WESTERN GRID GROUP

Western Grid 2050: Contrasting Futures, Contrasting Fortunes

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CLEAN ENERGY VISION

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Executive Summary

The western United States is at a crossroads. Wise electricity sector investment choices will lay the foundation for a robust, competitive and healthy West for generations to come. Unwise choices will leave western businesses at a competitive disadvantage in the global marketplace, western consumers with higher electricity bills and westerners of all walks of life with an unhealthy environment.

With the Western electricity sector investing more than $200 billion by 2030 regardless of the development path taken, the choices made will significantly affect quality of life in the West out to 2050 and beyond.[1] Significant investment will be required because coal, gas and nuclear facilities will need to be retired or replaced, population, economic growth, and electrification will drive gross electricity demand up, demand reduction efforts like energy efficiency programs will continue, new electric generation will be built and new transmission will be added. The question is not whether hundreds of billions will be invested but rather how they will be invested.

While existing renewable energy and energy saving statutory mandates will determine some investment choices, utilities and other electricity providers will recommend how the mandates are fulfilled and in where additional investment dollars are spent. These discretionary investment choices along with any new policy mandates will determine the direction and pace of grid evolution.

The policy and investment choices made could take the West in two very different directions. Western utilities and electricity providers may choose to operate the grid much as it is today and invest in refurbishing and expanding fossil generation, as well as building additional infrastructure to deliver fossil generated electricity. In other words, grid operation and expansion could follow a Business as Usual (BAU) trajectory.

Alternatively, policy makers and electricity providers may choose to modernize the grid and grid operations and focus their discretionary investment on information, communications and system control technologies that enable more energy saving, more low carbon energy production and more sophisticated grid operations. In other words, grid operations and expansion could follow a Clean Electricity Vision (CEV) trajectory.

If no choice is made, investment will be driven by inertia rather than intention and the grid of 2030 and 2050 will look very much like the grid of 2010. This report asserts that making an intentional choice between the BAU and CEV trajectories now is the responsible course of action.

Failure to make a wise, intentional choice now could saddle future electricity consumers with stranded costs, damage the natural environment, deprive job seekers of employment opportunities and leave western businesses with a grid that causes a competitive disadvantage in global markets. The choices made now will also affect the capacity of the West to reduce carbon emissions for decades to come.

[1] Chupka, et al. This Edison Electric Institute (EEI) funded study estimates that investment over the next two decades nationwide will be about $2 trillion for generation, demand reduction, transmission and distribution. The authors of the EEI study suggest the West accounts for about 15 percent of this investment then the western price tag would be about $250 billion. The business as usual portfolios developed in this paper show that even after the recession is taken into account more than $200 billion will be invested to build out a business as usual system.

Purpose of this Report

The purpose of this paper is to flesh out two contrasting views of the western electricity grid's development trajectory from the present to 2050 and to evaluate the relative economic, environmental, energy security and public health consequences. The two trajectories presented are a BAU trajectory and a CEV trajectory.

The BAU trajectory focuses discretionary investment on retrofitting, repowering and adding coal generation and on meeting any incremental needs with new gas fired generation. The CEV trajectory focuses discretionary electricity resource investment on energy saving and renewable energy technologies. The two alternatives require different infrastructure, different grid operations, different grid planning and different utility regulation so an intentional choice between the two must be made.

The goals of the paper include: clarifying generation, infrastructure and institutional differences between the BAU and CEV futures, contrasting performance differences between futures and encouraging an open dialogue on electricity system investment priorities in the West.

The paper complements previous work in the western interconnection in two respects. First, placing 2020 electricity system development projections in the context of a 2050 development trajectory provides a perspective on long term infrastructure development needs. The insight gleaned is that efficient use of land requires that 2050 infrastructure needs be anticipated when planning for 2030.

Second, the analysis expands portfolio evaluation criteria from a short term cost focus to a long term evaluation of economic, environmental, energy security and public health consequences provides a more comprehensive look at performance differences. The insight gleaned is that focusing narrowly on one dimension of short term performance yields poor long term plans.

The study seeks to answer those questions that it can, but it also frames questions for further investigation where answers require more analysis, data and modeling.

Conditions of the Present and Contrasting Grids of the Future

The generation, infrastructure and institutions in the West today were selected based on limitations and assumptions of the past. The generation portfolio was selected based on the abundance of fossil resources, the absence of proven renewable energy technologies, and the absence of real time electronics to manage variable generation resources. The generation was also selected on the assumption that clean air, clean water and land were abundant and essentially free for the taking.

The West's grid infrastructure, which includes its distribution, transmission and information systems, was selected to deliver base load electricity from large, remote coal, nuclear, hydro and natural gas generation fleet. Real time communications and system controls were not available and thus maintaining reliability required that system buffers be built in to allow for time consuming information exchange.

The West's grid institutions, which include its grid operations, grid planning and utility regulation rules and regulations, were implemented in accordance with limitations imposed by out-dated information, communications and system control technologies. The regulatory institutions, by and large, were based on traditional rate of return regulation and did not reward utilities for resource saving investment.

While both the CEV and BAU trajectories require changes from the grid of the past, the CEV benefits more from maximum implementation of advanced infrastructure, information, communications and control technologies because the CEV assumes rapid evolution of grid rules, operations and planning.

The investment portfolio suggested by a CEV trajectory is different from the investment portfolio suggested by a BAU trajectory. First, net electricity demand is lower in the CEV due to more aggressive investment in electricity saving and distributed generation policies. Figure ES-1 contrasts the net electricity demand of the BAU and CEV trajectories from the present to 2050. Second, the generation portfolios selected to meet the respective net electricity demand needs is very different. Figure ES-2 shows the BAU Base Case generation portfolio and Figure ES-3 shows the CEV Base Case portfolio.

Figure ES-1: BAU vs. CEV Net Electricity Demand

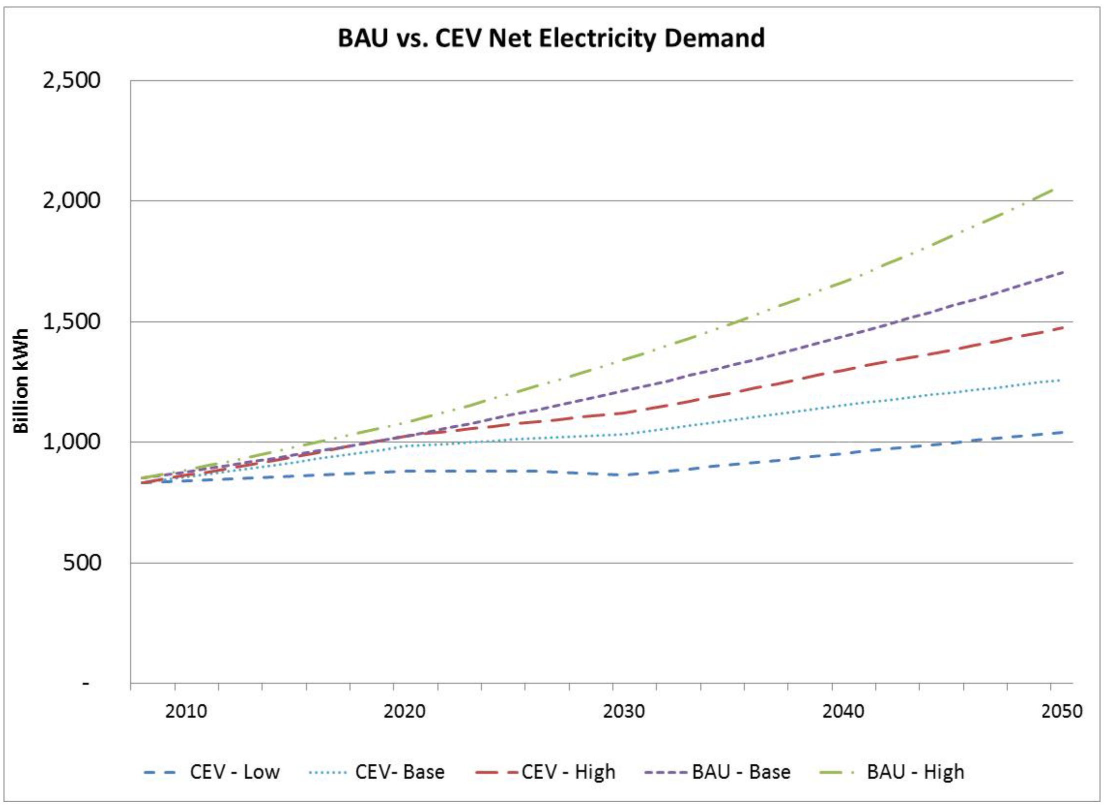


Figure ES-2: BAU Base Case Generation Portfolio

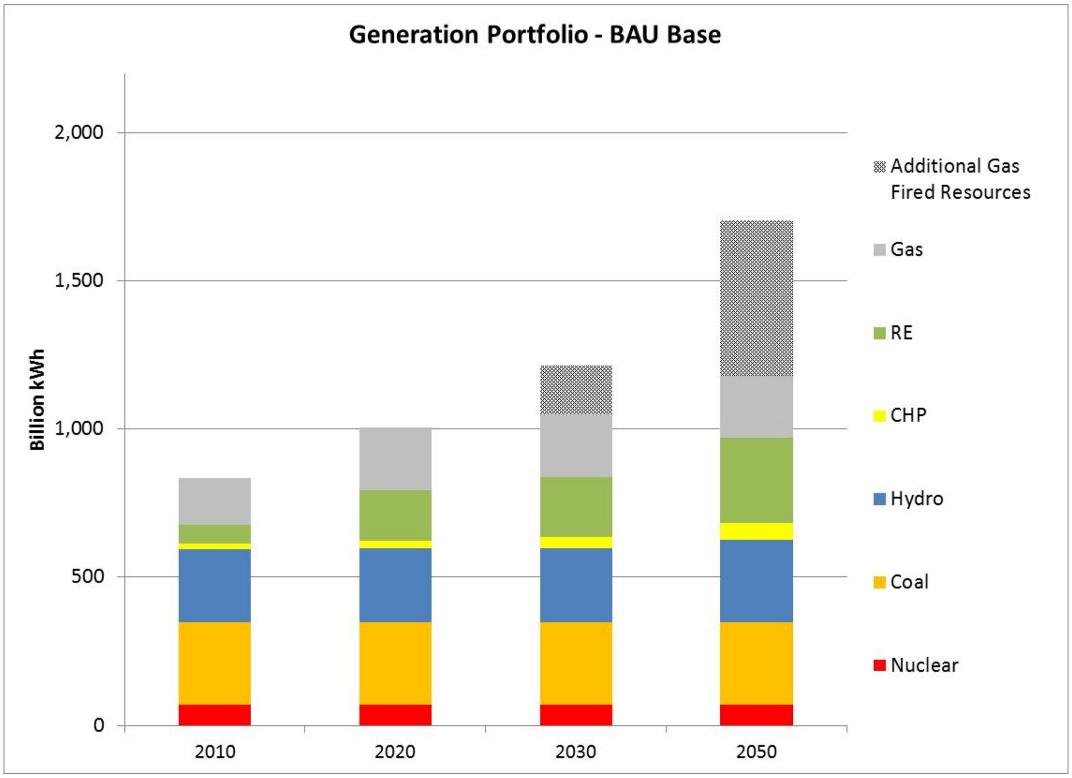
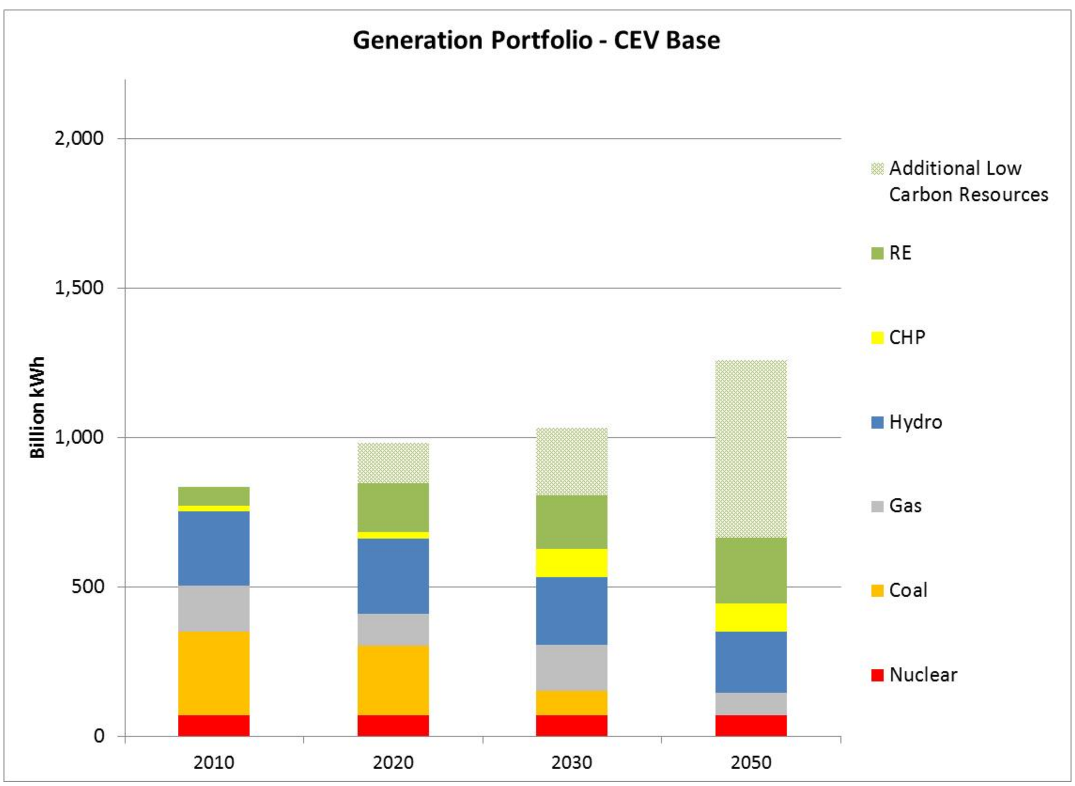


Figure ES-3: CEV Base Case Generation Portfolio



While both BAU and CEV trajectories presume growth in the renewable energy generation fleet due to enforcement of state mandated renewable energy standards, the CEV trajectory focuses its discretionary investment resources on energy saving and renewable energy technologies. The BAU trajectory focuses its discretionary financial resources on improving coal generation and building gas generation to meet emerging demand growth.

The infrastructure required by the CEV is also fundamentally different from the infrastructure required by the BAU. The CEV trajectory requires a western electricity infrastructure that includes transmission to access additional remote renewables, and information and control technologies that facilitate regional resources and demand side resources in meeting both reliability and energy needs. The BAU trajectory requires expanded transmission to deliver electricity from new gas fired resources and gas transmission infrastructure to serve expanded gas use, and it does not invest to facilitate demand side participation or regional cooperation.[2]

The institutional changes that are required to implement the BAU trajectory are also different from the institutional changes required to implement the CEV trajectory. The operation of the BAU grid would be very similar to the operation of the grid we have today so very few changes in operating rules and procedures would be expected. The CEV operation of the grid requires more regional cooperation and coordination among Balancing Areas (BA) and greater institutional flexibility to facilitate the best use of renewable energy resources in the West.

If an intentional choice is not made to transition toward infrastructure, institutions and investment choices that support a CEV trajectory, the inertia of conventional practice will lead to investment that builds a 2030 grid that looks very much like the grid of the last generation and a trajectory that looks like the BAU trajectory. Before allowing the BAU trajectory to be selected by default, it is appropriate to examine the relative performance of the BAU and CEV trajectories to ensure that hundreds of billions of investment dollars are not inadvertently wasted.

BAU and CEV Performance Differences

The research uses recent western interconnection modeling results and reviews a wide range of recent studies to characterize the BAU and CEV trajectories. The analysis then uses a simple model of the West and recent research results produced by others to identify differences in economic, environmental, energy security and public health performance between the trajectories.

The differences identified are substantial and presented in two parts. First, the differences that arise from the direct effects of the BAU and CEV development trajectories on economic, environmental, energy security and public health outcomes are presented. Table ES-1 on page 7 presents some highlights of the differences arising from these direct effects.

Second, differences in performance arising climate induced performance effects are considered. Since the CEV development dramatically reduces carbon emissions and the BAU development trajectory allows carbon emissions to grow, the two trajectories are very different in their contribution to

[2] The BAU trajectory assumed here assumes coal generation facilities will not effectively control carbon emissions. Coal facilities cost examines cases where no carbon sequestration costs are incurred as well as cases where coal facilities are required to be carbon sequestration “ready.” Actually sequestering large amounts of carbon emissions has not been proven in practice and the cost of building an infrastructure to pipe carbon and store it safely is likely to be very expensive. The economic, environmental, energy security and public health consequences of failing to control carbon emissions are explored in the performance comparisons.

addressing carbon accumulation in the atmosphere. While carbon emission reductions by other regions and sectors are necessary to affect global carbon accumulations, the CEV does its part to reduce its share of carbon emissions while the BAU does not. Therefore, the CEV can be thought of as an insurance policy against the potential negative consequences of climate change.

Table ES-2 on page 8 below presents some highlights of the differences arising from climate induced effects.

A $200 Billion Decision

Regardless of whether a BAU trajectory or CEV trajectory is pursued, electricity sector investment required over the next twenty years will be more than $200 billion. With the majority of generation facilities being more than 30 years old, aging generation will need to be replaced. With incremental electricity need emerging, albeit for very different reasons (electricity demand growth in the case of BAU, coal plant retirement in the case of CEV), new generation, distribution and transmission facilities will need to be built to meet incremental need.

The facilities constructed will lay the foundation for electricity provision in the West to 2030, 2050 and beyond and thus will affect the economic, environmental, energy security and public health of the West for generations. Table ES-1 contrasts the BAU and CEV economic and energy security differences. Table ES-2 presents the environmental and public health performance differences.

The potential benefits of the CEV relative to the BAU trajectory can be considered in two parts. The tables of performance differences include differences that arise from the direct impacts of choosing different development trajectories. The performance differences also include differences that arise from climate change induced impacts. Qualitative and quantitative differences are included.

While scientific evidence is cited supporting the potential impacts of climate change, people from around the West disagree about the likelihood and severity of impacts. However, even if parties cannot agree on the question of expected likelihood and expected severity, parties should be able to agree on the range of potential outcomes. Therefore, as one evaluates the climate change differences between the BAU and CEV trajectories, one should consider the CEV to be an insurance policy against potential adverse consequences of climate change. If the western electricity sector fails to do its part to reduce carbon emissions, the likelihood that other sectors and regions will fail to do their part increases, and the likelihood of severe, negative outcomes decreases. Thus, while parties may disagree on the value of the CEV as an insurance policy, parties should be able to agree that such an insurance policy's value is greater than zero.

A dialogue on alternative futures and the relative performance of alternative futures on a set of metrics that encompass economic, environmental, energy security and public health impacts is essential. Failure to explicitly choose an electricity sector trajectory for the West will allow the inertia of current business as usual practices to make the choice for us. The consequences of making the wrong choice are too great to leave the choice to inertia. This paper gets the discussion started by presenting BAU and CEV futures and presenting the relative direct and climate induced differences between the BAU and CEV futures.

Table ES-1: Economic and Energy Security Performance Highlights

Economic Highlights

- **CEV Addresses BAU Market Failures.** Accurate price signals and fair markets lead to highest value investment. CEV addresses externalities, public goods and market barriers and BAU does not. As a result, BAU over-invests in high emitting resources and under-invests in electricity saving resources, customer sited resources and regional resources.
- **BAU and CEV Face Different Cost Drivers.** While most CEV cases require more investment, the BAU portfolios have higher fuel and carbon costs. CEV portfolios cost consumers less unless natural gas prices and carbon prices stay low out to 2030 and beyond. For the cost differences quantified, cost differences in 2030 between the BAU Base Case and the CEV Low and Base Cases vary from BAU being $12 billion less expensive to $46 billion more expensive. The cost differences include a cost of carbon but do not include other externality costs.
- **BAU and CEV Job Creation Differences.** Job creation differences between trajectories arise due to differences in investment portfolios, differences in import replacement, differences in electric service quality and cost, and differences in rates of innovation. The direct and indirect job creation difference for the 20 year period ending in 2030 between the BAU Base Case and the CEV Low Case or Base Case portfolios is a CEV net addition of 100,000 to 130,000 full time equivalent person-years of employment. This difference does not reflect employment differences arising from changes in electric service quality and cost, nor does it reflect employment differences arising from differences in innovation.
- **BAU and CEV Risk Protection Differences.** CEV represents a credible commitment by the West to carbon reduction and therefore represents an insurance policy that partially mitigates risks associated with climate change. The social cost of carbon ranges from $20 per ton to hundreds of dollars per ton, depending on the severity of climate change outcomes. The CEV reduces the probability of higher social cost outcome.

