results, step change in performance, flexibility in providing industry with technology as development continues, increased fundamental understanding of nuclear technology and improved testing infrastructure.

These activities allow direct product development and development of the supporting enabling technology and understanding required to design and license a new generation of fuel. Without the specific silicon carbide ceramic matrix composite cladding development, another high value fuel development activity would be used to focus fuel development activities toward the roll out of a specific product.

3.2.3.1 Advanced Designs and Concepts. The purpose of this task area is to increase the understanding of advanced fuel design concepts, including use of new cladding materials, increases to fuel lifetime, and expansions to the allowable fuel performance envelope. These improvements will allow fuel performance-related plant operating limits to be optimized in areas such as operating temperatures, power densities, power ramp rates, and coolant chemistry. Accomplishing these goals leads to improved operating safety margins and improved economic benefits.

3.2.3.2 Mechanistic Understanding of Fuel Behavior. This task area will involve testing and modeling of specific aspects of LWR fuel, cladding, and coolant behavior. Examples include pellet cladding interaction, fission gas release, coolant chemistry effects on corrosion, and crud (oxide) formation. Improved understanding of fuel behavior can be used in fuel design, licensing, and performance prediction.

An improved fundamental understanding of phenomena that impose limitations on fuel performance will allow fuel designers, fabricators, plant chemists, and code developers to optimize the performance of current fuels and the designs of advanced fuel concepts. A life-cycle concept will be applied so that optimization applies to fabrication, in-reactor use, and performance as used fuel in storage. Fundamental mechanistic models will provide a foundation for supporting the LWRS Program strategic objectives in developing advanced fuels. The following models will be included in this task: (1) fuel mechanical property change model as a function of exposure, (2) pellet cladding interaction model development, (3) chemistry coolant model development, (4) mesoscale models of microstructure fuel behavior, and (5) hydrogen uptake behavior of zirconium cladding.

3.2.3.3 ***Advanced Tools.*** This task area will use increased understanding of specific fuel performance phenomena that will be integrated into encompassing fuel performance advanced tools. These advanced tools, including modeling and simulation codes, advanced experimental capabilities, and real-time performance monitoring, will be developed to enhance plant and repository efficiency. In addition, the advanced tools developed will be used to minimize the time required to realize the gains made through this R&D effort by decreasing the amount of time needed for materials development and fuel qualification. The following activities will be included in this task: (1) engineering design and safety analysis tool, (2) mechanical models of composite cladding, (3) irradiation design studies of advanced silicon carbide cladding, (4) experimental campaign to verify design and safety margin calculation tool, and (5) advanced mathematical tools to support advanced nuclear fuels calculations.

3.2.4 Industry Engagement and Cost Sharing

An initial activity in FY 2009 was a workshop held with EPRI, nuclear fuel vendors, universities, and DOE laboratories to review potential technologies or combinations of technologies that would best fit the LWRS Program mission. Various specific technologies were proposed, including fuel forms, high thermal conductivity uranium dioxide and a variety of metallic fuels, annular and cruciform fuel geometries, and silicon carbide ceramic cladding materials; other novel ideas were presented and reviewed at the meeting. Silicon carbide fiber reinforced silicon carbide matrix was selected as the initial focus for development. The silicon carbide cladding technology offers the potential for a step change in safety and economics. The implementation schedule for silicon carbide cladding also supports the asset owner's evaluation before the relicensing decision.

Follow on activities have engaged EPRI as a research partner. The EPRI Advanced Fuels and Fuel Reliability groups have been involved directly in the program. The Advanced Fuels group supports the program as part of the program guidance group with Oak Ridge National Laboratory. They also are supporting the LWRS Program with code support, experimental facilities, and independent fuel behavior research. This interaction has lead to EPRI requesting that the LWRS Program directly support an EPRI research task into the silicon carbide ceramic matrix composite boiling water reactor fuel channels. The goal is to demonstrate the potential for low bow silicon carbide fuel channels. INL will receive a contract for approximately $50K to produce prototypes and test samples. INL will gain fundamental silicon carbide fuel swelling models and knowledge. The LWRS Program also has been invited to attend the EPRI Fuel Users Group meeting.