Energy Security Highlights

- **BAU and CEV Coal and Natural Gas Differences.** CEV portfolios do not depend on increasing supplies of natural gas nor do they depend on continuing supplies of coal, thus CEV portfolios are insulated from potential supply disruptions or price spikes in natural gas or coal supplies. Natural gas supply and price has historically been volatile and the price of coal includes significant environmental, public health and carbon costs that are not yet reflected. BAU portfolios face the energy security risks of rising prices and the potential of fuel supply disruptions.
- **BAU and CEV Oil and Gas Differences.** CEV invests in advanced information, communication and control system technologies and introduces policy changes that vastly increase the flexibility of the grid. Therefore, CEV facilitates transportation electrification and thus provides the energy security benefit of transitioning the West away from imported oil.

Table ES-2: Environmental and Public Health Performance Difference Highlights

Environmental and Public Health Direct Impact Highlights

- **Direct Environmental Impact Differences.** BAU portfolios have higher criteria pollutant emissions, much higher carbon emissions, more than double the water use, and significant land impacts from fossil fuel exploration and production. CEV portfolios have much lower criteria pollutants, much lower carbon emissions and less than ½ the water use. CEV portfolios do require significant land use for low carbon generation and transmission, but CEV land requirements are reduced if aggressive energy saving and distributed generation deployment occur.

- **Direct Public Health Differences.** Fossil fired electric generation has direct air and water quality impacts and these impacts affect public health. The relative public health impacts of the BAU and CEV trajectories are primarily driven by differences in generation. Conventional coal generation is the largest source of mercury emissions and also emits SO_2, NOx and $PM_{2.5}$ fine particulate emissions and these particulates have impacts on public health. One study reports that emissions of small particulate matter (specifically, particulate emissions less than 2.5 micrometers ($PM_{2.5}$)) from coal plants, consisting of soot, NOX and SOX, resulted in nearly 24,000 premature deaths, 38,200 heart attacks, 554,000 asthma attacks, 21,850 hospital admissions, 26,000 emergency room visits and 3,186,000 lost work days throughout the U.S in 2004. Furthermore between 300,000 and 600,000 children are at risk for severe neurological and developmental disorders annually because of mercury exposure.

Environmental and Public Health Climate Change Induced Differences Highlights

- **Climate Change Induced Environmental Differences.** The CEV cases represent a credible commitment by the West to do its part to reduce carbon emissions to the IPCC 2050 target. If the West and other regions and sectors follow BAU practices and fail to make a commitment to carbon reduction then recent studies indicate that temperature will increase by 2 to 11 degrees Celsius, southwest run-off will decrease by 3 to 6 percent for every degree of temperature change, increased occurrence of drought, wildfires and flooding is expected. If a warming of 3.5 to 5.5°F occurs as expected under a BAU scenario, 20 to 30 percent of species that have been studied would be in climate zones that are far outside of their current ranges, and would therefore likely be at risk of extinction.

- **Climate Change Induced Public Health Differences.** If the West and other regions and sectors follow BAU practices and fail to make a commitment to carbon emissions reduction then recent studies indicate public health impacts that include increased incidence of disease, increased incidence of heat related mortality and the likelihood of declining food and water supply in the Southwest.

1. Introduction

The purpose of this paper is to flesh out Business as Usual (BAU) and Clean Electricity Vision (CEV) views of the western electricity grid out to 2050 and to evaluate the respective economic, environmental, energy security and public health consequences.

The 40 year time frame is chosen because most electric system investment has a life of 30 years or more and so choices made between now and 2030 will determine electric system performance out to 2050 and beyond. Since hundreds of billions of dollars will be invested over the next 20 years and since electric consumers will be paying for investments for 30 years or more, making the wrong near term investments can impose stranded costs on consumers, create competitive disadvantages for American business and expose consumers to more expensive fixes in the future.

Evaluating the performance of the BAU and CEV development trajectories based on economic, environmental, energy security and public health dimensions is important because electricity sector choices fundamentally affect each dimension.

Electric sector choices affect the economy by affecting jobs, economic development, competitiveness and exposure to financial risks and liabilities. Electric sector choices affect the environment by affecting air quality, water availability, wildlife and land use. Electric sector choices affect energy security by affecting the West's exposure to energy supply disruptions, to financial risks and liabilities and to risks of falling behind the leading edge of technological advances. Electric sector choices affect public health by affecting air quality, water quality and quantity, and land productivity.

In addition to these direct effects of electric sector choices on the economy, the environment, energy security and the public health, electric sector choices also affect these aspects of quality of life in the West through carbon emissions outcomes.

The majority of climate scientists believe that scientific facts collected to date indicate that continued carbon accumulation in the atmosphere is likely to have severe quality of life consequences in the West. If the western electricity sector and other sectors of the economy and regions of the world fail to significantly curb carbon emissions, climate change is expected to further affect the West's economy, environment, energy security and public health. The CEV ensures the western electricity sector does its part to reduce carbon emissions, and thus the CEV can be thought of as a climate change insurance policy that has the potential to help protect westerners from adverse climate consequences.[3] This paper attempts to convey the value of this insurance policy by separately identifying the potential damages to the economy, the environment, energy security and the public health if carbon emissions are allowed to grow at the pace expected with the BAU development trajectory.

[3] Actions by the western electricity sector alone cannot limit global carbon accumulation, but by doing its part to reduce carbon emissions the western electricity sector can increase the likelihood that comprehensive carbon emission reduction occurs.

Study Methodology and Approach

This Study Complements WCI, WECC and WGA Studies

The purpose of this analysis is to compare the results of transitioning to a low carbon, clean energy electricity sector versus continuing BAU policies and approaches. While the benefits of the CEV trajectory could be viewed through the lens of a multi-sector carbon regulation regime, carbon regulation has been stalled in the West and it is important to evaluate the benefits of moving ahead in the electricity sector to reduce carbon emissions regardless of how carbon regulation is ultimately implemented.[4]

The analysis focuses on electricity production and consumption and it does not directly consider energy use in transportation, buildings or other sectors.[5] It does, however, assume that the transportation sector will transition toward electrification and that the electricity consumption of buildings will decline over time as codes and standards become more effective, building practices improve and utility programs facilitate reduced occupied space energy consumption.

This study makes use of multi-sector economic analyses performed by others and these analyses provide important insights that are useful in this analysis. For example, the Western Climate Initiative (WCI) conducted a modeling effort that used an "integrated Assessment Model" (IAM) approach to examine the multi-sector implications of implementing a comprehensive cap and trade program in the west. The analysis directed by the WCI showed that western cap and trade policies could transition the west to a 15 percent reduction in carbon emissions below 2005 levels by 2020 with a net cost savings of $100 million.[6] The WCI IAM modeling results also show that 31 percent of carbon emissions reductions by 2020 come from the power sector. Since 33 percent of carbon emissions in the West in 2009 came from the power sector, the WCI results imply that achieving carbon goals requires the electricity sector to take responsibility for its proportional share of emission reductions. Therefore, the CEV assumes that achieving the economic, security and health benefits of reducing carbon emissions will require the western electricity sector to reduce carbon emissions by its proportional share.

The study also attempts to use and complement WECC 10 and 20 year study plan efforts. The BAU and CEV trajectories use assumptions, data and results that can be corroborated with WECC 10 year study plans completed to date. The study complements the WECC 10 and 20 year efforts by identifying the longer term policy and performance targets that should guide the 10 and 20 year generation and infrastructure choices.

While WECC and Western Governors Association (WGA) collaborative efforts through the input of the State and Provincial Steering Committee (SPSC) to the WECC have produced a suite of useful 10 year cases, looking beyond the WECC planning periods to a 40 year planning period is important. Investments the West makes over the next 20 years will be a part of the grid for at least 40 years. Furthermore, a rational, gradual transition that installs new technologies and infrastructure, improves grid operations and enhances regional cooperation will take longer than 20 years. Therefore, cost effective

[4] The analysis does assume there is a price for emitting carbon based on the externalities associated with carbon emissions, but the analysis does not address whether the market will come to recognize that cost by way of cap and trade markets or carbon emission taxes.

[5] The California Council on Science and Technology recently published a multi-sector evaluation of GHG reduction opportunities for California which includes the assessment of potential breakthrough technologies toward meeting aggressive carbon reduction goals in 2050. See California Council on Science and Technology (2011).

[6] Western Climate Initiative, 2010 (b), p. 1.

transformation of the grid to lay the proper foundation for the grid of 2050 requires some long term choices be made now so that the infrastructure built now can accommodate the supply and demand side resource portfolio desired 20 to 40 years hence.

Trajectory Characteristics and Comparisons

This paper characterizes a BAU electricity sector trajectory and proposes a contrasting CEV electricity sector trajectory. Each "trajectory" specifies how electricity is produced, delivered and consumed.

The BAU and CEV trajectories are compared in this paper by: 1) characterizing how the CEV trajectory represents a departure from BAU with respect to technology and infrastructure investment, operations and planning practices and the regulation and business models that will be required; 2) examining BAU and CEV growth scenarios and comparing the BAU and CEV portfolios resulting from the scenarios; and, 3) evaluating economic, energy security, environmental and public health performance differences between the BAU and CEV trajectories.

The next few sections of the introduction compare the BAU and CEV trajectories in three respects.

BAU and CEV Trajectory Differences

Characterizing the BAU Trajectory

The BAU trajectory assumes that technology choices, participant behavior and participant relationships observed today persist out to 2050. Renewable technologies are selected only up to the point required by legislative mandates; coal, nuclear and large hydro generation continue to operate at current levels; efficiency, conservation and transport electrification efforts are modest; grid operation and planning practices are largely unchanged; and regulatory and business models continue to favor the traditional rate base, rate of return paradigm dominant for the last 70 years. A consequence of retaining traditional regulation would be that public capital and private capital incentives would be necessary to induce utilities to invest in electricity saving efforts.

Each of the 38 Balancing Areas (BAs) would continue to invest in meeting its own reliability requirements and relatively little cooperation among balancing authorities would be observed. New gas fired generation would be added to ensure reliability and significant investments in gas generation and gas delivery infrastructure would be required to maintain local reliability.

CEV Trajectory Differences

The CEV trajectory assumes that technology choices, participant behavior and participant relationships change dramatically from what is observed today. A dramatic shift toward demand reduction on the customer side of the meter occurs. Energy efficiency programs, demand response programs, and distributed generation are pursued as aggressively as possible which produces significant demand reduction. Carbon reduction goals lead to a transition away from coal generation. Large scale renewable energy development fills the gap created by coal retirements and any residual load growth, and thus renewable energy development exceeds statutory minimum portfolio standards. Gas fired generation continues to be used to ensure resource adequacy and reliability as base load coal is retired and, over time, gas fired generation is repurposed to flexible gas fired generation facilities and, where feasible, highly efficient combined heat and power (CHP) facilities.

The transition from the current fleet of generation resources to the CEV generation and demand side resource mix is accompanied by changes in grid operation and planning and changes in regulatory and business models.

Changes in grid operation and planning effectively add tools to the system operator's reliability tool box. Greater coordination of the grid on a sub-regional and interconnection wide basis allows renewable energy resources in diverse locations to help balance each other reducing needs for new gas fired generation for firming. Creation of liquid short term regional energy imbalance markets and improved forecasting reduces the need for local spinning reserves.[7] Installation of state of the art grid information and automated control technologies on the customer side of the meter and the supplier side of the meter facilitate the real time balancing of loads and the full participation of customer side of the meter resources in reliability assurance services. These new reliability tools reduce needs for dispatchable fossil resources to meet short and long term reliability targets.

Changes in regulatory and business models effectively remove utility disincentives to invest in energy saving and regional projects and thus channel private and public capital into least cost, long term grid investments. Improved regulatory models and accurate price signals facilitate alignment of business models with CEV objectives and thus get private capital flowing toward technology and infrastructure improvements that make transition possible. With private capital driving much of the transition, public capital is less needed to push conservation and electricity saving efforts.

BAU and CEV Scenarios and Portfolios[8]

Two BAU trajectory scenarios and three CEV trajectory scenarios are presented and a 2020, 2030 and 2050 portfolios of electricity supply and demand resources are presented for each scenario. The portfolio selected for each scenario is selected to meet forecasted energy requirements.[9]

The five scenarios each use recent WECC study case data as a starting point, but the scenarios vary as to which WECC study case data and assumptions are used. The five scenarios include: BAU Base Case and High Case growth scenarios[10], and CEV Low Case, Base Case and High Case growth scenarios[11]. For each scenario load growth and demand reduction assumptions drive the need for supply side resources in 2020, 2030, and 2050, and a portfolio of resources is compiled that ensures that the energy requirements are met in each year.

The two BAU trajectory scenarios use the 2010 WECC 10 year Base Case as a starting point.[12] Beyond 2020, the BAU Base Case and High Case load growth, efficiency effects and supply portfolios are

[7] A regional energy imbalance market is a market that allows buyers and sellers of short term electricity to trade excess electricity on a regional basis to meet local reliability requirements.

[8] A "scenario" is defined in this analysis to include a trajectory (BAU or CEV), levels of load growth and demand reduction, and portfolios of resources that comport with trajectory characteristics and meet net electricity demand requirements.

[9] The focus of the analysis is on meeting energy requirements but a resource adequacy test is performed on each portfolio that indicates whether additional resources might be required to meet reliability requirements.

[10] The BAU Base and High Cases are based on base and high gross demand, respectively. The cases have the same assumed demand saving.

[11] The CEV Low, Base and High Cases are based on two gross demand cases (base and high) and two energy saving cases (base and high). The combinations of gross demand and demand saving for the Low, Base and High cases are (base, high), (base, base), and (high, base), respectively.

[12] WECC refers to the Base Case as PC0 and data for this case was developed by WECC through the use of utility data submitted to the Loads and Resources Sub-committee (LRS).

extrapolated out to 2030 and 2050 using growth rates embedded in the WECC Base Case and High Case, respectively.[13] Thus the BAU trajectory scenarios assume that the demand side and supply side resource trends embedded in the WECC Base Case are continued beyond 2020.

The practical consequences of continuing Base Case portfolio trends in BAU projections include maintaining coal generation at 2020 levels, limiting renewable energy development to statutory requirements, limiting the contribution of demand reduction to the modest levels reflected in the submitted utility data and meeting all incremental needs with additional gas fired generation.

The CEV trajectory scenarios make use of two additional WECC study case data sets. WECC worked with the State-Provincial Steering Committee (SPSC) to produce Reference and High Demand-Side Management (DSM) Cases that reflect higher levels of energy efficiency.[14] The SPSC noted that the WECC Base Case does not assume that State and Federal energy efficiency policies are effective and thus advocated for the creation of new cases.[15] WECC and the SPSC worked together to produce a Reference Case that assumes all state and federal energy efficiency policies are effective and a High DSM Case that assumes all cost effective energy efficiency is implemented by 2020.

The three CEV trajectory scenarios use the WECC/SPSC Reference Case and High DSM Case data to characterize demand reduction attributable to energy efficiency, the WECC/SPSC Reference and High Load growth data to characterize gross demand growth rates, and combined assumptions produce three scenarios to represent low, base and high net demand levels in 2020. Beyond 2020, the CEV trajectory scenario net demand growth rates are consistent with the 2010 to 2020 embedded growth rates, and the portfolios selected are consistent with the Western Clean Energy Advocates' (WCEA) planning principles.[16]

WCEA planning principles relevant to resource CEV trajectory portfolio construction include: use energy efficiency and distributed generation to the maximum extent possible, transition away from coal and fossil resources and toward renewable resources in order to reduce carbon emissions steadily to reach the 2050 Intergovernmental Panel on Climate Change (IPCC) goal, and limit the land requirements caused by new construction by sharing transmission and resources regionally to the maximum extent possible.

Comparing BAU and CEV Performance

The BAU and CEV trajectories are compared relative to their economic, environmental, energy security and public health performance. The direct effects of the BAU and CEV trajectories on these four dimensions of performance are assessed first, and then climate change induced performance differences are assessed second.

[13] The High Case uses the higher demand growth rates embedded in the WECC PC2 case to increase the assumed growth of the Base Case demand. The energy efficiency assumptions for the High Case are based on the Base Case data.
[14] WECC identifies the Reference Case as PC1 and the High DSM case as PC3.
[15] For example, the data submitted by utilities to the LRS did not appear to include the fact that some states have efficiency standards and the Federal government has adopted some new building codes and appliance standards.
[16] Western Clean Energy Advocates Planning Principles, December 2010. A complete statement of the planning principles can be found at: www.westerngrid.net

BAU and CEV Direct Performance Differences

- They differ in how they affect the economy. They differ in the quantity of investment dollars and the choice of where to dedicate investment. They differ in customer cost impacts and they differ in job creation prospects.
- The trajectories differ in how they affect the environment. They exhibit differences in air quality impacts, water supply impacts, and land use impacts.
- The trajectories differ in how they affect energy security. They exhibit differences in their respective dependence on imported fuels, they differ in their respective exposure to interruption in vital supplies, they differ in the security of the water supply and they differ in the productivity of land.
- The trajectories differ in how they affect public health. The differences stem from differences in air quality, water supply and land productivity.

BAU and CEV Climate Change Induced Performance Differences

- The trajectories differ in how climate change might affect the economy. Climate change affects economic growth, job creation, and land productivity.
- The trajectories differ in how climate change might affect the environment. Climate change is likely to affect air, water, wildlife and land.
- The trajectories differ in how climate change might affect energy security. Climate change affects water availability, land productivity, and population migration.
- The trajectories differ in how climate change might affect public health. Climate change affects air quality, water supply, and land productivity.

Roadmap for the Paper

Chapters 2 through 5 present the BAU and CEV scenarios and build the BAU and CEV portfolios. Chapter 2 presents base and high gross demand forecasts for BAU and CEV futures out to 2050. Chapter 3 presents the BAU demand reduction forecast and a base and high demand reduction forecast for CEV futures. Chapter 4 provides a survey of distributed generation (DG) forecasts. Chapter 5 presents net demand forecasts and portfolios of energy resources for 2010, 2020, 2030 and 2050 for the two BAU cases and three CEV cases. The chapter also presents energy resource portfolios to meet energy need shown in the five cases.

Chapter 6 presents 2020 and 2030 resource adequacy assessments of the energy portfolios presented in chapter 5. The current WECC resource adequacy assessment methodology is appropriate for the BAU cases but it is not appropriate without modification for the CEV cases. The CEV cases include local and regional system operations changes that expand the reliability tool box of the system operators and the current WECC methodology does not capture the effects of these new tools. Chapter 6 explains the impacts of the CEV reliability enhancements and then presents resource adequacy results for the conventional WECC analysis for both the BAU and CEV cases.

Chapters 7 through 11 compare the performance of BAU and CEV portfolios. Chapter 7 identifies differences between the trajectories regarding technology and infrastructure deployment, operations and planning practices and regulatory and business models. Chapter 7 also includes an overview of the performance comparisons presented in Chapters 8 through 11.

Chapter 8 compares the relative economic performance of BAU and CEV trajectories including differences in investment, cost of service, job creation, and global competitiveness. Chapter 8 also presents the economic effects of failing to limit carbon accumulation in the atmosphere. Chapter 9 compares the relative environmental performance of BAU and CEV trajectories including comparing the differences in air quality, water use, and land use. Chapter 9 also presents the effects of failing to limit carbon accumulation on water availability, land productivity, wildlife and ecosystems. Chapter 10 compares the relative energy security performance of BAU and CEV trajectories including differences in fuel supply security, natural resource productivity and economic competitiveness. Chapter 11 compares the relative public health performance of BAU and CEV trajectories including comparing the differences in air emission health impacts, water supply adequacy and food supply adequacy.

Chapter 12 combines the findings of Chapters 8 through 11 and evaluates the economic, environmental, energy security and public health performance of the BAU and CEV futures.

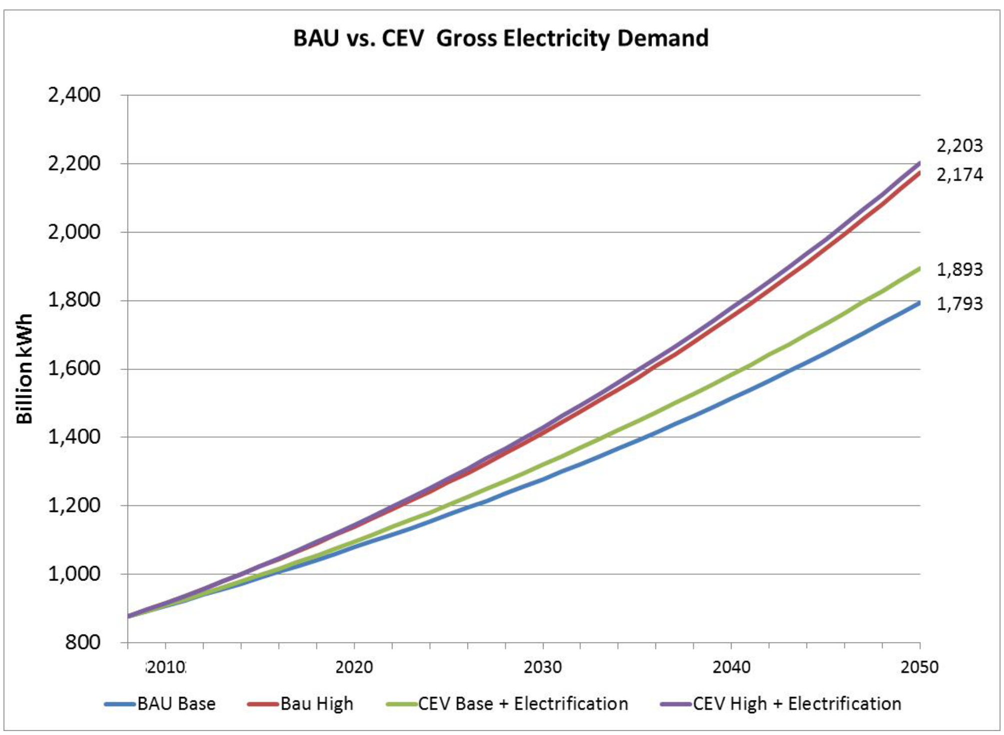
2. Gross Electricity Demand

Introduction

Gross electricity demand refers to the level of demand prior to taking into account demand reducing factors. The key drivers for gross electricity demand include population growth, economic growth and intensity of electricity use. Examples of changes in energy intensity use over the forecast period include increases in demand due to plug-in electronic devices, higher levels of air conditioning demand and the growth of energy-intensive industries such as computer server farms. Increases in projected demand associated with the emergence and penetration of plug-in electric vehicles is addressed at the end of this chapter.

Chapter 2 Overview: Gross Electricity Demand

Gross electricity demand refers to the level of demand prior to taking into account demand reducing factors. The key drivers for gross electricity demand include population growth, economic growth and intensity of electricity use. Intensity is expected to increase in the coming decades due to plug-in electronic devices and electric vehicles, higher levels of air conditioning demand and the growth of energy-intensive industries such as computer server farms. This chapter estimates gross energy demand out to 2050 for BAU and CEV cases, the results of which can be seen in the figure below. Historically, electricity demand has grown roughly 3 percent on average per year, and as the figure shows, it will continue to grow. As of 2008, gross demand was 880 billion kWh. It will increase to 1,410 billion kWh in 2030 and 2,170 billion kWh in 2050 in the BAU High Case, an average annual increase of 1.9 percent. Gross demand will be higher in 2050 for the CEV High Case, 2,200 billion kWh, because the CEV cases include a high penetration of electric vehicles. The same reasoning can be used to explain the fact that gross demand in the CEV Base Case is higher in 2050 than in the BAU Base Case.



The gross demand forecasts do not address the impact of demand reducing factors such as the effects of building codes and standards, energy efficiency programs, naturally occurring demand reduction stemming from price responsiveness, changes in tariffs, and changes in consumer tastes and preferences. Gross demand also does not take into account demand reducing factors such as retail distributed generation.[17] Demand reducing impacts will be addressed in Chapters 3 and 4.

The WECC 10 year study cases are used as a starting point for creating gross demand forecasts for both the BAU and CEV trajectories out to 2020. The BAU analysis of gross demand is based on the WECC Base Case and High Load Cases for the BAU Base and High case, respectively. The SPSC Reference Case and the WECC High Load Case are used to generate the two gross demand scenarios for the CEV.[18]

The per capita demand growth rates from 2010 to 2020 are used with population forecasts to extrapolate growth beyond 2020 out to 2050.[19] A more detailed analysis would explicitly take into account factors such as economic growth and changes in commercial and industrial sector composition and changes in energy intensity. For the purpose of this analysis a focus on per capita consumption and population growth is an adequate proxy. The implicit assumption in taking this approach is that the growth trends embedded in the WECC cases are reflective of changes in industry composition and so forth that would happen beyond 2020. This is a simplifying assumption but it is adequate for the purpose of this analysis.

Gross Electricity Demand Cases

Producing a gross demand forecast to 2050 is the first step. Gross demand refers to the annual quantity of electricity demand where all energy efficiency and other demand reduction adjustments to demand embedded in the SPSC forecasts are added back into the net demand forecast in order to strip any demand reducing factors from the forecasts. The gross demand forecast from 2010 to 2020 and a population forecast for the same period are then used to establish a per capita growth trend that can be used to generate 2030 and 2050 gross demand forecasts that perpetuate per capita demand growth rates implicit in the WECC 2020 cases.

Population projections for 2020 and 2030 were obtained and extended out to 2050 using the growth rate in population from 2020 to 2030 to create the Base Case.[20]

CEV Base and High Gross Demand

Figure 1 depicts gross energy demand per capita within the WECC region for the CEV Base Case. The CEV Gross Demand Base Case is calculated using the SPSC's 2020 reference case electricity demand

[17] Wholesale distributed generation is generation less than 20 MW that is interconnected to the distribution system and the energy produced is primarily sold into the market as wholesale electricity. Retail distributed generation is generation less than 20 MW that is interconnected to the distribution system on the customer's side of the meter and the energy is primarily consumed by the customer (e.g., a residence or a business) or group of customers (e.g. a business park or a mall).

[18] The growth rates implicit in the WECC high load case are used to create the CEV high load scenario from the SPSC reference case.

[19] The analysis is "long term" because we are looking beyond 10 years out. The analysis is "low resolution" because we are not doing a detailed analysis of each state or each balancing authority and we are focusing on annual data. Long term and low resolution appropriately go together because significant changes in infrastructure must be contemplated in analyses longer than 10 years, and high resolution analysis in the presence of changing infrastructure is a poor match.

[20] US Census Bureau. *Interim Projections of the Total Population for the United States and States: April 1, 2000 to July 1, 2030.*

forecast and base population forecast out to 2020.[21] Extending the embedded growth in gross demand per capita from 2008 to 2020 causes the gross demand per capita to increase steadily over time. It grows from 11,450 kWh per person in 2008 to over 14,490 kWh per person in 2050. This represents a projected 30 percent increase in gross demand per person over the time frame and an average annual growth rate of about 0.6 percent.

The CEV per capita energy demand from 2010 to 2050 multiplied by a population forecast to 2050 yields a gross demand forecast. Figure 2 depicts the base and high gross energy demand using a population projection out to 2050. The base gross demand is driven by the WECC SPSC gross demand growth between 2010 and 2020 which is an annual average growth rate of 1.8 percent per year. The high gross demand is driven by the WECC High Load forecast which has an annual growth rate of 2.2 percent per year.

Figure 2 shows base gross energy demand in the WECC region in 2050 to be 1,860 billion kWh while the high gross demand is about 2,170 billion kWh by 2050. The base gross demand represents an increase of over 110 percent from 2008 demand levels.

BAU Base and High Gross Demand

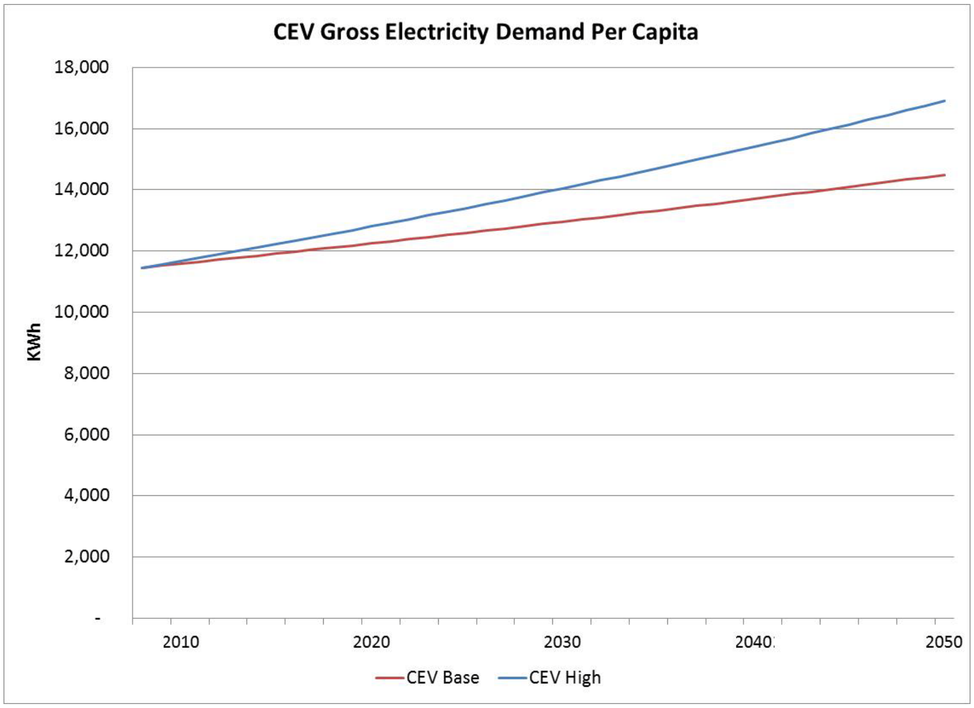
The BAU High gross demand is based on the same WECC case, the High Load Case, as the CEV High Case but the BAU Base gross demand is based on the WECC Base Case rather than the WECC SPSC case. The BAU Base case is based on the WECC Base Case because the WECC Base Case represents a business as usual forecast by the Loads and Resources Subcommittee (LRS) of the WECC. Like the CEV gross demand cases, the BAU gross demand cases add back the energy efficiency embedded in the respective forecasts. Gross demand per capita is then derived using the same population forecast as was used with the CEV cases.

Figure 3 shows per-capita gross demand for the two BAU cases. Per-capita demand in 2050 for the BAU Base and High cases is estimated to be 13,940 kWh and 16,900 kWh, respectively. For the BAU Base Case this represents more than a 20 percent increase over the 2008 to 2050 time frame and an average annual growth rate of 0.5 percent. In contrast, the BAU High Case grows nearly 50 percent over the same time frame with an average annual growth rate of 0.9 percent. Figure 4 compares per-capita gross demand for the CEV and BAU cases.

Figure 5 shows BAU gross demand estimates. For the BAU Base Case, gross demand in 2050 is 1,790 billion kWh. This represents over a 100 percent increase over 2008 gross demand and an annual average growth rate of 1.7 percent over the period. 2050 gross demand in the BAU High Case gross demand is the same as the CEV High Case gross demand at 2,170 billion kWh. This is 150 percent higher than in 2008.

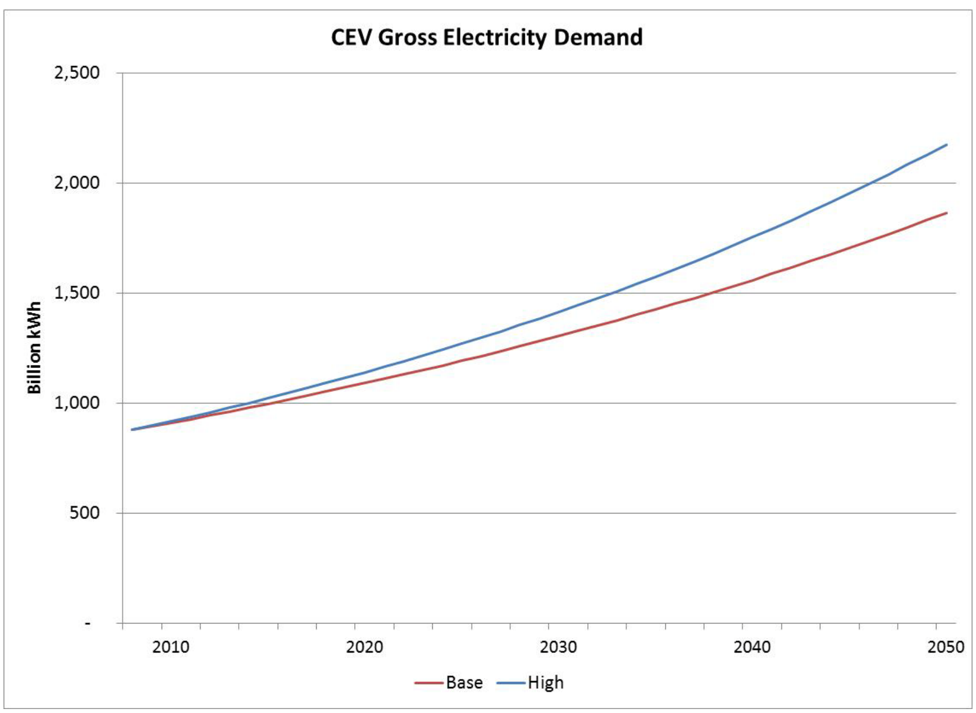
[21] Dec. 2, 2010, run of SPSC Reference Case <http://www.wecc.biz/committees/BOD/TEPPC/TAS/SWG/8Dec/Lists/Presentations/1/SWG%20Report%208%20December%202010.pdf>

Figure 1: Gross Electricity Demand Per Capita



Gross energy demand per capita was calculated using U.S. Census population estimates *(http://www.census.gov/population/www/projections/files/SummaryTabA1.pdf) and the Dec. 2, 2010, run of SPSC's reference case forecast of generation in the WECC region (http://www.wecc.biz/committees/BOD/TEPPC/TAS/SWG/8Dec/Lists/Presentations/1/SWG%20Report%208%20December%202010.pdf*

Figure 2: Projected CEV Gross Electricity Demand Base and High Cases



*Source: SPSC – Adjusted State Load Forecasts (*http://www.westgov.org/sptsc/site/workgroups/dsmwg.htm)

Figure 3: BAU Per Capita Electricity Demand High and Base Cases

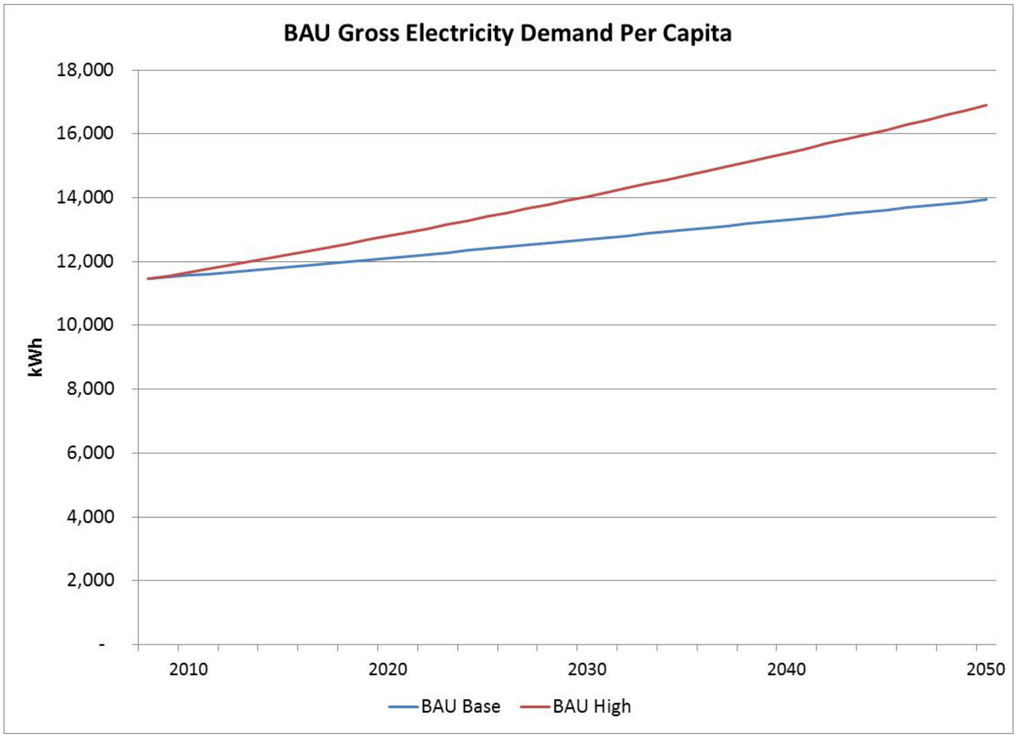


Figure 4: Comparison of BAU and CEV per Capita Gross Electricity Demand Cases

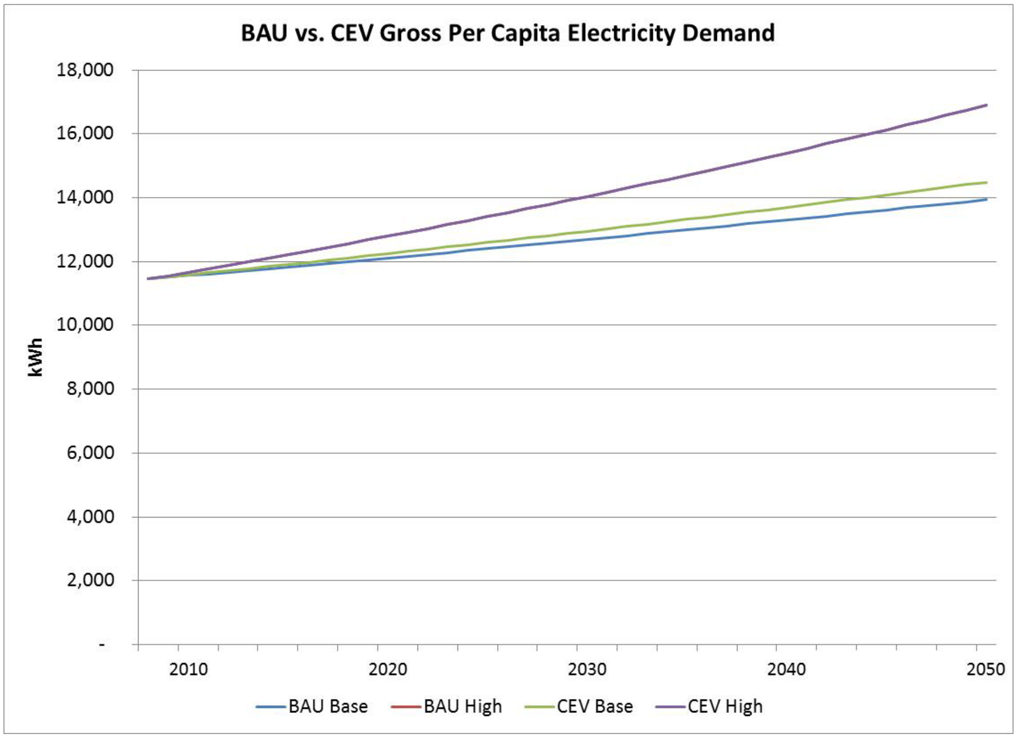
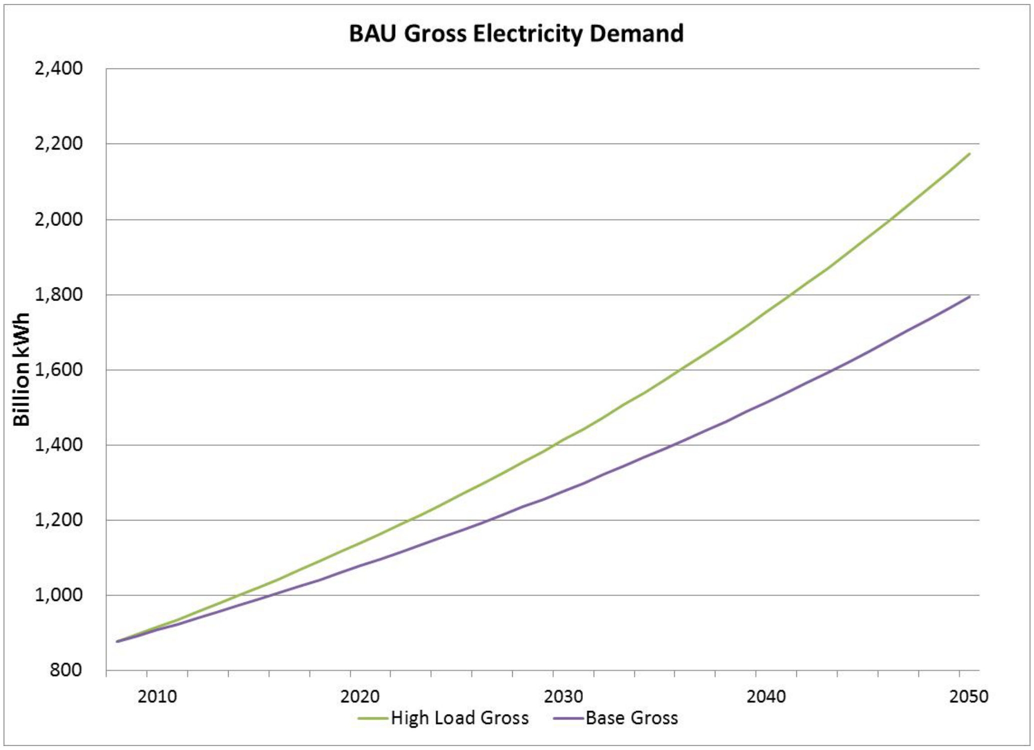


Figure 5: BAU High and Base Gross Electricity Demand Cases



Additional sensitivities to net demand growth are addressed in Chapter 3 with a series of demand reduction cases.