Westinghouse Electric Company has entered into a nondisclosure agreement with INL/Battelle Energy Alliance that should lead to cooperative R&D agreements on specific research tasks. Currently, INL is receiving commercial zirconium cladding research results. In the future, Westinghouse will supply uranium dioxide fuel pellets and access to testing and irradiation facilities. These commitments will greatly advance the program. The LWRS Program will provide in-kind support with irradiation facilities, materials, and research results.

These interactions are models for industry interaction going forward. The LWRS Program advanced LWR nuclear program element will provide useful infrastructure for testing and advanced technology to leverage with industry partners to advance both programs. The planned near-term results and direct testing programs provide a value to industry.

Industry is working on manufacturing issues of a specific technology related to producing quality functional components that can be used in a commercial reactor. Industry is required to focus on near-term proof of concepts that can lead directly to licensed commercial products. DOE's research is focused on the needed science-based knowledge to confidently understand, design, predict performance, and license advanced fuel. In the case of the LWRS Program with a near-term demonstration of 2015, industry and DOE research activities are very similar as discussed with industry representatives.

3.2.5 Facility Requirements

All fuel development requires the understanding of irradiation effects on fuel performance and relies on irradiation experiments that range from separate effects to integral effects under representative and prototypic conditions. Test facilities for irradiation of advanced nuclear fuels need to be developed to allow the Advanced Test Reactor and the High-Flux Isotope Reactor to irradiate unique size/length samples. This includes the total number of test locations for efficiently simulating LWR neutron environments. The provision of adequate LWR pressure loops to simulate chemistry and temperatures at which advanced fuels will operate is a capability that can be added to the Advanced Test Reactor or procured from other existing reactors such as the Halden Reactor Project. New facilities are required where transient and failure modes can be tested with exposed nuclear fuel to provide an adequate demonstration of nuclear fuel performance for safety analysis. These test facilities exist in Europe at high cost and time requirements. Some transient testing facilities could be installed into the Advanced Test Reactor. The Transient Reactor and Experiment Test Facility reactor (at INL) would provide the required, single-purpose test reactor to provide the range of transients required without interfering with other planned Advanced Test Reactor programs.

Pre and post-irradiation testing facilities that are adequate for producing results in a reasonable time are required. Non-irradiated tests of the prototype fuel to minimize required irradiation testing and to speed initial modeling and design development are primary needs. Some capability exists among DOE laboratories. The bulk of the non-nuclear testing is anticipated to occur at university facilities. Analysis of irradiated samples at microstructure and smaller levels will play an important role in developing detailed fuel performance understanding and models.

The need for people capable of developing sophisticated nuclear fuel models and providing analysis for unique reactor fuel tests is likely to be a limiting factor. This requirement will be filled with DOE, university, and vendor personnel.

3.2.6 Products and Implementation Schedule

Advanced nuclear fuel cladding, nuclear fuel materials, and nuclear fuel geometries are the critical technologies to be developed. The understanding gained and computational tools developed in evaluating and testing the critical technologies will allow for higher performing nuclear fuel and better predictions of nuclear fuel behavior.

The implementation schedule shown in Figure 3-4 is structured to support the following high-level milestones:

- 2010:
    - Design and planning of silicon carbide/silicon carbide fiber rodlet irradiation campaign
    - Rodlet testing planning/design with silicon carbide
    - Rodlet irradiation with silicon carbide
    - Mechanical modeling of silicon carbide/silicon carbide fiber matrix
    - Evaluation of silicon carbide technology for further development
    - Licensing case for silicon carbide applications in commercial applications
    - Out-of-core testing, repeated stress, thermal cycles, and failure modes for advanced fuel.
- 2015:
    - Initial lead test rod design with advanced fuel and planning
    - Rod testing planning/design with advanced fuel
    - Development of advanced fuel with multiple technologies
    - Rod irradiation with advanced fuel.
- 2020:
    - Initial advanced fuel lead test assembly licensing
    - Reload testing planning/design with advanced fuel
    - Reload irradiation with advanced fuel.
- 2025:
    - Initial advanced fuel reload design
    - Initial core reload with advanced fuel

- Irradiation program for increased enrichment bundles
- Irradiation program for increased exposure bundles.

- 2030:
  - Fleetwide implementation of advanced fuel reload under way
  - Lead test assembly for increased enrichment fuel
  - Lead test assembly for increased exposure fuel.
- 2040:
  - Advanced fuel designs
  - Advanced uprated cores using advanced fuel cores.