One expected effect on CEV gross demand that is clearly new and not reflected in the 2010 to 2020 electricity demand growth data is electrification of the transportation fleet. The next section considers how CEV gross demand might be affected.

Transportation Electrification Impacts

An additional source of future electricity demand in the US is the expected electrification of the nation's transportation fleet. In 2015 alone, President Obama's goal is 1 million grid-enabled vehicles on the road.[22] This will put an increased demand on the grid and lead to additional energy demand throughout the US. The projected energy demand caused by plug-in hybrid electric vehicles (PHEVs) in the WECC through 2050 for different levels of market penetration is shown in Figure 6. Demand from PHEVs starts out low but gradually increases over time as more plug-in vehicles enter the market. With 50 percent market penetration in 2050, energy demand from PHEVs is estimated to increase from roughly 60 million kWh in 2010 to nearly 20 billion kWh in 2050. With 75 percent market penetration of PHEVs by

[22] Electrification Coalition
NWPPC. 6th Northwest Power Plan. Appendix C, p. C-35, Table C-19.
<http://www.nwcouncil.org/energy/powerplan/6/final/SixthPowerPlan_Appendix_C.pdf>
Bureau of Transportation Statistics. State Transportation Statistics. 2009.
<http://www.bts.gov/publications/state_transportation_statistics/state_transportation_statistics_2009/pdf/entire.pdf>

2050 demand associated with serving this electric vehicle fleet is projected to reach nearly 30 billion kWh by 2050.[23]

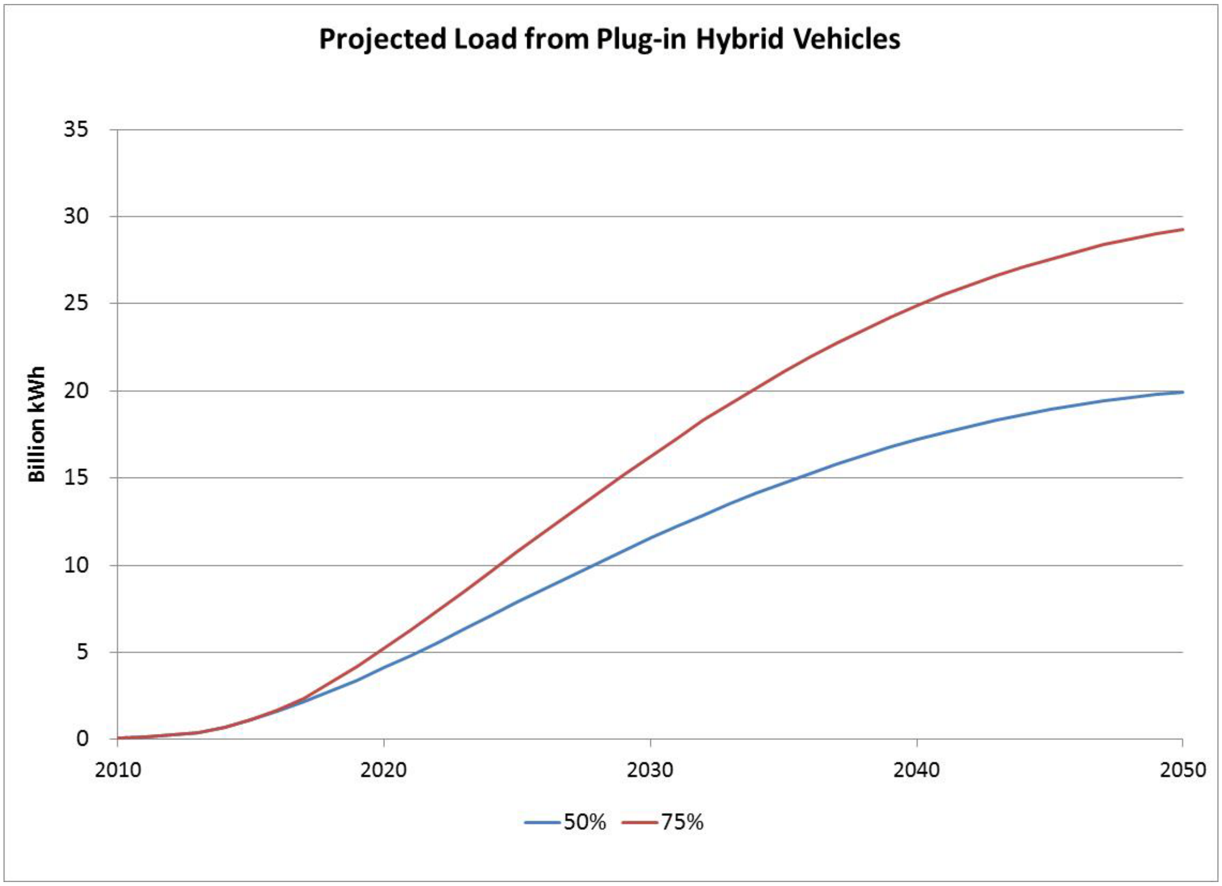
Projected CEV Gross Energy Demand with Electrification

In Figure 7, energy demand from PHEVs is added to the CEV Base and the High gross demand estimate to obtain the final forecasts of CEV gross energy demand in the WECC region through 2050. In the Base Case, gross demand in 2050 is estimated to be 1,890 billion kWh as compared to 1,860 billion kWh without electrification. In the High Case, gross demand in 2050 with electrification is estimated to be 2,200 billion kWh.[24]

Overall, gross energy demand in the WECC region in the CEV Base and High cases is projected to increase by approximately 115 percent and 150 percent, respectively, in the 42 year period between 2008 and 2050. The large increase is fueled by increases in population and assumed gross energy demand growth per capita during the time period.

[23] PHEVs do not affect electricity demand as much as plug-in electric vehicles and examining a case that looks at the demand created by purely electric vehicles would be an interesting companion to the PHEV case addressed here.
[24] The impact of electrification varies depending on the percentage of miles that are assumed to be powered by the electric charge vs. fossil fuels.

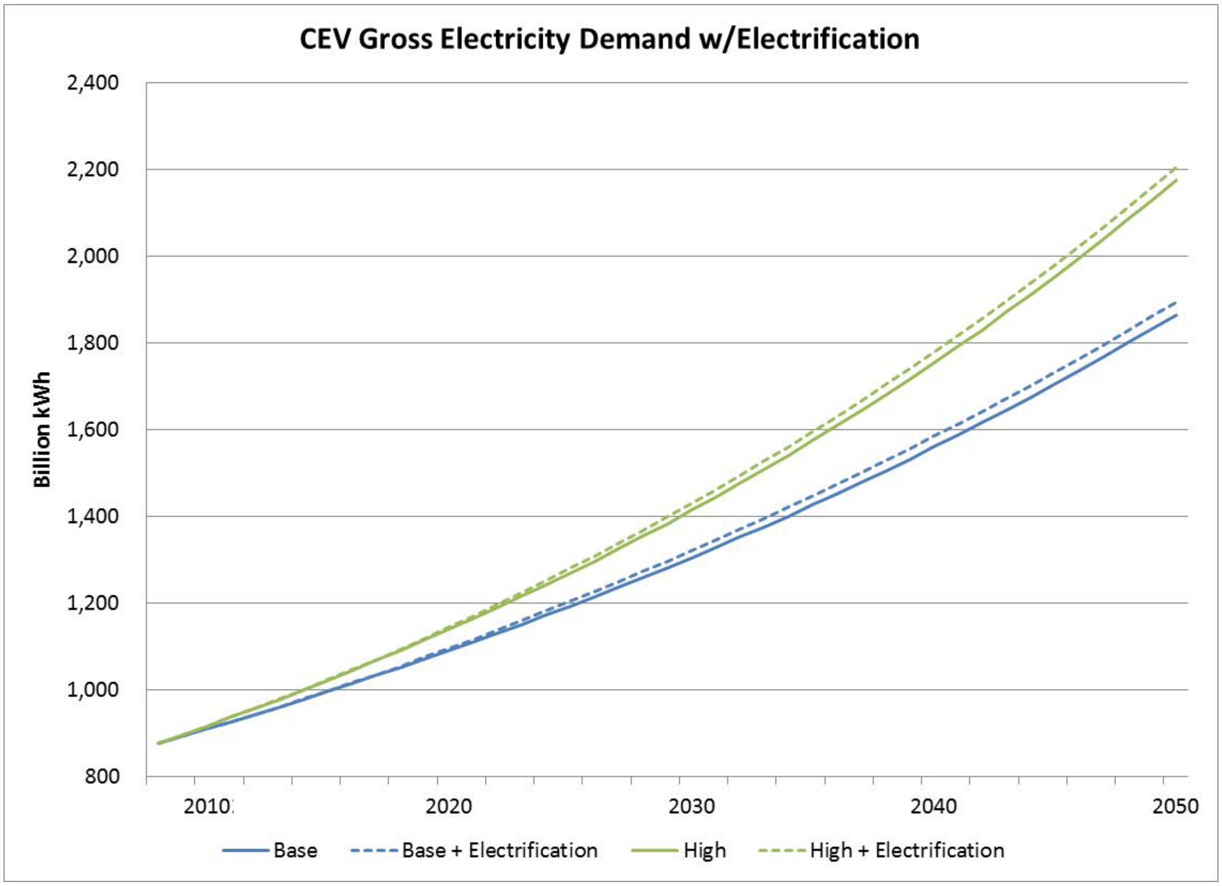
Figure 6: PHEV Load with 50 Percent & 75 Percent Market Penetration[25]



Calculated using estimates of total vehicle miles traveled (VMT) and per capita VMT for states in the WECC region from the Bureau of Transportation Statistics' 2009 State Transportation Statistics (*http://www.bts.gov/publications/state_transportation_statistics/state_transportation_statistics_2009/pdf/entire.pdf*), estimates of the number of new vehicles in the WECC region in 2010 from Appendix C of the 6th Northwest Power Plan dated 2010 (http://www.nwcouncil.org/energy/powerplan/6/final/SixthPowerPlan_Appendix_C.pdf), & the average annual growth rate in VMT (0.66%) from the EC's Electrification Roadmap (*http://electrificationcoalition.org/535928473533888957466293/EC-Roadmap-screen.pdf*).

25 Assumptions used to calculate increased energy demand due by electrification: Electric vehicles become cheaper over time due to lower costs of batteries, not because of increased MPkWh; penetration rate applies to 26 million new vehicles expected from 2010 to 2050 to be sold in NWPPC states, or 650,000 per year; VMT = 12045 per year; WECC VMT is constant 22% of US VMT; relationship between VMT and number of vehicles in NWPPC applies WECC-wide; no PHEVs retire before 2050; total VMT grows at a rate of 0.66% per year; electricity use per mile at .3 kWh (NWPPC); the Electric Coalition has .25 kWh (used .3) and increasing at rate of 5% per year which means that 3.3 MPkWh turns into 8.8 MPkWh by 2030 and 23.2 MPkWh by 2050 [this point needs rewriting],;NWPPC states are scaled up to WECC-wide at of roughly 5; CO2 average emissions from WECC portfolio is 1,100 lb/MWh; PHEV miles per vehicle are the same as petroleum-fueled vehicles.

Figure 7: CEV Gross Electricity Demand Forecast with Electrification



Electrification increases projected gross energy in the WECC region in 2050 by nearly 30,000 GWh.

Sources: The U.S. Census Bureau's population projections dated 2010 (http://www.census.gov/population/www/projections/files/SummaryTabA1.pdf), SPSC – Adjusted State Load Forecasts dated 2010 (http://www.westgov.org/sptsc/site/workgroups/dsmwg.htm), Appendix C of the 6th Northwest Power Plan dated 2010 (http://www.nwcouncil.org/energy/powerplan/6/final/SixthPowerPlan_Appendix_C.pdf), The Bureau of Transportation Statistic's State Transportation Statistics dated 2009 (http://www.bts.gov/publications/state_transportation_statistics/state_transportation_statistics_2009/pdf/entire.pdf), & The Electric Coalition's The Electrification Roadmap (http://electrificationcoalition.org/535928473533888957466293/EC-Roadmap-screen.pdf)

3. Net Electricity Demand

Introduction

Energy efficiency programs are widely regarded as a cost effective method of reducing energy demand, and in turn carbon emissions. Demand reduction can also be caused by changes in codes and standards, increasing electricity rates, and innovative rate designs and tariffs enabled by smart grids. Some demand reduction occurs "naturally" as price increases induce reduced consumption.

Attributing demand reduction to its specific causes is an imperfect science and demand reduction projections are subject to error if take back, rebound and decay effects are ignored.[26] Nonetheless, projections of Demand Side Management (DSM) and energy efficiency (EE) program-caused savings will be assumed to be a reasonable proxy for demand reduction savings that could be enabled by the bundle of potential demand-reducing causes.

Chapter 3 Overview: Net Electricity Demand

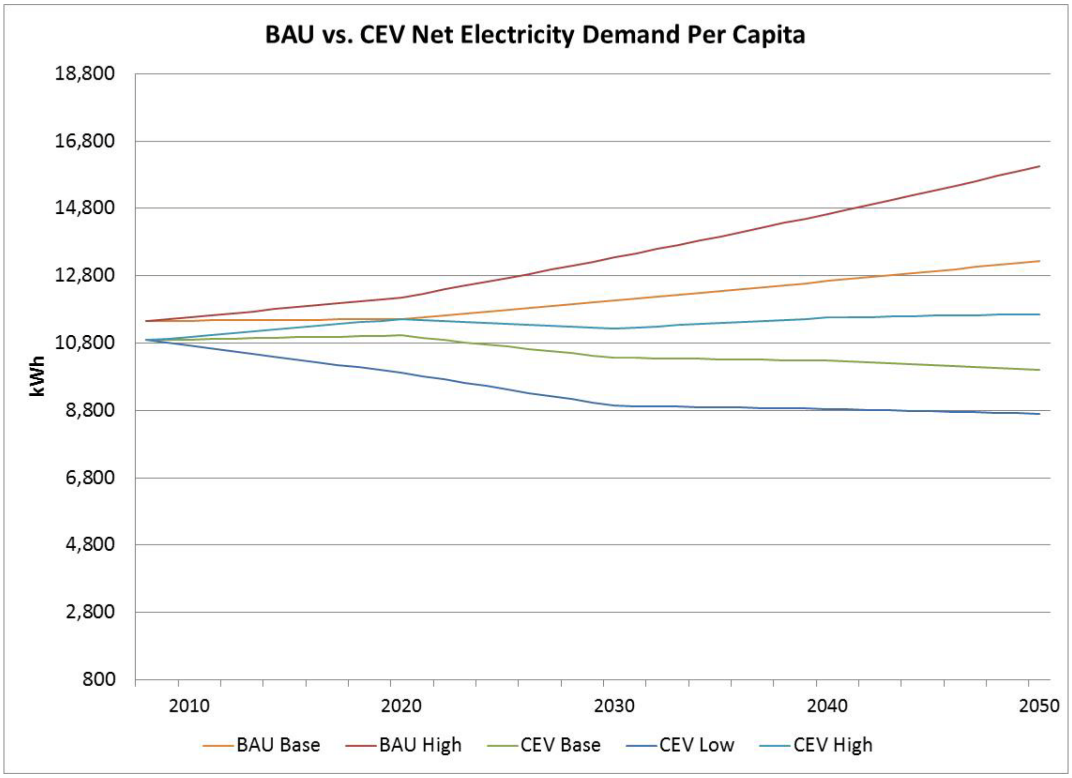
Energy efficiency programs, changes in codes and standards, increasing electricity rates, and innovative rate designs and tariffs enabled by smart grids can all help to significantly **reduce electricity demand**. This chapter presents electricity demand net of these demand reducing factors, where demand reduction in the CEV cases includes smart grid deployment, innovative rate designs, codes and standards effects and energy efficiency effects. Demand reduction in the BAU cases is limited to the small amount of energy efficiency embedded in the WECC base and high forecasts.

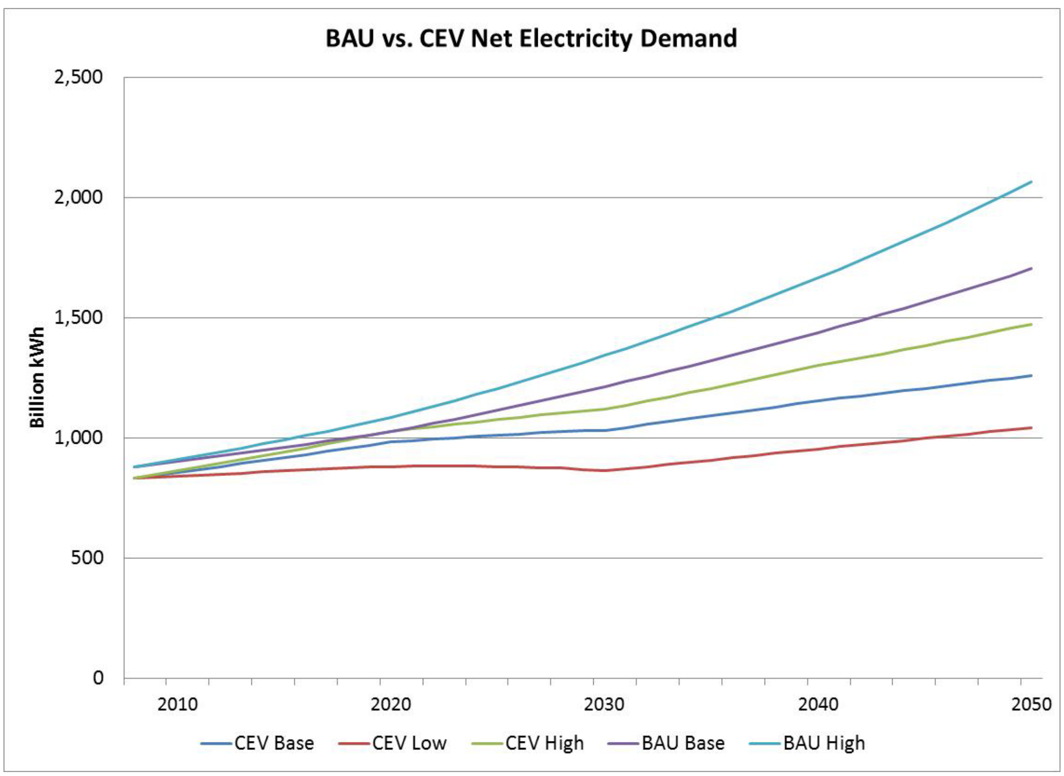
The first figure presents net energy demand per capita for BAU and CEV cases. Whereas net energy demand per capita increases for both BAU cases, it remains relatively stable and even decreases by the end of the period for the CEV Low and Base cases. Net electricity demand per capita falls increases by 25 percent, from 10,880 billion kWh 8,690 billion kWh, in the period from 2008 to 2050 in the CEV Low Case.

Decreases in electricity demand per capita do not guarantee decreases in net electricity demand because population is growing throughout the period. The second figure (shown on the next page) shows BAU and CEV net demand for each of the cases. It shows that despite decreases in per capita energy use for two of the CEV scenarios, net demand still increases from 2008 to 2050 in all BAU and CEV cases, though the degree to which it increases is much lower for the CEV cases. The CEV Low Case increases from 830 billion kWh in 2008 to 1,040 billion kWh in 2050, an increase of just 25 percent. In contrast, net demand in the BAU High Case increases 135 percent, going from 880 billion kWh in 2008 to 2,065 billion kWh in 2050.

[26] Take back refers to a tendency for some consumers to "take back" some of the savings they enjoy from increased appliance efficiency by purchasing a larger or more sophisticated appliance. Rebound refers to a tendency for some consumers to use energy expenses saved from enhanced efficiency to purchase more energy for some other purpose. Decay refers to a tendency for some consumers to replace incentivized program behavior, devices or appliances with less efficient behavior or equipment over time.