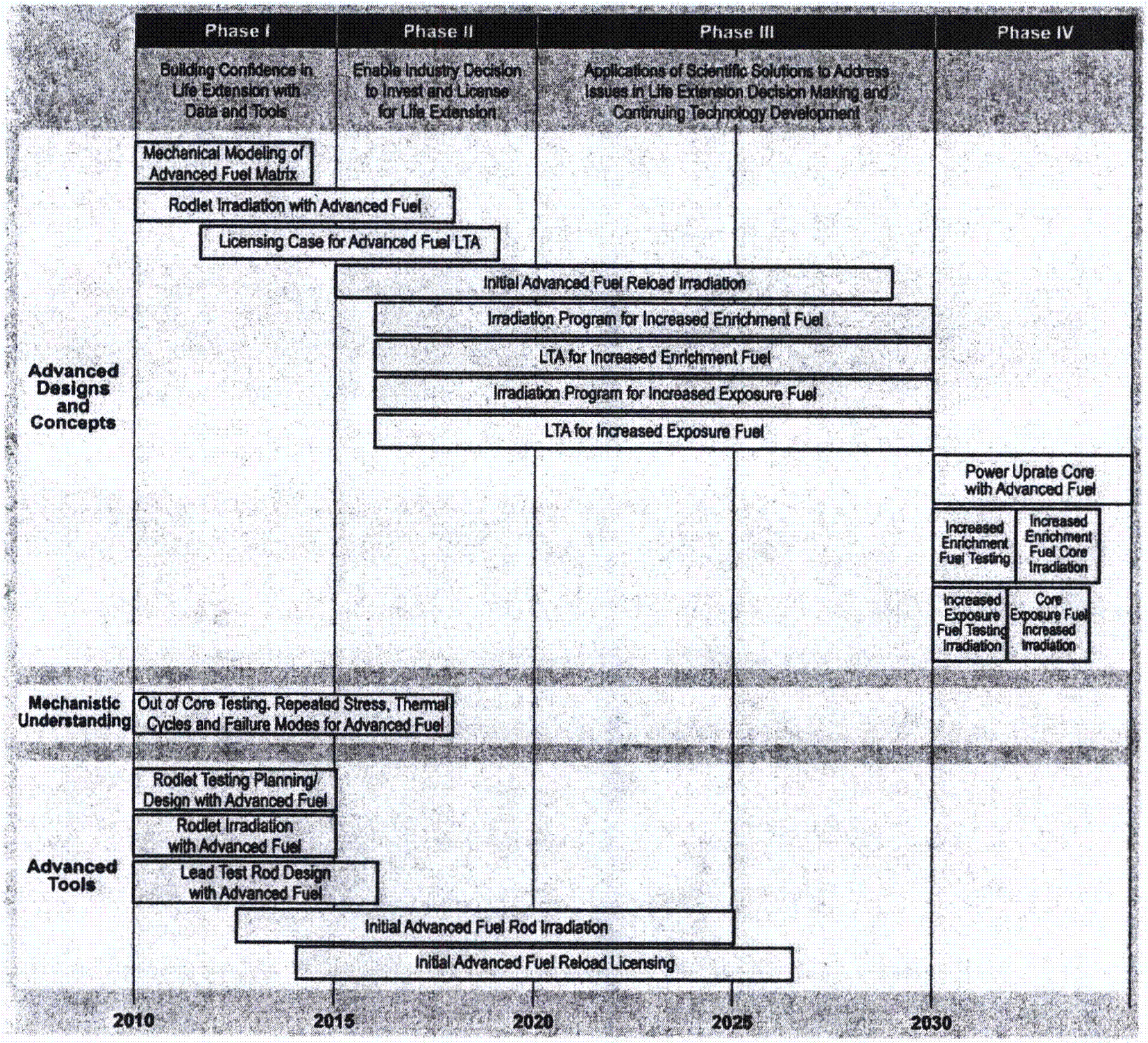


Figure 3-4. Advanced Light Water Reactor Nuclear Fuels Development pathway implementation schedule.

3.2.7 Nuclear Fuels Program Coordination

Advanced nuclear fuel development is not restricted to the LWRS Program. The Advanced LWRS Nuclear Fuels R&D pathway is working in conjunction with other nuclear fuel programs. Direct cooperation with the Fuel Cycle R&D Program (Objective 3) is ongoing. Principal investigators are sharing work packages and attend meetings for both programs. Specific tasks for both programs are being coordinated to avoid overlap but promote progress on required tasks. The LWRS Program has a relatively near-term focus compared to the Fuel Cycle R&D Program. The LWRS Program looks to implement technology in support of the nuclear power plant reinvestment decision. This provides a focus on technologies and supporting tasks that will apply to the current fleet of nuclear power plants.

The Advanced LWRS Nuclear Fuels R&D pathway also is gaining benefit from the Nuclear Energy Advanced Modeling and Simulation Program in development of advanced nuclear fuel computer models. Currently, research for the LWRS Program and the Nuclear Energy Advanced Modeling and Simulation Program use common staff. Close coordination and cooperation among the three fuels-related R&D activities ensures information sharing and avoids potential duplication.

3.3 Advanced Instrumentation, Information, and Control Systems Technologies

3.3.1 Background and Introduction

Instrumentation, information, and control (II&C) systems technologies are essential to ensuring delivery and effective operation of nuclear power systems. They are enabling technologies that affect every aspect of nuclear power plant and secondary plant operations – analogous to a central nervous system. In 1997, the National Research Council conducted a study concerning the challenges involved in modernization of digital instrumentation and control systems in nuclear power plants. Their findings identify the need for new II&C technology integration. Unfortunately, this report, issued in 1997, still reflects the current state of affairs at nuclear power plants. Numerous issues that must be addressed in order to implement new types of II&C systems in commercial nuclear power plants have not been satisfactorily demonstrated in the commercial nuclear power industry of the United States. Without new types of II&C systems, today's nuclear power plants II&C systems will become antiquated and unreliable, unfamiliar to a future workforce, and a liability on the corporate balance sheet.

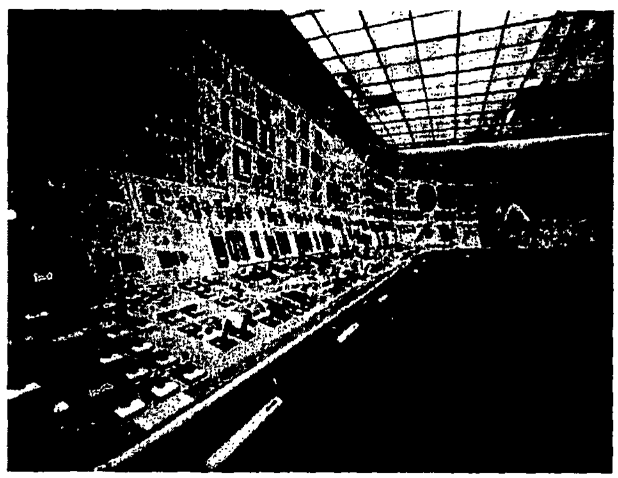


Figure 3-5. A contemporary control room at a nuclear power plant.

Digital II&C technologies are deployed in a number of power generation settings worldwide. The situation in the United States nuclear power sector differs from these other settings in several key respects: analog systems that have been operated beyond their intended service lifetimes dominate II&C systems in place today; regulatory uncertainty and associated business risk concerns are dominant contributors to the status quo; and current utility business models have not evolved to take full advantage of digital technologies to achieve performance gains. As a consequence, digital technologies are implemented as point solutions to performance and obsolescence concerns with individual II&C components. This reactive approach is characterized by planning horizons that are short and typically only allow for 'like-for-like' replacements to be made. This results in a fragmented, non-optimized approach that is driven by immediate needs. As a long-term strategy, this is not sustainable in light of the evolution of II&C technology, availability of skills needed to maintain this antiquated technology, and high costs and uncertainties associated with doing so.

In addition to some of the technical challenges and associated R&D needs, in order to be successful in supporting long-term operational goals, a different approach is needed to encourage digital technology deployment. These must be recognized in light of current industry trends and factors. The first is the rigor of qualification activities needed to deploy new engineered systems in nuclear power plants. Within this power generation sector, II&C specialists frequently refer to the "N" stamp (meaning the nuclear stamp) as shorthand for the rigorous and highly demanding requirements for qualification of II&C technologies intended for integration into nuclear plant II&C architecture. At a minimum, some operational history or tests are needed to demonstrate a commensurate level of safety sufficient to acquire confidence in the new technology. Facilities for research and tests to support these needs are simply lacking in the United States and elsewhere. Also, currently there is little experience in using these kinds of facilities to demonstrate new technologies and produce data that can be used to formulate a regulatory technical basis for digital technology. Rather, most attempts to introduce digital technologies are performed on an as-needed basis by individual utilities. Some of these efforts have resulted in lengthy and very costly efforts and have, according to some, had a chilling effect on other utilities considering a migration to digital technologies.