Chapter Overview (continued)





BAU demand reduction scenarios are based upon information submitted by Balancing Areas to the WECC. The amounts of demand reduction embedded in the WECC base and high load cases are small, growing to a maximum of only 5 percent load reduction by 2020.[27]

In an effort to more accurately capture demand reduction potential, the SPSC DSM work group set out to better reflect current programs and policies in demand forecasts. Analysis by Lawrence Berkeley National Laboratory for the SPSC uncovered a 4.1 percent reduction in energy demand due to current energy efficiency policies at the federal and state levels that were not fully reflected in the load forecasts that balancing authorities submitted to WECC.[28] These include new federal appliance and lighting standards, as well as state requirements to acquire all cost-effective energy efficiency or Energy Efficiency Resource Standards (EERSs), which require utilities to reduce energy use by a given amount.[29] As of August 2010, 28 states have enacted or have pending energy savings goals or EERSs through legislation, including many states in the WECC region.[30] WECC energy efficiency policies are detailed in Table 1.

Going beyond current energy efficiency programs and policies, the SPSC high DSM case establishes aggressive efficiency targets for the western states in 2020. The high DSM case analyzes the effects of or acquiring all cost-effective energy efficiency by 2020.[31]

The SPSC high DSM case is a very aggressive case, particularly when one considers the potential for take back, rebound and decay. However, naturally occurring savings caused by price effects are also not explicitly included in the high DSM case. A detailed discussion of the reasonableness of the SPSC reference case and high DSM case efficiency impacts is included in the technical appendix for the CEV report.

SPSC Reference and High DSM Savings in 2020

The SPSC adjustments to the WECC Base Case take into account the amount of EE savings already embedded in the forecasts and include incremental savings for each state and province within the WECC region. Savings embedded in forecasts include existing codes and standards programs and commission or board approved DSM and EE programs. Incremental savings are savings that are expected in the forecast period but that are not included in embedded savings.[32]

[27] The NWPPC and CEC have demonstrated that demand reduction in excess of 20 percent has been achieved through combinations of codes and standards, programs and naturally occurring efficiency improvement.

[28] http://www.wecc.biz/Planning/TransmissionExpansion/RTEP/10272010/Lists/Presentations/1/WECC%20Webinar_102710_2-2.pdf

[29] The PEW Center for Climate Change. *Energy Efficiency Standards and Targets*

[30] ACEE. In addition to strict EERS requirements, ACEEE includes states with Commission-ordered efficiency targets, states that allow efficiency to count toward renewable energy standards, and states with a rate cap triggering a relaxation of EERS requirements.

[31] All cost-effective energy efficiency includes all efficiency measures where the benefits of the measure exceed the cost of the measure over the life of the measure on a total resource cost basis. These measures have a total resource cost test score greater than one.

[32] The reference case energy efficiency savings include: (1) ratepayer-funded energy efficiency programs and (2) new federal appliance and lighting standards. Savings levels are calculated on a state-by-state basis. Incremental savings for each state are equal to the difference between the total reference case savings for that state and the energy savings from the same programs/policies that are already embedded within the load forecast that each balancing authority submitted to WECC. Incremental savings estimates focus of new standards because it is assumed that existing standards are embedded in the forecast.

The SPSC Reference Case estimates show embedded EE savings equal to 5 percent of 2020 gross demand and incremental EE savings of 5 percent of 2020 gross demand, for a total EE savings in the WECC region of 10 percent of gross demand in 2020.The SPSC also developed a high DSM scenario that includes all economically efficient energy efficiency savings in 2020.[33] They estimated the economically efficient savings in 2020 to be nearly 208 billion kWh, which amounts to roughly 19 percent of projected gross demand in 2020. This high DSM case leaves load growth approximately flat from 2010 to 2020.

Demand Savings Beyond 2020

In order to estimate all cost-effective energy efficiency savings in the WECC out to 2050 other sources must be examined to determine whether it is reasonable to apply the SPSC's savings estimates to 2020 and beyond. A summary of the studies consulted can be found in the technical appendix.

The EE savings estimates for California, the Northwest, and the nation as a whole examined in the technical appendix range between 21 percent and 23 percent of gross demand for the 2020 to 2030 time frame. The results are consistent with the SPSC's 19 percent aggregate estimate of economic potential in 2020 relative to gross energy demand for the west. Thus, the SPSC high DSM savings rate appears reasonable for an aggressive 2020 estimate.

[33] SPSC. High *DSM Scenario*

Table 1: Western State EE Policies/Targets

State	EERS Policy	Reference
Arizona 2009	ACC ordered that all IOUs and rural elective cooperatives achieve 2% annual savings beginning in 2014. By 2020, the state should reach 20% cumulative savings, relative to 2005 sales, along with 2% credit from peak demand reductions from demand response programs. Electric distribution cooperatives are required to meet 75% of the standard in any year.	Docket Nos. RE-00000C-09-0427 Decision NO. 71436
California 2004 and 2009	Long-term targets for its IOUs indicate that they plan to save over 16,000 GWh and over 4,500 MW between 2012 and 2020. The most recent 2010-12 program plan sets interim targets of 1,500 MW and 7,000 GWh, which is equivalent to 2.6% of total retail electric sales in CA	Rulemaking 06-004-010; Application 08-07-021
Colorado 2007	Encourage implementation of all cost-effective energy-saving programs. CPUC established cumulative reductions goal of 11.5% of energy sales by 2020 for Xcel Energy and set the same 2011 targets for Black Hills Energy	HB-07-1037; CPUC Docket No. 07A420E; Docket No. 08A-518E
Montana	None	
Nevada 2005	RPS of 25% by 2025 with EE contributions capped at a quarter of the total standard in any one year	2009 Senate Bill 358
New Mexico 2008	Electric and gas utilities must acquire all cost-effective and achievable energy efficiency resources. IOUs must achieve 5% energy savings from 2005 sales by 2014 and 10% by 2020	NMSA SS 62-17-62-17-11
Oregon 2010	Energy savings goals between 2010 and 2014 of 256 average megawatts (2,242.6 GWh) of electricity and 22.5 million annual therms of natural gas. These goals include savings from Northwest Energy Efficiency Alliance Programs. The electric targets are equivalent to 0.8% of 2009 electric sales in 2010, ramping up to 1% in 2013 and 2014.	
Utah (Pending)	Pending bill urges UT PUC to set energy savings goals of at least 1% per year for regulated electric utilities and at least 0.5% per year for gas utilities, though it does not penalize utilities that do not meet the savings goals as long as they make good faith efforts	Docket No. 09-035-T08, House Joint Resolution 9
Washington 2006	Utilities are required to pursue all available conservation measures that are cost-effective, reliable, and feasible. By January 1, 2010 qualifying utilities must determine their achievable cost-effective conservation potential through 2019 and establish and meet biennial targets for conservation.	Ballot initiative 937; Draft Sixth Northwest Power Plan
Wyoming	None	

Source: State Energy Resource Standard (EERS) Activity. ACEEE, 2010

Further, energy codes, standards, measures and programs that do not make the "economic potential" cut in 2020 may move into the economic potential basket after 2020 as technology improves, as the cost of technology declines, as energy costs continue to increase and the use of technology improves through learning-by-doing effects.[34] McKinsey & Company's study of efficiency potential by 2025 is about 4 percent higher than the savings indicated by the SPSC High DSM case and since the High DSM case did not endeavor to include all smart grid impacts, additional energy efficiency potential exists that might be obtained after 2020.[35] Pacific Northwest National Laboratory (PNNL) projects that smart grid direct impacts will reduce gross demand by 12 percent, but it is unclear how much of the PNNL impacts are captured by the High DSM Case.[36]

BAU Demand Reduction

Both the Base Case and high load forecasts, on which the BAU energy demand scenarios are based, account for energy efficiency savings included in the forecasts submitted to WECC by the individual BAs. The savings accumulate at approximately 0.2 percent per year out to 2020 with total savings topping out at 5 percent of gross demand by 2020.

To extend this out to 2050, existing demand reduction measures are assumed to continue but no additional measures are implemented between 2020 and 2050. Thus, the BAU case demand reduction increases from 3 percent of gross energy demand in 2010 to 5 percent in 2020 and then remains constant out to 2050.

CEV Demand Reduction

Two CEV demand reduction cases were developed, a base demand reduction case and an aggressive demand reduction case.

The base CEV demand reduction case assumes the SPSC reference case savings of 10 percent is achieved by 2020, assumes the SPSC's all economically efficient savings is achieved by 2030, and assumes the 12 percent increment due to McKinsey and smart grid impacts is achieved between 2030 and 2050. This base demand savings case results in savings of 10 percent of gross demand by 2020, 19 percent of gross demand by 2030, and 31 percent of gross demand by 2050.

The aggressive case assumes immediate and aggressive action is taken to reduce demand as quickly as possible. This case front-end loads the savings and assumes the 19 percent savings from base gross demand are achieved by 2020.

Demand savings beyond 2020 in the aggressive demand reduction case draw upon findings of several studies. The SPSC High DSM case assumes implementation of all cost-effective energy efficiency but there is a large reservoir of programs with technical efficiency potential that could migrate into the economic potential category as noted above. Sources of extra savings beyond the high DSM case may include additional savings attributable to the extra savings identified by McKinsey (4 percent), smart grid savings identified by PNNL (12 percent) and other changes such as migration of programs from technical potential to economic potential based on increases in electricity prices or reductions in technology

[34] Learning by doing means that as experience is gained in producing and using new technologies, the cost of using the technology declines.
[35] The technical appendix discusses the additional savings included in the McKinsey and Company study.
[36] Pacific Northwest National Laboratory, *The Smart Grid: An Estimate of Energy and CO2 Benefits*, Table 3.2, January 2010.

costs, or development of new technologies not known today. Based on the magnitude of these potential contributing factors, an additional 12 percent reduction in demand in 2030 beyond the 19 percent achieved by 2020 is assumed.

The aggressive case further assumes that emerging technologies and maturation of smart grid capabilities lead to incremental savings of 9 percent between 2030 and 2050 from new technologies. So, on a cumulative basis, the aggressive demand reduction case yields net demand 19 percent below gross demand in 2020, 31 percent below gross demand in 2030, and 40 percent below gross demand in 2050.

Energy efficiency savings estimates for 2020 through 2050 can be seen in Figure 8.

Net Electricity Demand

CEV

Three net demand cases (high, base and low) are developed for the CEV scenario where the CEV High Case corresponds to high gross demand and base demand reduction, CEV Base Case corresponds to base gross demand and base demand reduction, and CEV Low Case corresponds to base gross demand and aggressive demand reduction. Each net demand case is shown with and without electrification implementation.

Figure 9 compares net and gross energy demand through 2050 for the WECC region for the CEV high net demand. The CEV high net demand case assumes CEV-high gross demand and base demand reduction. The differences between gross and net demand on the figure show the contribution of demand reduction to net demand. Figure 10 shows net and gross energy demand through 2050 for the CEV base net demand case with and without electrification. The CEV base net demand case assumes CEV base gross demand and base demand reduction. Figure 11 shows the net and gross energy demand through 2050 for the low net demand case with and without electrification. The low net demand case assumes base gross demand and high demand reduction.

Figure 12 compares net demand for the three CEV cases on one graph. Note that the CEV low demand case keeps demand approximately constant out to 2030. Due to the fact that demand reductions are front end loaded in the low demand case, demand growth resumes at a slow rate of growth after 2030 due to decreased opportunities for new energy efficiency savings, continuing population growth and maturation of electrification. The CEV base and high net demand cases show slow to moderate demand growth out to 2050.

Figure 13 show CEV net and gross energy demand per capita. Gross energy demand per capita increases steadily due to increased plug-in loads (such as new plug-in appliances, computers and communications devices), emerging high energy consumption industries (like server farms) and electrification of vehicles. In contrast, net energy demand per capita remains relatively constant and even decreases for some CEV cases.

One simple way of seeing the difference between gross and net per capita growth is to examine the difference in average annual growth rates. Average annual growth for the Base Case gross electricity demand per capita is 0.6 percent per year while the Base Case net electricity demand per capita is -0.2 percent per year. Note that net electricity demand per capita actually decreases by over 20 percent over the 2008 to 2050 period in the CEV Low Case scenario.

BAU

Two net demand cases are developed for the BAU scenario, base and high. These correspond to the respective gross demand forecasts and both assume a common level of BAU demand reduction. Figure 14 compares net electricity demand for the two BAU scenarios. In both cases, net electricity demand increases significantly from 2008 to 2050. Net demand for the BAU Base Case increases from 880 billion kWh in 2008 to 1,700 billion kWh in 2050. In contrast, BAU high net demand increases roughly 135 percent from 2008 to 2050 to 2,065 billion kWh, which is an annual average rate of growth slightly greater than 2 percent.

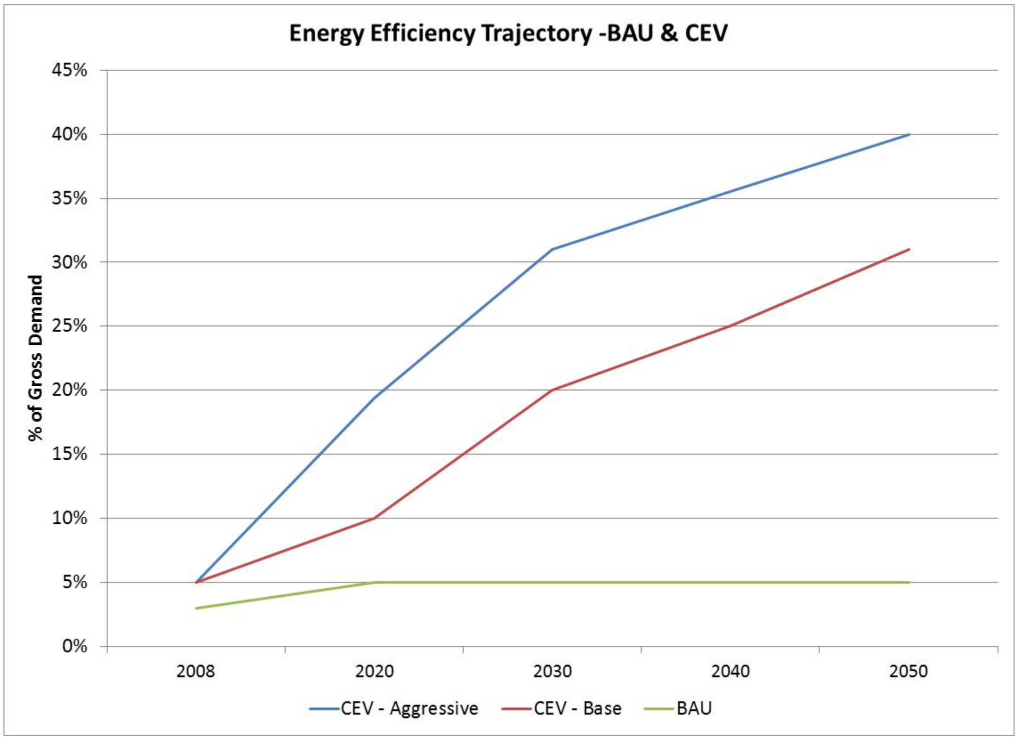
The potential importance of demand saving efforts is clearly illustrated on Figure 15. Figure 15 compares net demand for the BAU and CEV Cases. Note that 2050 net demand in the BAU Base Case is roughly 70 percent higher than the net demand experienced in the CEV Low Case. That is, the BAU Base Case requires about 700 billion kWh more electricity generation, or almost twice as much, by 2050 compared with the CEV Low Case.

It is also interesting to note how much higher consumption per person is when demand saving is not pursued aggressively. Figure 16 shows the two BAU net energy demand per-capita cases along with the CEV net energy demand per capita cases. In the BAU Base Case, net demand per capita increases from 11,450 kWh in 2010 to 13,940 kWh in 2050. That is, each person average uses 20 percent more electricity per year. In contrast, the CEV Low Case reduces consumption per person to 8,800 kWh per year.

Thus, it is clear that for the BAU cases, net demand growth is driven both by population growth and by increases in consumption per capita. In the CEV cases, population is the driving factor behind growth and demand saving efforts reduces consumption per capita and act to dampen growth.

In summary, aggressively implementing all cost-effective demand reducing measures eliminates projected growth in energy demand over the next 40 years in the CEV Low Case.

Figure 8: EE Savings as a Percent of Gross Demand



High DSM and reference case efficiency savings estimates are from the *SPSC - High DSM Load Forecasts* (http://www.westgov.org/sptsc/site/workgroups/dsmwg.htm). Smart grid savings estimates are from page 22 of Pacific Northwest National Laboratory's *Benefits and Costs of Achieving CO2 Reductions with a Smart Grid* dated 2009 and page 87 of McKinsey & Company's *Unlocking Energy Efficiency in the U.S. Economy* dated 2009.