Second, digital technologies are deployed on an as-needed basis to replace failing analog devices that are no longer maintainable. Because these technologies replace like-for-like capability – analog with digital – the planning horizon for such activities is typically short, which tends to marginalize the potential benefits that can be achieved through digital II&C technology development and deployment Digital replacements of this kind do not displace any of the old costs, but add to them. Hence, digital technologies do not impact the current business models of asset owners or become viewed from the perspective of long-term nuclear asset management. Paradoxically, the potential benefits from additional digital functionality are rarely realized as in other power generation sectors.

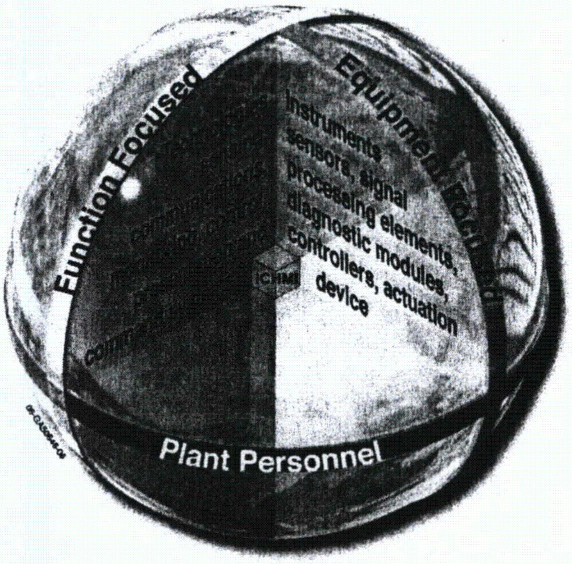
However, the nuclear industry as a whole now recognizes that it is achieving ever-diminishing returns on its constant efforts to improve performance. In part, many of the early potential gains from human performance improvement programs have been achieved and utilities are beginning to recognize that they are approaching the limits of returns on human performance initiatives. Compounding this is the fact that the quotidian costs of energy production in the nuclear power industry continue to be driven by operation and management (i.e., personnel) costs, in contrast to the fossil power generation sector whose daily generation costs are driven by the price of fuel. Individual force-fitting approaches to digital technology deployment and ever increasing obsolescence, long-term safety, and reliability of analog devices necessitate reconsideration of potential solutions involving digital technologies for nuclear energy systems. This reconsideration must include the long-term issues associated with monitoring and managing aging and degradation of plant systems and initiatives that must be undertaken to ensure long-term sustainability of II&C systems in a way that achieves availability of a cost-competitive, reliable nuclear energy supply.

A technology-driven approach in this R&D area alone will be insufficient to yield the type of transformation that is needed to secure a long-term source of nuclear energy base load; a new approach is needed. An effective R&D initiative must engage the perspectives of stakeholders (i.e., asset owners, regulators, vendors, and R&D organizations) in order to articulate and initiate relevant R&D activities.

In order to displace the piecemeal approach to digital technology deployment, a new vision for efficiency, safety, and reliability is needed that leverages the future potential of a range of digital options. This includes consideration of goals for nuclear power plant staff numbers and types of specialized resources; targeting operation and management costs and the plant capacity factor to ensure commercial viability of proposed long-term operations; improved methods for achieving plant safety margins and reductions in unnecessary conservatisms; and leveraging expertise from across the nuclear enterprise. This last point is especially noteworthy because mergers and acquisitions have redefined nuclear asset ownership and nuclear energy supply in the United States and Europe in terms of a substantially reduced ownership set and one that is no longer characterized by regional location or even national boundaries.

3.3.2 Vision and Goals

Maintaining the reliability and safety of II&C systems used for process measurement and control is crucial in meeting the licensing basis of nuclear power generation assets. Aging and obsolescence of the installed technologies is a continuing concern for asset owners. Advances are needed to support crucial characterization and monitoring activities that will become increasingly important as materials age. The aim of collaborations, demonstrations, and approaches envisioned by this R&D pathway are intended to lessen the inertia that sustains the current status quo of today's II&C systems technology and to motivate transformational change and a shift in strategy – informed by business objectives – to a long-term approach to II&C modernization that is more sustainable.



One of the goals of this program is to ensure the issues do not become a limiting factor in the decisions on long-term operation of these assets. Goals for technology introduction are to enhance efficiency, safety, and reliability; improve characterizations of the performance and capabilities of passive and active components during periods of extended operation; and to facilitate introduction of other advanced II&C systems technologies by reducing regulatory uncertainties. The R&D activities of this program are intended to set the agenda for a long-term vision of future operations, including fleetwide integration of new technologies.

3.3.3 Highlights of Research and Development

A program element of R&D activities is proposed to develop some of the specific needed critical capabilities of digital technologies to support long-term nuclear asset operations and management. The supporting technologies will enable the large integrated changes that industry cannot achieve without direct R&D support. This includes comprehensive programs intended to do the following:

- Support creation of new technologies that can be deployed to address the sustainability of today's II&C systems technologies
- Improve understanding of, confidence in, and facilitate transition to these new technologies
- Support development of the technical basis needed to achieve technology deployments

- Develop national capabilities at the university and laboratory level to support R&D
- Create or renew infrastructure needed for long-term research, education, and testing.

3.3.3.1 Centralized Online Monitoring and Information Integration. As nuclear power systems begin to be operated during periods longer than originally anticipated, the need arises for more and better types of monitoring of material and system performance. This includes the need to move from periodic, manual assessments and surveillances of physical systems to online condition monitoring. This represents an important transformational step in the management of physical assets. It enables real-time assessment and monitoring of physical systems and better management of active components based on their actual performance. It also provides the ability to gather substantially more data through automated means and to analyze and trend performance using new methods to make more informed decisions about asset management and safety management.

3.3.3.2 New Instrumentation and Control and Human System Interface Capabilities. R&D activities are aimed at the eventual modernization of II&C systems technologies used in nuclear energy production. Asset owners and regulators view these as enabling in the dialogue of long-term asset and safety management. The evidence of aged and obsolete technologies is abundant in the control centers of nuclear power plants. The analogy of control rooms as the tip of the iceberg for aging analog technology is particularly apt because it typifies both the problem and a substantial opportunity for R&D to impact systems on a plant scale much larger than what can be readily observed.

Through long-term collaborations with leading international research institutes and capitalizing on new national capabilities for simulation-based technology development and testing, research in visualization, process control, and automation is planned. The long-term objectives of these research activities are to demonstrate new concepts of operations for nuclear power generation assets that address the need for technology modernization, improved state awareness, improved safety, and optimized asset management. These objectives will be achieved by a series of multiyear pilot programs aimed at developing and demonstrating new technologies and concepts for information and control technologies, including the following: (1) advanced instrumentation and information pilot projects, (2) future concept of operations pilot projects, and (3) advanced automation pilot projects.

Advanced instrumentation and information pilot projects will conduct research that employs new instrumentation to monitor and assess the performance of nuclear power plant systems and techniques for using the resulting information (e.g., signals) to improve state awareness, availability, and performance in power generation. Examples of this include instrumentation of major system components (e.g., steam generator and generator) to generate data that can be used with online monitoring technologies, data mining technologies, and other advanced algorithms to provide better real-time information for processing control automation and for plant operators to improve operational efficiencies.

Future concepts of operations will include pilot projects and demonstrations of advanced concepts to enhance information presentation and control technologies for operation, technologies to incorporate centralized expertise for real-time support in operations (e.g., engineering, maintenance, work orders, and support organizations), and promote fleetwide integration of resources. Examples of this include reengineering of control system concepts and demonstrations to leverage the full capabilities of digital technologies for visualization and improved information processing; new assistive technologies to support real-time operational decision making and control; and tools to mine plant data and display results to achieve fine control of plant systems.

Advanced automation pilot projects will conduct research into assistive automation that can provide real-time adaptive control of process systems and reduce the likelihood and consequences of human error and automation failure. Examples of this include development and demonstration of resilient control systems that are mode-sensitive (i.e., sense the plant and system mode and adjust their setpoints and behavior accordingly), can be made more fault tolerant (i.e., individual failures are sensed within the system and are accommodated based on a real-time system model), and are adaptive to system conditions and demands.