Figure 9: Projected Net and Gross Electricity Demand for CEV High Demand Case

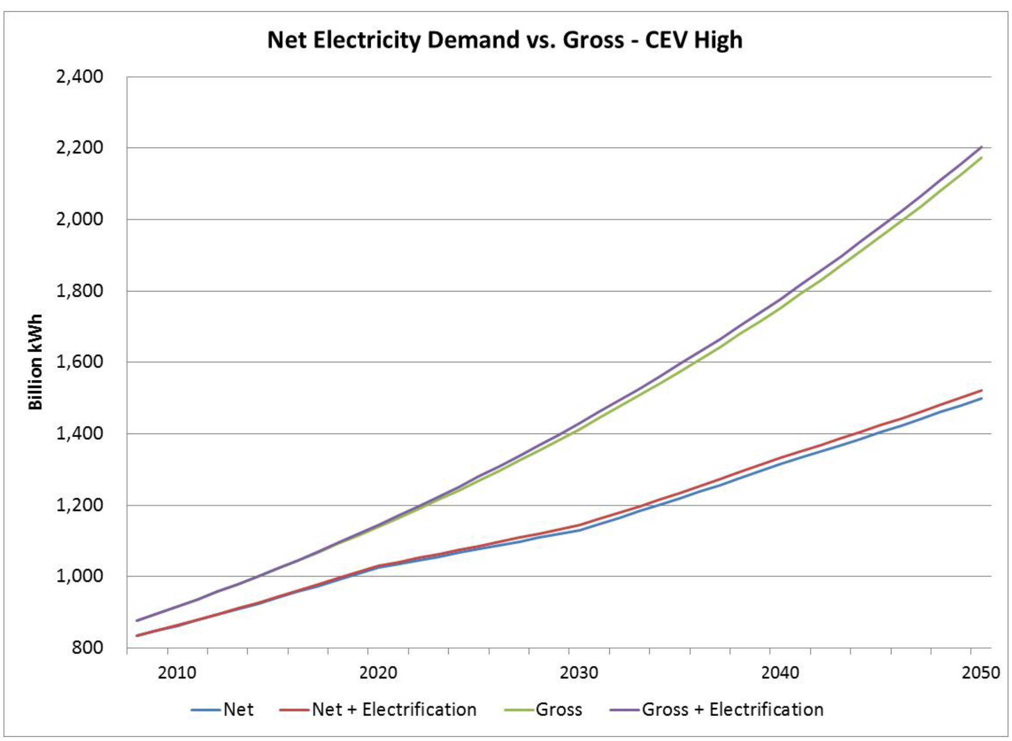


Figure 10: Projected Net and Gross Electricity Demand for CEV Base Case

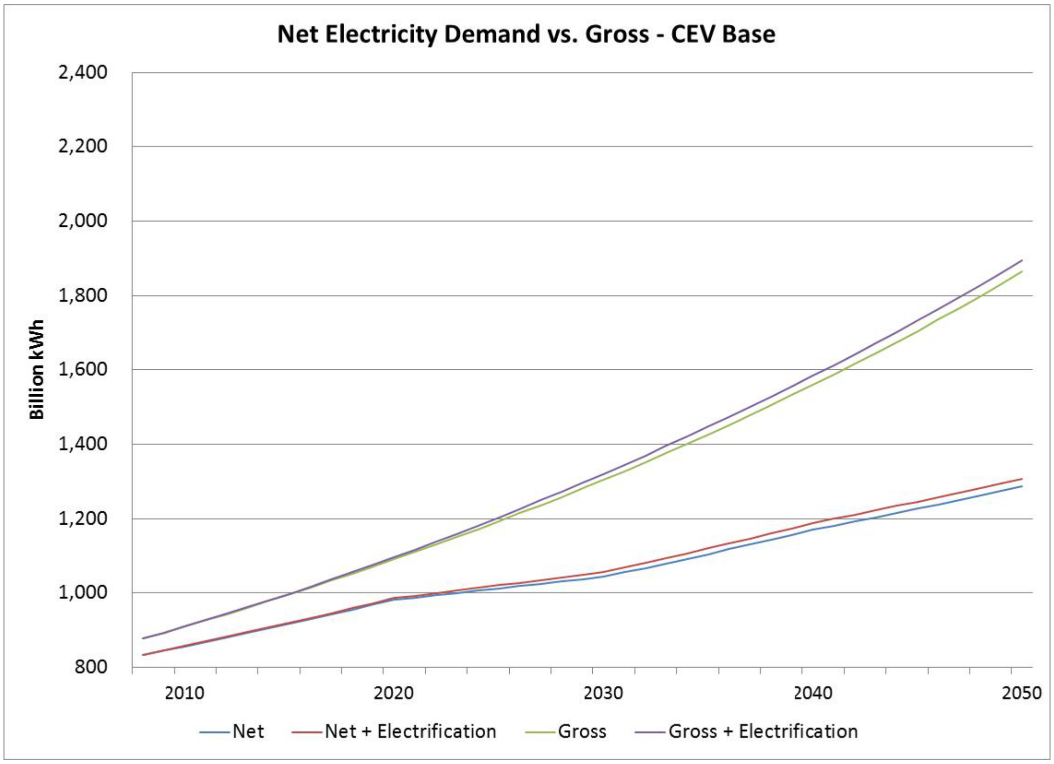


Figure 11: Projected Net and Gross Electricity Demand for CEV Low Case

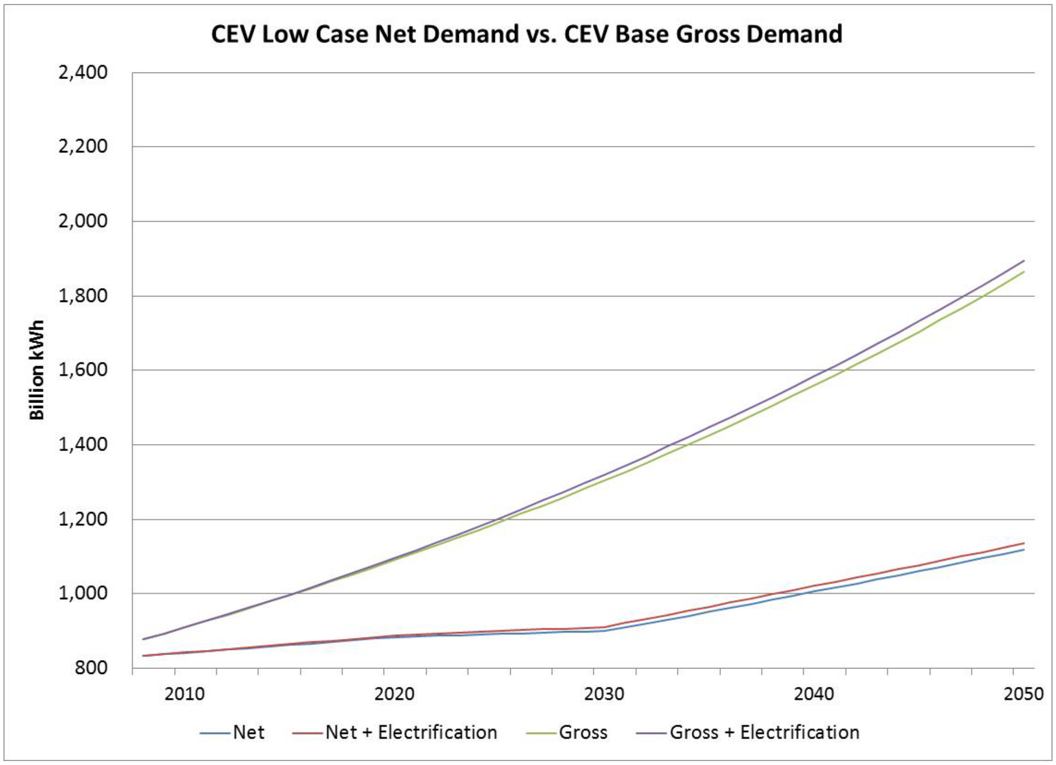


Figure 12: Comparison of Net Electricity Demand in Three CEV Scenarios

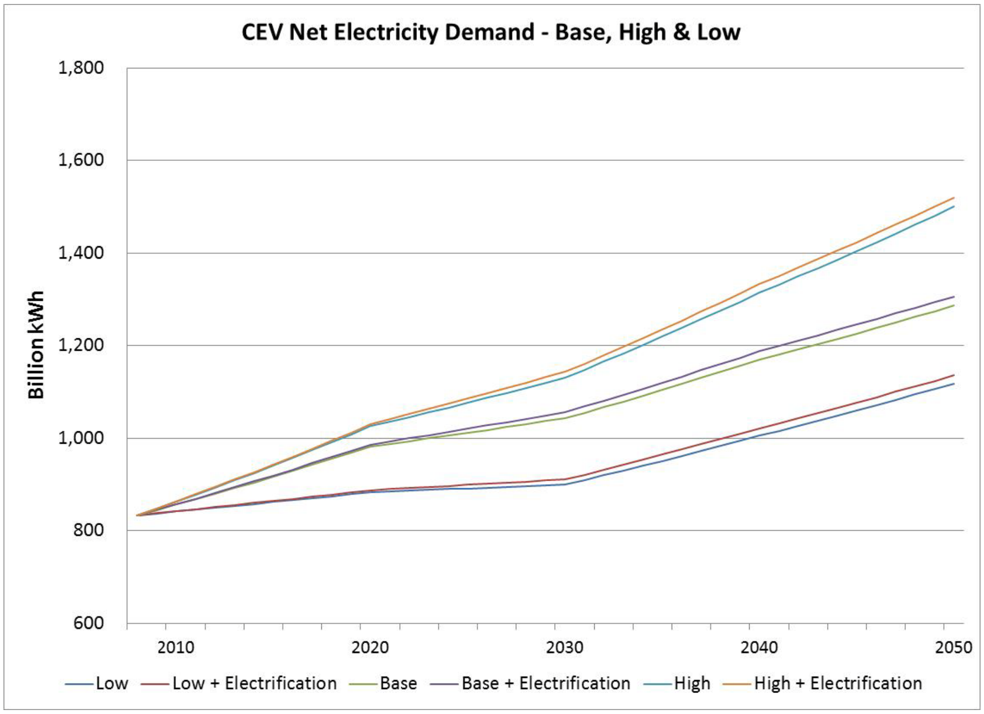
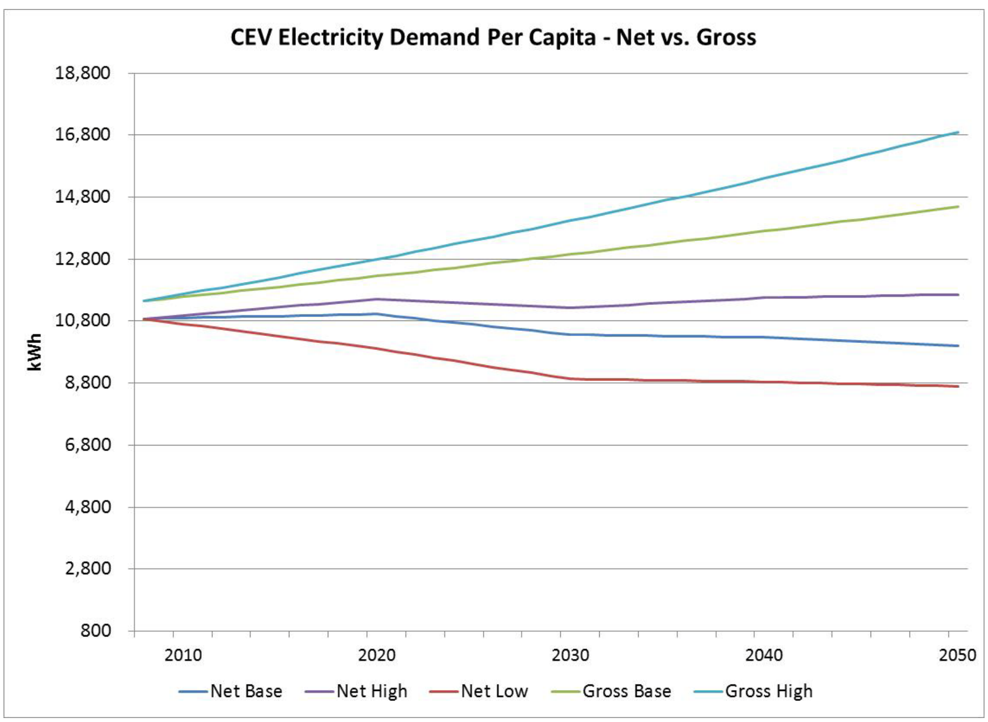


Figure 13: CEV Net and Gross Electricity Demand Per Capita



Population source: The U.S. Census Bureau (http://www.census.gov/population/www/projections/files/SummaryTabA1.pdf), Energy demand and efficiency savings sources: SPSC – Adjusted State Load Forecasts dated 2010 (http://www.westgov.org/sptsc/site/workgroups/dsmwg.htm) and SPSC High DSM Load Forecasts dated 2010 (http://www.westgov.org/sptsc/site/workgroups/dsmwg.htm

Figure 14: BAU Base and High Net Electricity Demand

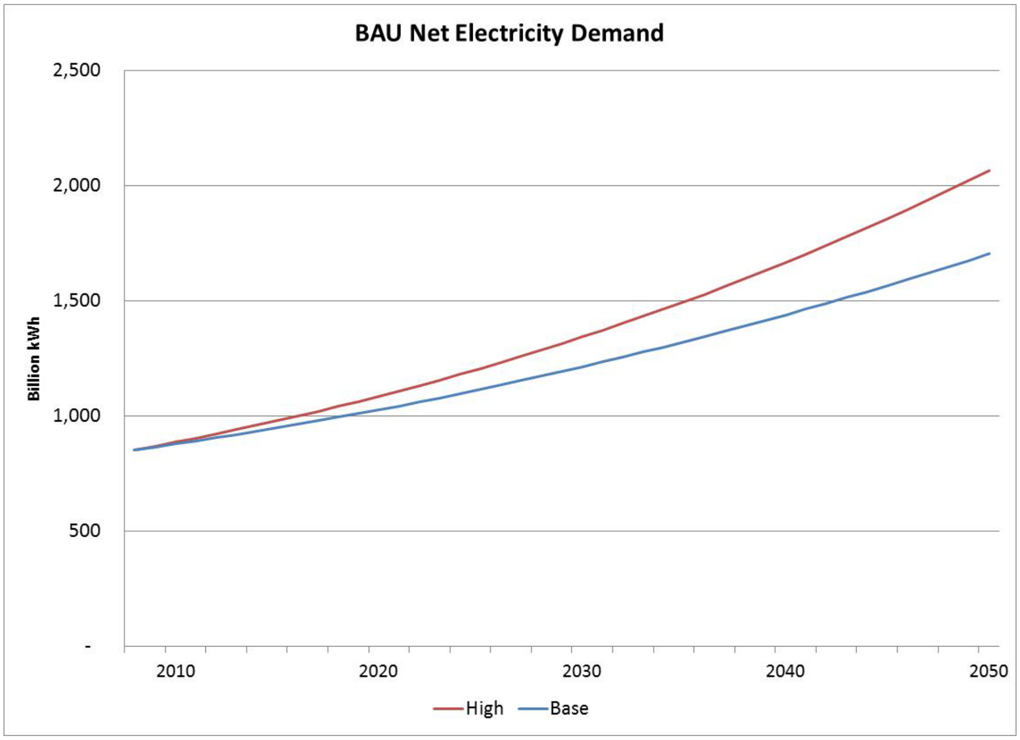


Figure 15: BAU vs. CEV Net Electricity Demand

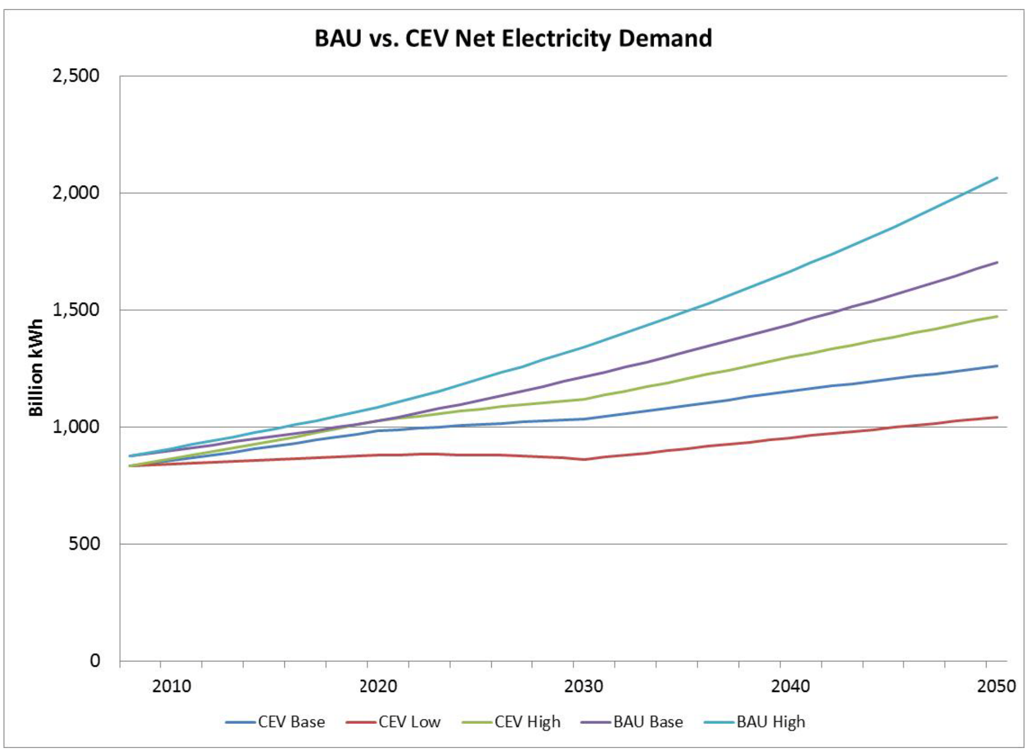
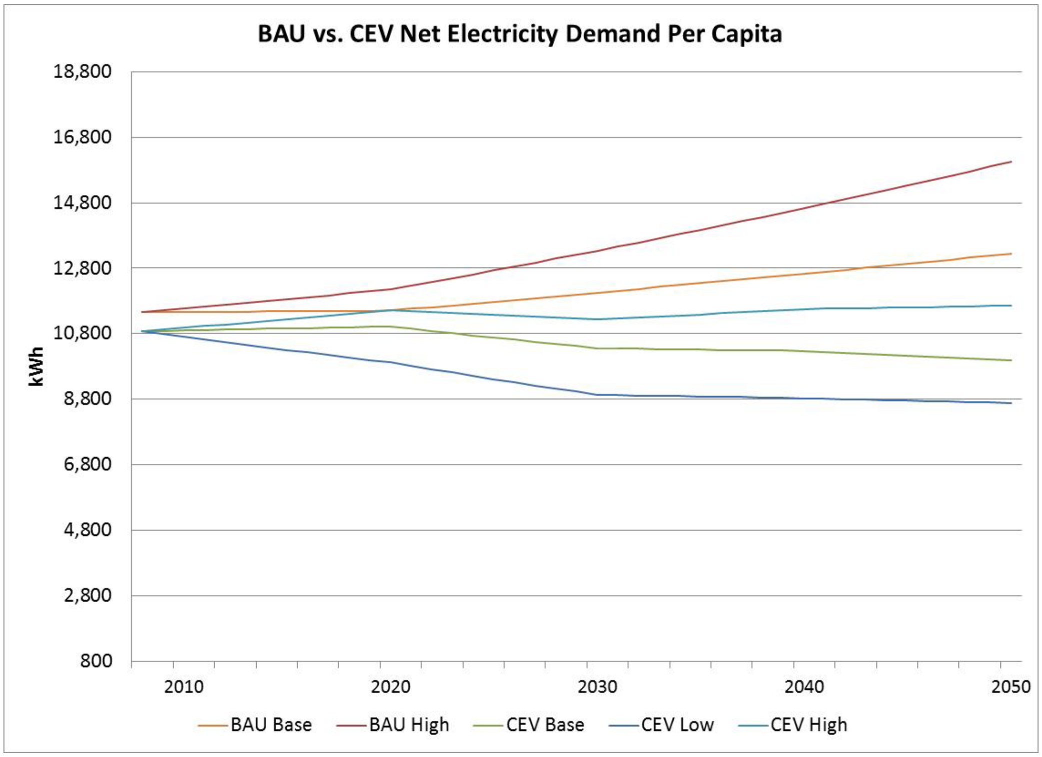


Figure 16: BAU vs. CEV Net Electricity Demand Per Capita



4. Distributed Generation

Introduction

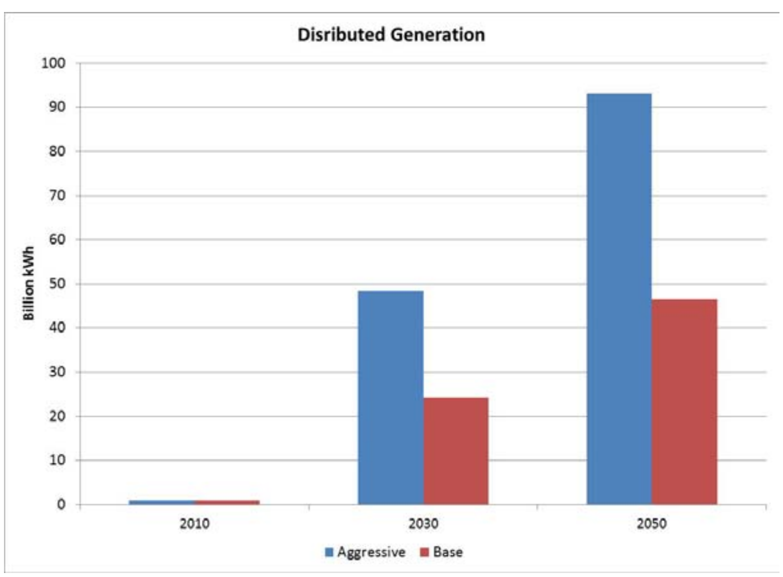
The State and Provincial Steering Committee (SPSC) recently proposed that Distributed Generation (DG) should include, "Small-scale installations located in such a way as to minimize the combined environmental footprint of generation and transmission." SPSC proposes that resources qualifying as DG should include: behind-the-meter resources (solar photovoltaic (PV), wind, combined heat and

Chapter 4 Overview: Distributed Generation

Distributed Generation (DG) is an electricity resource that is located at a customer's premises or is directly interconnected to the distribution system. Electricity produced by DG facilities, like demand saving discussed in Chapter 3, reduces demand for electricity from large scale generation. While DG can include fossil generation such as Combined Heat and Power (CHP) and renewable energy generation, this Chapter focuses on quantifying potential contributions of renewable energy DG. Solar Photovoltaic (PV) technology is the largest source of renewable DG potential for the foreseeable future and thus is the focus of this Chapter.

In 2010, approximately 1 billion kWh was produced by DG facilities operating in the WECC. This chapter estimates an upper bound potential for DG by 2030 and 2050 in the WECC. While a vast amount of DG is technically feasible in the West, operational barriers and cost limit the economic potential of DG and thus subsidies are required to support most renewable DG adoption at present, given how DG benefits are recognized and counted. However, as cost declines, benefits are recognized and counted, and barriers are removed, Solar PV DG is expected by most experts to be economically competitive with grid delivered power before 2030 and perhaps as early as 2015. Based on the studies conducted to date, the most aggressive DG penetration for the West that appears supportable is 48.4 billion kWh (about 30,000 MW) in 2030 and to 93 billion kWh (60,000 MW) by 2050. These are very aggressive targets. We estimated a less aggressive case with 50 percent less DG, referred to as the DG Base Case, that is applied to the CEV Base and High Cases.

The BAU Cases assume no incremental DG generation beyond what is reflected in the Balancing Area load forecasts. The CEV Low Case assumes aggressive penetration of DG while the CEV Base and High Cases assume 50 percent of aggressive penetration. Net demand for the CEV cases is adjusted to reflect DG penetration at the levels estimated above in Chapter 5.



power (CHP) located close to load; small scale biomass or biogas located close to load; and remote wholesale DG (up to 20 MW) that does not require major new transmission; and supply-side CHP.

The WECC Base and SPSC Reference cases produced in late 2010 include DG to the extent that it is incorporated into demand forecasts submitted to WECC.[37] The BAU Cases maintain that assumption and do not explicitly account for additional DG. The CEV Cases assume additional DG beyond the amount reflected in the WECC demand forecasts. The remainder of this Chapter derives the CEV DG forecast. The CHP portion of the DG forecast will be accounted for as a supply side resource and will be considered along with other supply side resources in Chapter 5.