3.3.3.3 Nondestructive Examination Technologies. Activities are proposed to develop and test sensors and characterization methods and technologies for a range of nondestructive examination applications. Working closely with the Nuclear Materials Aging and Degradation R&D pathway, this pathway will develop sensors and accompanying technologies to detect and characterize the condition of material parameters needed to assess the performance of SSC materials during long-term operation, including sensors for measuring material properties to derive parameter estimates of specific aging and performance features and analytic capabilities and methods for characterizing the state and condition of material properties in order to obtain 'diagnostic' accuracy about material aging and degradation. This will provide the ability to move from identification of damage and incipient change to more precise descriptions about the underlying mechanisms of change, their progression in materials, and a description of the specific transformations that affect a material or system's ability to achieve its design function.

Activities also are proposed to build on sensors, characterization, and more refined diagnostics to enable prognostic assessments of materials and performance to be made. These capabilities will aid in answering the 'so what' types of questions that arise in connection with material assessments. This entails extending our knowledge and models of materials and material change processes to include predictions about the eventual consequences of change. This requires the need to incorporate information from material science studies and from other R&D pathways and research programs, including international consortia, to develop interim prognostic models that can be validated and improved through bench scale, engineering scale, and accelerated testing to yield models for predicting the effects of different aging mechanisms and associated phenomena.

3.3.4 Industry Engagement and Cost Sharing

A systematic engagement activity is underway with both nuclear asset owners and with NRC. The II&C R&D pathway maintains a dedicated industry-working group, currently composed of eight nuclear utilities and EPRI. The purpose of this working group is to define and sponsor research projects that will collectively enable significant plant performance gains, maintain and improve safety, and minimize operating costs as part of the larger national effort to ensure long-term sustainability of the LWR fleet. Specifically, the working group will do the following:

- Develop agreements with host utilities to demonstrate beneficial digital applications that improve performance at lower cost
- Obtain funding for these projects through a variety of means, such as cost-shared public-private funding and pay-for-performance financial business models
- Coordinate project development among research organizations associated with the U.S. commercial nuclear industry to the degree practical to minimize duplication of effort
- Sponsor research to achieve a long-term vision of the nuclear power plant operating and support model based on substantial digital technology integration, and sponsor research on methodologies to identify the cost-beneficial opportunities to transition various plant support functions to a digital technology infrastructure

- Communicate the work of this research program to utility and support industry decision makers to build a collective vision for a transformed plant operating and support model based on digital technologies

- Coordinate with major nuclear industry support organizations (e.g., the Nuclear Energy Institute, EPRI, and the Institute of Nuclear Power Operations), to the degree practical, in the pursuit of complementary digital technology developments such as appropriate regulatory requirements, technology applications and guidance, and standards of excellence in digital implementation.

Thus far, several workshops have been held with representatives from the industry working group, system vendors, research personnel engaged in this program, and members from NRC. These workshops have been held for the purposes of planning and prioritizing R&D activities in the II&C R&D pathway for both advanced digital II&C technologies and online-monitoring technologies R&D.

The industry working group meets regularly three to four times a year. Certain criteria have been developed for identifying, prioritizing, and selecting potential advanced II&C pilot projects performed by this R&D pathway. These criteria are discussed openly in working group meetings and a consensus approach is fostered.

- A pilot project can be proposed by an individual utility or a group of utilities.

- The pilot project must focus on an aspect of current plant operations and technologies that may contribute to or constitute a roadblock to long-term sustained safe, reliable, or economic performance.

- A pilot project partner utility must have a project designated for work at its own location; it must be funded and appear in a utility master schedule for the year.

- Potential vendors are able to participate in the research so that the results of the effort can be transitioned to a commercially delivered product.

- There is a commitment to attempt to field the system or technologies that are the focus of the pilot project.

- The pilot project partner will make the results of the R&D available and accessible to other commercial nuclear utilities and participate in efforts to support deployment of systems, technologies, and lessons learned by other nuclear asset owners.

Periodic informational meetings are held between DOE Headquarters personnel and members of NRC management to communicate about aims and activities of individual R&D pathways. Briefings and informal meetings will continue to be provided to inform staff from the Office of Regulatory Research about technical scope and objectives of the R&D program. An essential next step is for EPRI and asset owners to identify the best methods of engagement with the regulator through this research program.

Together, these engagement activities are intended to ensure that R&D activities focus on issues of challenge and uncertainty for asset owners and regulators alike, the products of research can be commercialized, and roadblocks to deployment are systematically addressed.