The DG forecast is intended to reflect all DG penetration other than CHP installations. Since solar photovoltaic (PV) installations at customer sites or as wholesale resources are expected to be predominant resources supplying DG, the forecast focuses on solar PV penetration. Some projections reviewed in constructing the CEV forecast also include other potential DG resources such as wind and biomass but the contribution of these resources is small in all forecasts reviewed.

Most solar PV installed today, driven by policy and customer participation, is induced with subsidies that reduce solar costs to customers. The current market for PV in the U.S. is encouraged by national, state, and local government incentives (e.g., federal tax credits, up-front cash rebates, and production-based incentives) and some state requirements that include DG as part of meeting a Renewable Portfolio Standard (RPS). States can provide for DG within their respective RPS requirements in some combination of two ways:

- As a solar share or set-aside (either a requirement for solar or for DG), or
- As a solar multiplier effectively making solar PV more competitive with central station renewable energy sources by providing more RPS credits per kWh delivered.

However, PV costs have declined by 50 percent over the last few years, solar cell efficiency is increasing and elimination of barriers that have kept PV from competing on a level playing field relative to other resources are combining to make PV more competitive. Experts disagree on the year in which PV will be competitive without policy preferences, but the year generally varies between 2015 and 2030 depending on the study. When that cross-over occurs, simple economics will drive much larger solar penetrations.

Table 2 indicates which Western states have enacted RPS solar or DG set-asides. Of the approximately 48 MW (DC) of PV that were developed in the U.S. through 2006 as a result of solar set-asides, about 43 MW are in four Western states: California, Nevada, Arizona and Colorado.[38,39] Current information identifies a total of 871 MW of installed PV in California.[40]

Current Levels of PV DG in the West

California is, by far, the largest solar PV DG market. California does not specify a level of solar or DG within its RPS, however, the State has required utilities to move toward a goal 1,940 MW of solar PV by

[37] The High DSM case is being adjusted in 2011 to include DG.
[38] PV that is interconnected on the consumer side of the meter is produced with Direct Current (DC) and is converted to Alternating Current (AC) on systems interconnected with the grid in order to ensure compatibility between the system AC electricity and the PV generated electricity. The size of the PV system expressed in DC represents the amount of electricity produced by the PV cells and transmitted to the inverter.
[39] Green Tech Media, "Classifying the Top States for Utility-Scale PV Development in the U.S." February 18, 2010.
[40] See http://www.gosolarcalifornia.ca.gov/, cited on April 3, 2011.

2016. The utilities and the California Public Utilities Commission (CPUC) have supported the State goal through providing financial incentives. California programs that support the customer side of the meter include the California Solar Initiative, Self-Generation Incentive Program, New Solar Homes Partnership Program, and Emerging Renewables Program. More recently, Governor Brown has endorsed pursuing a goal of 12,000 MW of DG by 2020.

Other States with active programs include the Arizona Public Service (APS) (Solar Partners Incentive Program), Oregon (the Energy Trust of Oregon Solar Electric Program), Xcel (Solar Rewards Program),[41] and Nevada (Solar Generations Program).

Table 3 provides information on the installed PV in California, Arizona and Oregon through2008.[42] California had the most installed PV – 83 percent of over 360 MW of grid-connected, residential and non-residential PV systems reviewed by Wiser et al. The 37,000 PV systems in the dataset represent roughly 75 percent of all grid-connected PV capacity installed in the U.S. through 2007, and about 70 percent of the PV capacity installed in 2007. California had 69 percent of all grid-connected PV capacity installed in the U.S. through 2007, and had installed about 33,000 out of the nation's 48,000 solar systems by the end of 2007. New Jersey, at 9 percent of the total installed capacity, was the next largest state.

Future Projections for PV Technical/Economic Potential

A vast amount of distributed generation in the West is technically feasible, and a number of recent studies provide projections of future PV potential. These studies are reviewed in the Technical Appendix and a summary of the study projections for 2030 and 2050 is presented in Table 4 below.

Most studies use 2030 as the end point and the studies use different methodologies to arrive at the potential estimates. The 20 percent Solar Vision case coordinated by DOE carefully considers limitations based on growth in global manufacturing. The NRDC study considers diffusion rates of rapidly disseminating technologies in the last century like cars, personal computers and cell phones, and uses these observed diffusion rates to place an upper bound on the growth rate of DG installations. Other studies focus on economic potential with and without subsidies.

The DG studies also differ in the technologies that they consider. The 20 percent Solar Vision study naturally focuses only on solar and the NRDC case considers wind and solar.

The CEV Low Demand Case seeks to establish a bounding case that shows maximum demand reduction. The 20 percent Solar Vision study (48.4 billion kWh) and the NRDC study (42.4 billion kWh) represent the most aggressive penetration levels by 2030. Penetration levels consistent with the 20 percent Solar Vision of 48.4 billion kWh of electricity by 2030 were selected for this forecast and are assumed to include customer sited and wholesale DG.

For 2050 there is less information available. A 2050 Synapse Study estimates 45.1 billion kWh for 2050. The Scientific American 2050 vision piece estimates 93 billion kWh by 2050. Given our use of 48.4 billion kWh by 2030, the Scientific American estimate appears reasonable for an aggressive 2050 case.

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[41] The Xcel program has paid over $200 million dollars in incentives to customers, installed more 7,000 PV systems and more than 85 MW of solar in Colorado. See http://www.xcelenergy.com/Save_Money_&_Energy/Find_a_Rebate/Solar*Rewards_-_CO.

[42] Wiser, Ryan, Galen Barbose and Carla Peterman.

Thus, the DG Aggressive Case includes approximately 48 billion kWh of DG by 2030 and 95 billion kWh by 2050. Because these aggressive targets may not be met, we estimate a DG base case, in which 50 percent less DG is achieved. This amounts to 24 billion kWh of DG in 2030 and 47 billion kWh of DG in 2050.

The BAU Cases assume no incremental DG generation beyond what is reflected in the Balancing Area load forecasts. The CEV Low Case assumes aggressive penetration of DG while the CEV Base and High Cases assume 50 percent of aggressive penetration, the DG base case. Net demand for the CEV cases is adjusted to reflect DG penetration at the levels estimated above in Chapter 5.

The DG growth scenarios used in the CEV cases is shown in Figure 17 below. These DG energy estimates are subtracted from the CEV net demand cases in Chapter 5 presentations of net demand. The effect of the DG on peak demand is considered in Chapter 6.

Table 2: Western State RPS Solar/DG Set-Asides

State	RPS Level
Arizona	4.5% customer-sited DG by 2025 (half from residential)
Colorado	0.8% solar electric by 2020 (half from customer-sited projects; 1.25x multiplier for in-state projects; 3x multiplier for co-ops and munis for solar installed before July 2015
Nevada	6% solar of 25% RPS by 2020 [1.5% of total]; 2.45x multiplier for distributed PV
New Mexico	20% solar of 20% RPS by 2020 [4.6% of total]; 3% DG by 2011
Washington	2x multiplier for DG

Source: Wiser and Bolinger, 2007; http://www.greentechmedia.com/articles/read/classifying-the-top-states-for-utility-scale-pv-development-in-the-u.s/

Table 3: Data Summary for Western States PV Incentive Programs

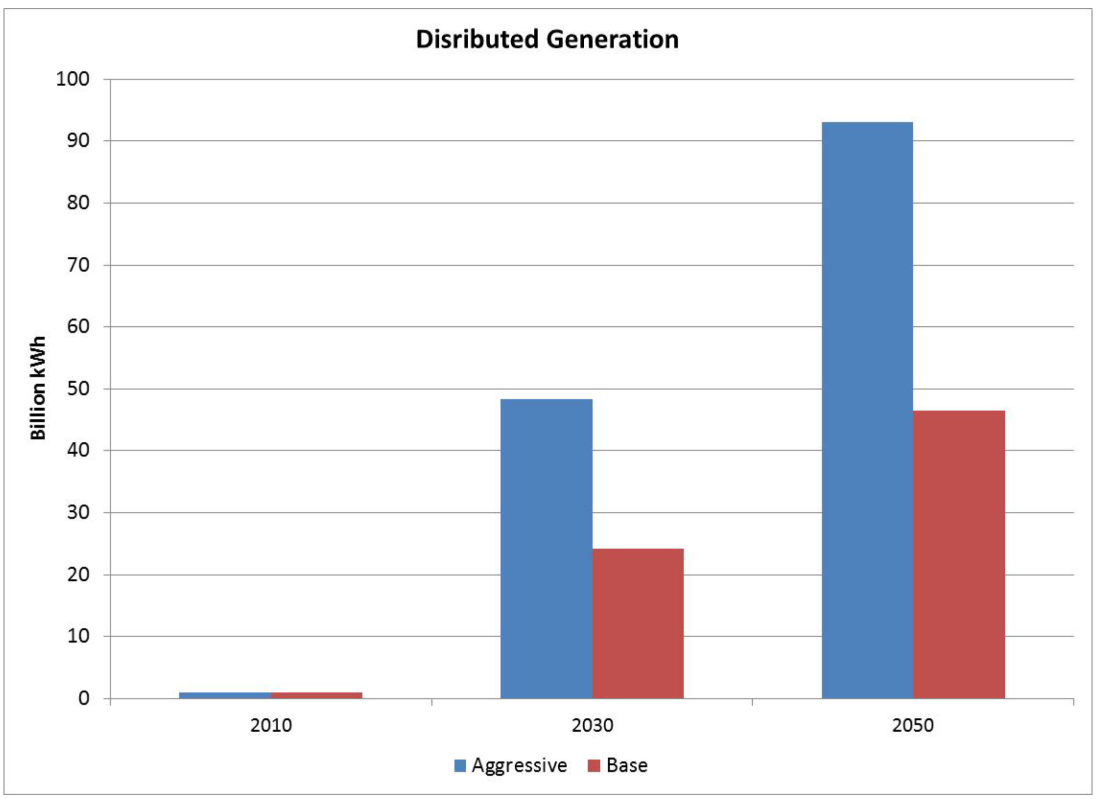
PV Incentive Program	No. of Systems	Total MW	% of Total MW	Size Range (kW)	Year Range
CA – Emerging Renewables Program	27,267	143	39.4%	0.1 - 670	1998 -2007
CA – Self Generation Incentive Program	801	132.6	36.5%	34 – 1,265	2002 – 2007
CA – California Solar Initiative	2, 303	14.3	3.9%	1.2 – 1,182	2007
CA - Solar Incentive Program (LADWP)	592	10.6	2.9%	0.3 - 467	1996 – 2006
AZ – Solar Partners Incentive Program	540	3.1	0.9%	0.4 – 255	2002 – 2007
OR – Solar Electric Program	600	2.3	0.6%	0.8 – 67	2003 – 2007

Source: Wiser, Barbosa and Peterman, 2009

Table 4: 2030 and 2050 Distributed PV in the West

Study	2030	2050	Notes
Navigant 2008	8,360 – 10,380 MW Economic Potential		Navigant only studied a 2015 case; these are the best case estimates for 2015
Denholm, Drury and Margolis 2009	72.4 GW 107.9 TWh Technical Potential		U.S. projection of 193 GW is prorated for the West using the ratio of installed capacity for U.S./West from the Solar Vision 2030 study (37.5% from West).
Solar Vision	36 GW 48.4 TWh		Highest case from the Solar Vision study; case indicates barriers to overcome to get from 10% to 20% penetration.
Google Clean Energy 2030	63.8 GW 95 TWh		U.S. projection of 170 GW by 2030 is prorated for the West (West is 37.5% of national load).
NRDC Aggressive Scenario	28.5 GW 42.4 TWh		U.S. projection of 76 GW is prorated for the West (37.5%), based on aggressive new technology diffusion estimates and includes consideration of solar and wind DG.
Synapse	23.8 TWh 16 GW	45.1 TWh 30 GW	Synapse produced a solar estimate for the west; these estimates are made using PV as a percentage of total solar additions as a proxy for DG percentages.
Scientific American		93 TWh 63 GW	Scientific American produced a 2050 solar penetration projection. The solar DG estimate was derived using 2050 total electricity production from Synapse Report, and the ratio of west/total US from the Solar Vision report.

Figure 17: CEV Distribution Generation Projection



5. Large Scale Generation Portfolios

Introduction

Chapters 2 through 4 developed net demand forecasts for the 2010 to 2050 time period. The purpose of this chapter is to specify the portfolios of large scale generation resources for each of the five cases.

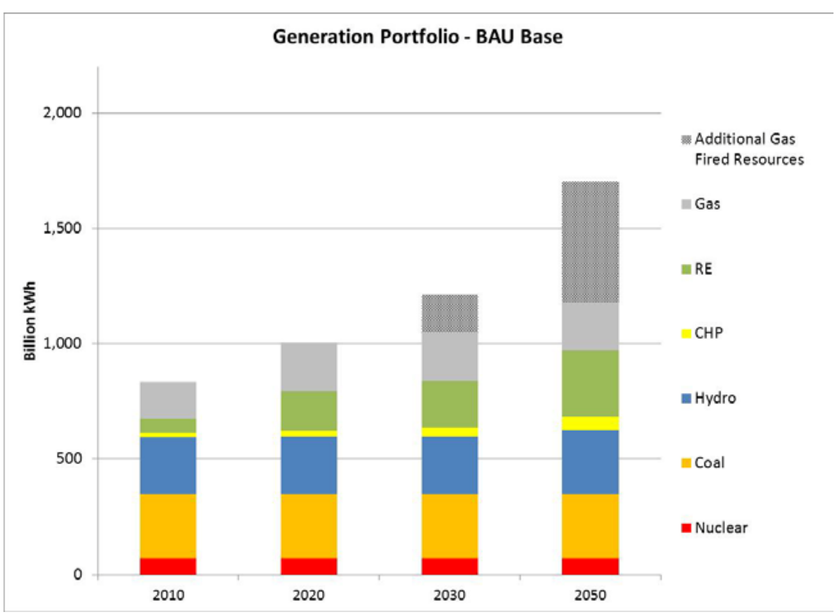
Basic BAU Portfolio Assumptions

The BAU portfolios of 2020 to 2050 developed in this chapter look similar to the portfolio of resources in the West today. Nuclear, large hydroelectric and conventional coal fired generation are assumed to

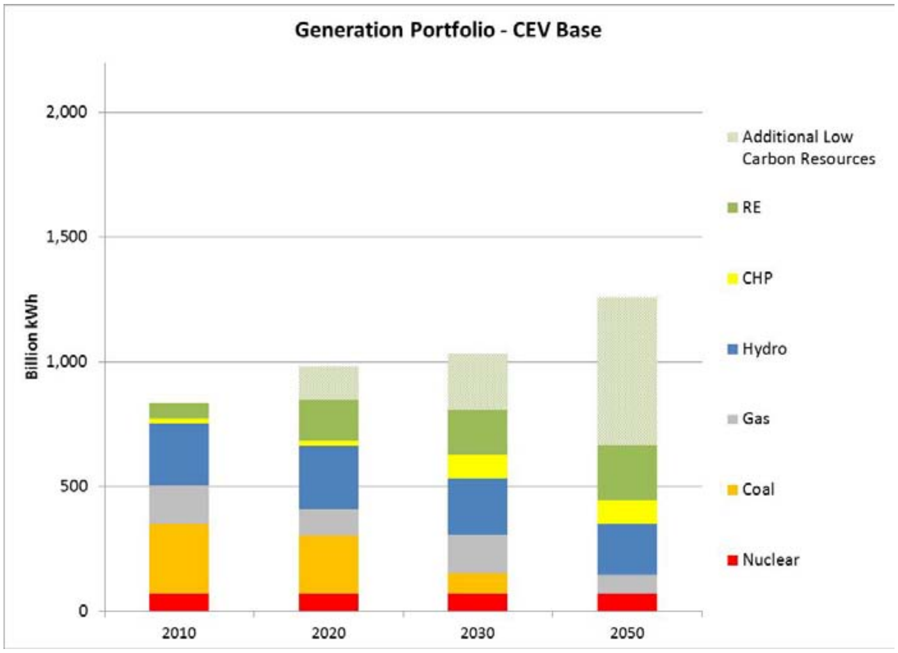
Chapter 5 Overview: Large Scale Generation Portfolios

This chapter presents the net need for additional large scale generation resources to meet energy requirements in the West for two BAU cases and three CEV cases and builds portfolios of resources for each case. Portfolios are built for each case for 2020, 2030 and 2050. The BAU cases continue recent utility investment patterns and rely upon additional natural gas generation to meet incremental needs. The CEV cases meet carbon reduction targets by transitioning away from coal generation and by filling incremental needs with renewable resources. All BAU and CEV meet the renewable energy standard statutory requirements of the western states.

The BAU and CEV Base Case generation portfolios for 2020, 2030 and 2050 are shown in the two figures below. Dramatic differences in net demand, coal generation, gas generation, and renewable generation stand out. The BAU portfolios invest less in electricity saving and DG and thus the BAU Base Case net demand is significantly higher than the CEV Base Case in 2030 and 2050. The CEV transitions away from coal in order to meet carbon reduction targets and the BAU does not. The BAU meets any residual net need with incremental gas generation and thus the BAU much more gas fired generation in 2030 and 2050. The CEV meets residual net need with low carbon resources in order to live within the carbon emission targets and thus the CEV has somewhat more renewable energy in 2030 and far more renewable energy in 2050.



Chapter Overview (continued)



meet the same need that these resources meet today. Since most coal plant is more than 30 years old, the BAU portfolio assumes that retiring coal plant will need to be replaced with new coal facilities. Renewable energy facilities are built in the BAU cases to meet State statutory requirements so increases in renewable energy generation are observed in future BAU portfolios.

Incremental demand, that portion of demand that results from growth in consumption, is assumed in BAU cases to be met with new gas generation. Building gas generation to meet incremental need has been common practice over the last 20 years and utility resource plans typically indicate that new gas generation will fill incremental needs so this BAU assumption is well-founded in recent practice and declared intentions.

Basic CEV Portfolio Assumptions

The CEV cases have lower net demand so the incremental demand caused by consumption growth is far smaller than the BAU cases. However, the CEV cases assume that fossil generation is limited by a carbon emissions constraint and the constraint implies that many coal plants are not replaced when they retire and the ability to build new gas fired facilities to meet incremental needs is constrained. As a result, there is a need for new generation to meet the incremental need caused by the transition away from coal and the incremental need must be met with low carbon resources in order to keep within the carbon emissions constraint.[43]

The low carbon resources that are proven and viable today are renewable energy resources. While the lifecycle carbon emissions of renewable energy sources are not zero they are much lower than fossil

[43] Renewable resources have close to zero carbon emissions when they generate but do have some lifecycle carbon emissions. The resources are modeled as having zero carbon emissions. If lifecycle emissions are accounted for then even more low carbon resources are required to meet the carbon goals.

generation sources.[44] While large scale carbon capture and sequestration may one day be able to qualify as a low carbon resource and fill part of the demand, the technology is not technically proven at the scale of a conventional coal plant and thus the CEV assumes that it will not be available as a low carbon resource in 2030. While nuclear generation is sometimes classified as a low carbon resource, concerns over nuclear safety and nuclear waste are assumed to preclude new nuclear generation from being built to meet need in 2030. While tidal power may one day be proven and economically competitive, it is not assumed to be part of the renewable energy portfolio.

2030 and 2050 Portfolios

Portfolios are specified for 2030 and 2050 for all BAU and CEV cases but the 2030 portfolios are more specific with respect to the renewable portfolios. For the 2030 cases, the renewable portfolios range from a low of 200 billion kWh for the BAU Base Case to a high of 490 billion kWh for the CEV High Case and these portfolios are built using the WECC 2010 study cases and the WREZ Peer Analysis Tool. These cases, thus, give an indication of the infrastructure that is needed to build a portfolio that includes up to 490 billion kWh of large scale renewable energy.

The 2050 CEV portfolios require low carbon large scale generation ranging from 600 billion kWh to 1,030 billion kWh. The size of these portfolios clearly indicates that the 490 billion kWh portfolio of resources specified for the 2030 CEV High Case will be needed, if not in 2030 then certainly at some time before 2050. Specific resources are not selected beyond the 490 billion kWh level because the location of specific resources and the competitiveness of renewable technologies specified in the WREZ tool is uncertain enough beyond 2030 that choosing the selection of one resource over another, or one location over another becomes highly speculative. As a result, the 2050 portfolios include a category of "additional low carbon resources" that reflects the demand without specifying locations or technologies.

BAU and CEV Net Demand

The BAU net demand cases do not assume additional DG beyond what is reflected in the BAU load forecasts, so the BAU net demand cases shown in Figure 14 are appropriate for determining net need for new large scale generation.

The CEV cases require an adjustment to reflect the aggressive and base DG penetration developed in Chapter 4. The CEV Low Case is assumed to experience aggressive DG penetration, whereas the CEV Base and Low Cases experience 50 percent of aggressive penetration. Net demand assumptions discussed earlier in Chapter 3 were developed to reflect aggressive demand reduction (including aggressive energy efficiency policy) and moderate population and gross demand growth. Chapter 4 then developed aggressive and base distributed generation assumptions. The net demand that must be met by low carbon generation resources is then net demand less projected DG. Resulting CEV Low, Base and High net demand levels and the CEV high and base gross demand levels are shown in Figure 18 below.

Note that the CEV low net demand, the case with the most aggressive demand reductions, experiences almost no growth from the present out to 2030 and very little growth beyond 2030. The CEV base net demand case shows rates of growth to 2030 far below historical averages (1 percent per year versus

[44] IPCC Working Group III – Mitigation of Climate Change, May 2011, *Special Report on Renewable Energy Sources and Climate Change Mitigation: Technical Summary*, table TS 10-15.

historical averages of about 3 percent per year) and the CEV high net demand case shows growth but the rate of growth is modest by historic standards (1.3 percent per year).

Combined Heat and Power

Combined Heat and Power (CHP) DG systems generate electricity and use thermal energy in an integrated system.[45] As a result, CHP systems can reduce electricity demand by generating power on site and using thermal energy from the power generation equipment, instead of electricity or natural gas, to operate plant equipment or provide heat to on-site processes.[46] Some CHP facilities provide electricity to the grid, while other CHP facilities do not.

As with other DG, the BAU cases from 2010 to 2020 indicate very little new investment in CHP, so BAU CHP growth continues this trend.

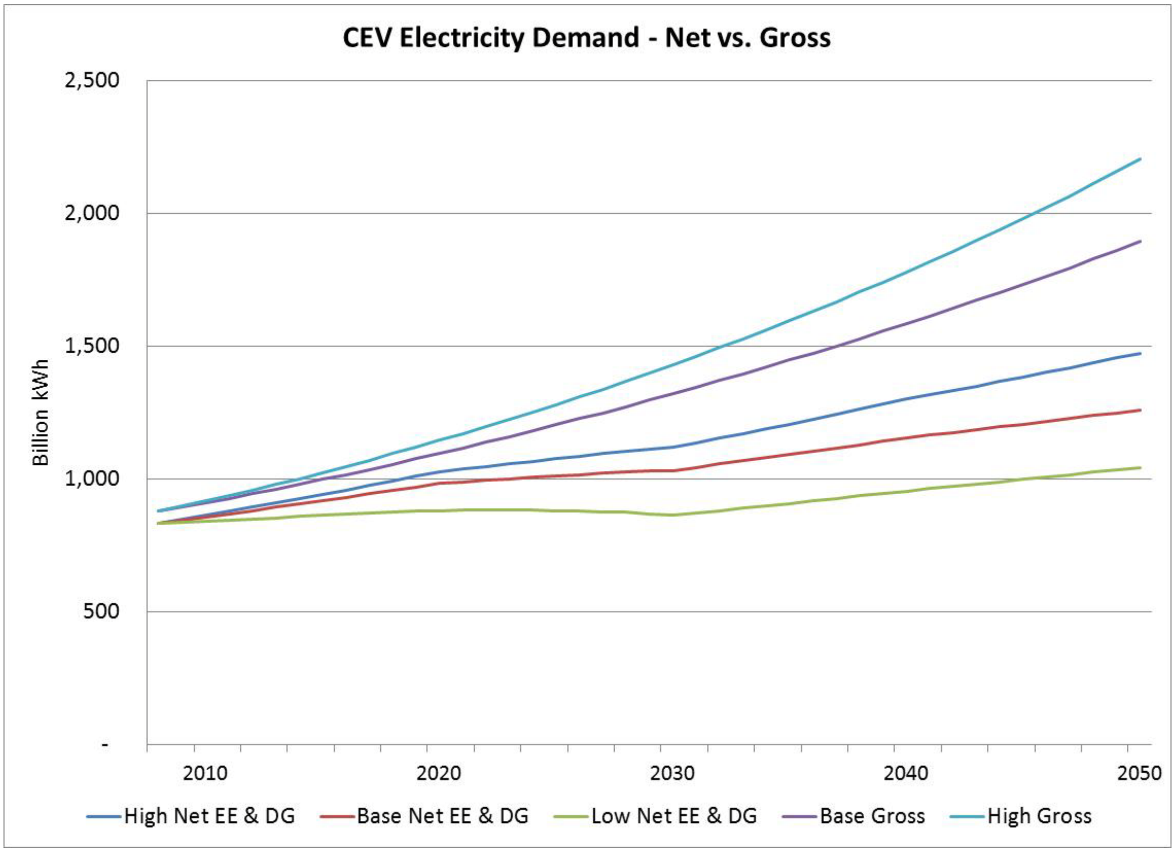
The CEV cases include the common assumption that all economically viable CHP is assumed to be built by 2030. The extent to which CHP will reduce future electricity demand depends on future market penetration of the technology. Oak Ridge National Laboratory (ORNL) estimates market penetration of CHP in the WECC region to be roughly 12,000 MW by 2025, which translates to about 95 billion kWh of electricity.[47,48] While the ORNL study is considered too aggressive by some technical experts, an alternative projection has not been prepared so the ORNL estimates are used for the time being. Based on these projections, CHP is assumed to serve 95 billion kWh of demand for energy in the CEV low, base and high demand cases by 2030. Since the 12,000 MW represents all known economic potential, no additional growth in CHP occurs after 2030.

Nuclear and Large Hydroelectric Generation

Nuclear generation contributes 70 billion kWh to serving WECC loads at the present and large hydroelectric generation contributes about 250 billion kWh. Nuclear generation is assumed to stay at current levels in 2030 and 2050 for both the BAU and CEV cases. This assumption allows for the possibility that some new nuclear generation is brought on line to replace any retiring generation, but no net generation addition occurs. The role of nuclear is kept at current generation levels due to waste storage, operating risks, and public acceptance issues, which are likely to continue for the foreseeable future (out to 2030 and beyond). WECC BAU projections from 2010 to 2020 reflect approximately constant large hydro generation, and so BAU cases presume this trend continues. CEV large hydroelectric generation is expected to be affected by reduced hydro flows due to climate change during the period, some dams are expected to be decommissioned and no new large hydroelectric dams are expected to be constructed. To reflect these assumptions, the amount of large hydro generation is assumed to be 10 percent below current annual levels by 2030 and 20 percent below current levels by 2050 in all three CEV cases.

Figure 18: Projected Gross and Net Electricity Demand for the CEV Cases through 2050

[45] McKinsey & Company p. 87
[46] Mid-Atlantic Clean Energy Application Center
[47] Oak Ridge National Laboratory (ORNL) p. 22
[48] The 95 billion kWh of electricity production assumes that all need served by the CHP systems would have been served by electricity had the CHP system not been installed. This is an upper end estimate because some of the heat needs could well be served by direct gas heat and not electricity in the absence of the CHP unit.



Net energy demand is calculated by subtracting savings due to energy efficiency, CHP, and DG from gross demand projections.

Sources: SPSC – Adjusted State Load Forecasts (http://www.westgov.org/sptsc/site/workgroups/dsmwg.htm), SPSC High DSM Load Forecasts (http://www.westgov.org/sptsc/site/workgroups/dsmwg.htm, ORNL's *CHP Market Potential in the Western States Task Report 5* dated September 2010, & Scientific American's *A Solar Grand Plan* Dated Dec. 16, 2007.

BAU Net Need for Large Scale Generation Resources

WECC Base and High Load cases show renewable energy filling the need prescribed by state statutes and policies, coal fired generation continuing to serve approximately the same load as in 2010 and natural gas fired generation being added to meet all residual demand. Figure 19 shows BAU portfolios by decade out to 2050 for the Base load case and Figure 20 shows portfolios for the High Load case. Tables 6 through 8 show generation energy and capacity quantities by resource type and by decade. Chapter 6 will provide more information on how large scale renewable energy resources were selected.

The striking differences that one notices in comparing BAU and CEV cases are dramatic contrasts in load growth and the amount of new gas generation required in the BAU case. Carbon emissions associated with the BAU cases shown in Figure 21 indicate a steady upward trend.

Figure 19: BAU Base Demand Generation Portfolios in 2030

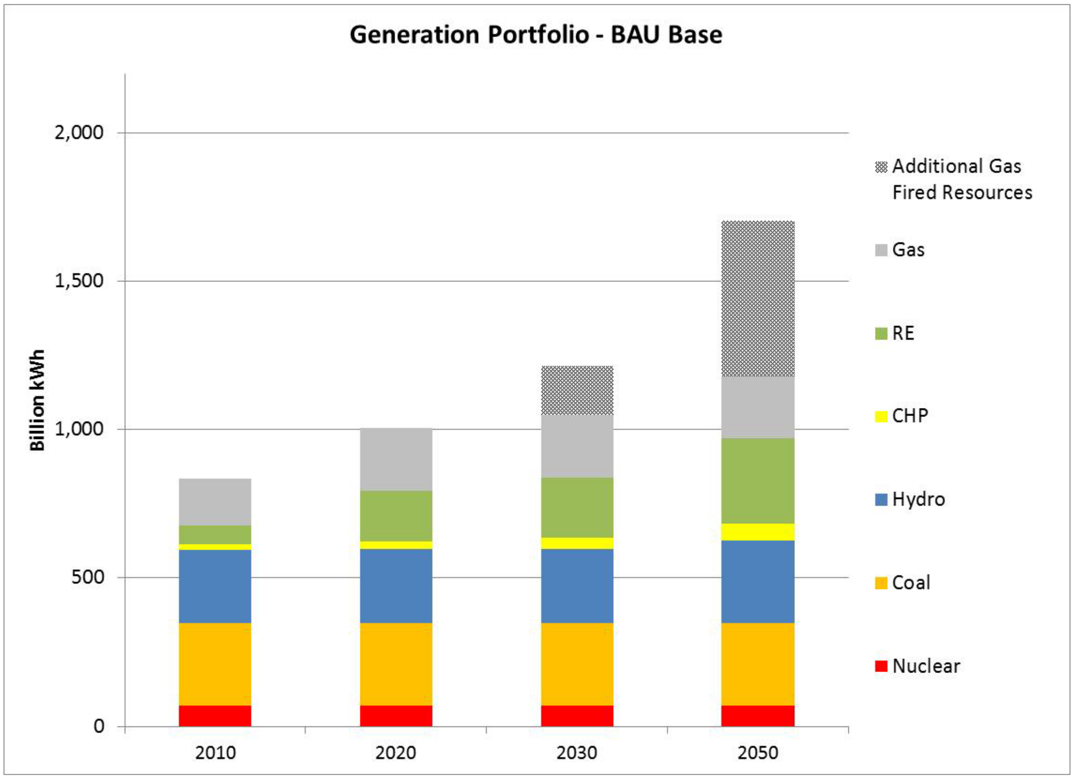


Figure 20: BAU High Demand Generation Portfolios in 2030

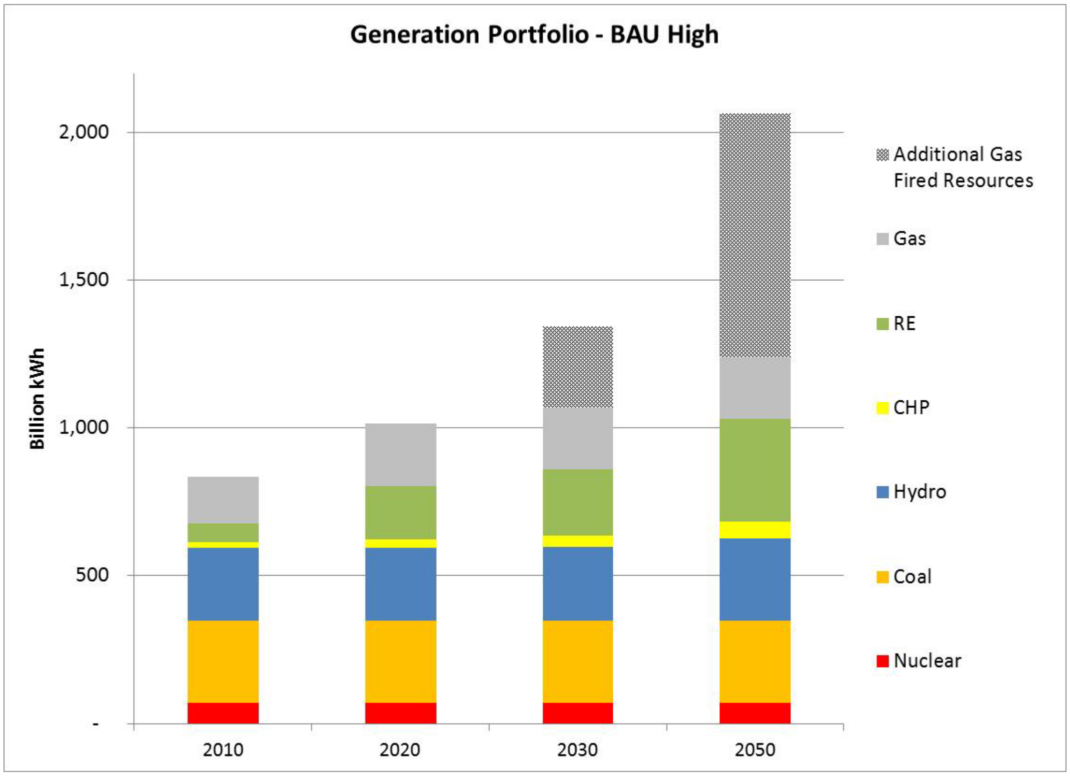

Generation Portfolio - BAU High
Billion kWh
2,000
1,500
1,000
500
-
2010
2020
2030
2050
Additional Gas Fired Resources
Gas
RE
CHP
Hydro
Coal
Nuclear

Table 5: Generation in Billions of kWh by Resource Type by Case

			Nuclear	Coal	Gas	RE	Hydro	CHP	Efficiency Resources	DG	Added Gas Fired Resources	Net Demand
BAU	Base	2010*	70	278	157	63	246	19	-	**	0	901
BAU	Base	2020	70	278	210	172	248	26	54	**	0	1025
BAU	Base	2030	70	278	210	204	248	39	64	**	165	1214
BAU	Base	2050	70	278	210	286	278	58	89	**	524	1704
BAU	High	2010*	70	278	157	63	246	19	-	**	0	909
BAU	High	2020	70	278	210	181	247	28	56	**	0	1083
BAU	High	2030	70	278	210	224	248	39	71	**	274	1343
BAU	High	2050	70	278	210	345	278	58	109	**	826	2065
			Nuclear	**Coal**	**Gas**	**RE**	**Hydro**	**CHP**	**Efficiency Resources**	**DG**	**Added Low carbon Resources**	**Net Demand**
CEV	Low	2010*	70	278	157	63	246	19	-	1	0	841
CEV	Low	2020	70	233	106	153	252	22	208	20	48	881
CEV	Low	2030	70	80	156	149	227	95	409	48	88	863
CEV	Low	2050	70	0	76	180	204	95	767	93	421	1043
CEV	Base	2010*	70	278	157	63	246	19	-	1	0	857
CEV	Base	2020	70	233	106	165	252	22	108	20	130	983
CEV	Base	2030	70	80	156	179	227	95	264	24	209	1,032
CEV	Base	2050	70	0	76	218	204	95	587	47	562	1,260
CEV	High	2010*	70	278	157	63	246	19	-	1	0	863
CEV	High	2020	70	233	106	172	252	22	114	20	167	1,027
CEV	High	2030	70	80	156	194	227	95	286	24	281	1,120
CEV	High	2050	70	0	76	255	204	95	683	47	739	1,474

*2010 values vary among cases because 2008 is the last year of historical data so 2010 is a forecast year and varies by case.

**BAU DG resources are included in the load reduction trend in the demand forecast.

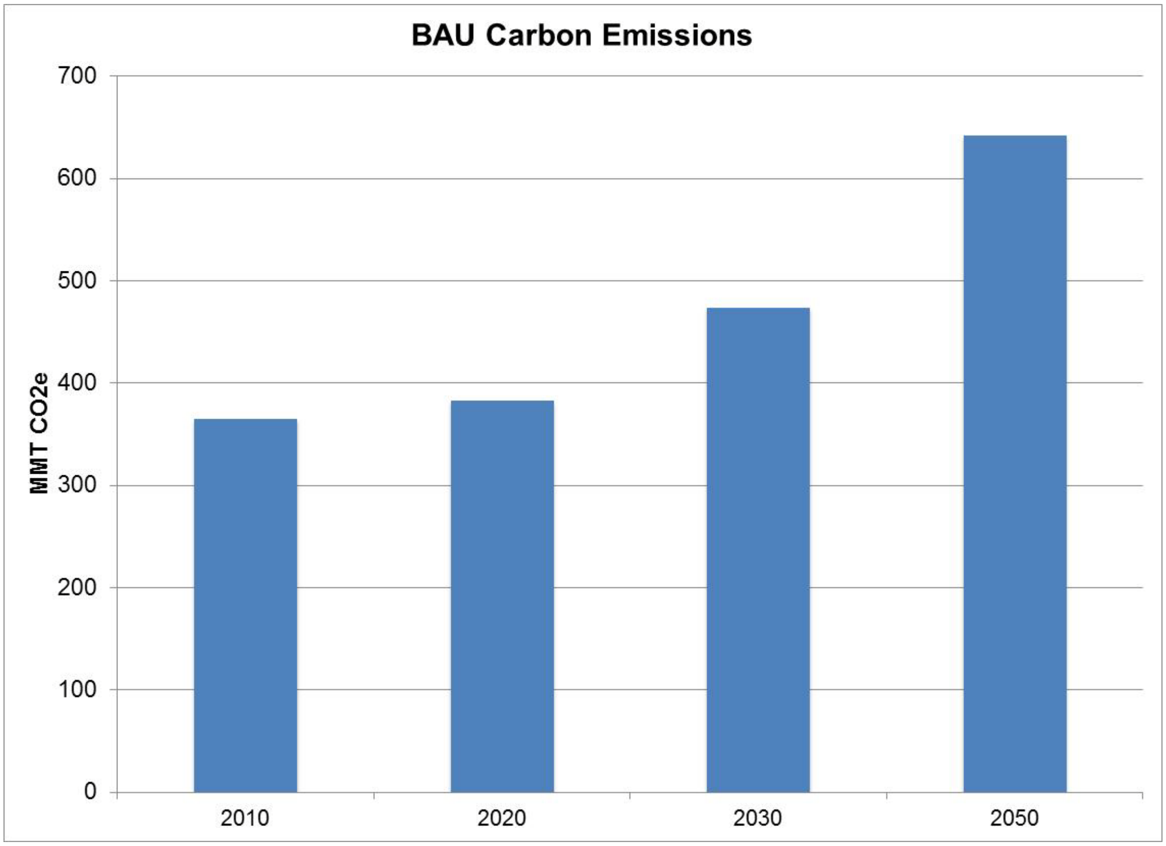
			Nuclear	Coal	Gas	RE	Hydro	Cogen & CHP	Added Gas Capacity
BAU	Base	2020	9,681	38,000	92,479	54,262	73,395	3,957	0
		2030	9,681	38,000	92,479	66,030	73,448	5,936	70,183
		2050	9,681	38,000	92,479	96,186	82,332	8,828	222,884
	High	2020	9,681	38,000	92,479	57,572	73,152	4,262	0
		2030	9,681	38,000	92,479	73,385	73,448	5,936	70,183
		2050	9,681	38,000	92,479	117,883	82,332	8,828	351,402
CEV	Low		**Nuclear**	**Coal**	**Gas**	**RE**	**Hydro**	**Cogen & CHP**	**Added Low carbon Capacity**
		2020	9,681	32,300	92,479	61,617	72,855	3,349	0
		2030	9,681	10,467	92,479	59,779	67,228	14,460	17,652
		2050	9,681	0	92,479	74,121	60,417	14,460	126,873
	Base	2020	9,681	30,484	92,479	68,972	74,632	3,349	29,461
		2030	9,681	10,467	92,479	74,672	67,229	14,460	71,707
		2050	9,681	0	92,479	92,834	60,417	14,460	210,606
	High	2020	9,681	30,484	92,479	72,650	74,633	3,349	43,762
		2030	9,681	10,467	92,479	81,534	67,229	14,460	96,214
		2050	9,681	0	92,479	110,112	60,417	14,460	272,020

Table 6: Nameplate Capacity (MW)

Table 7: Large Scale Renewable Energy Capacities 2020 to 2050 (MW)

			Wind	Geo	Solar Thermal	Solar PV	Small Hydro	Biomass	Total
BAU	**Base**	**2020**	29,841	5,126	7,444	7,444	1,964	2,444	54,262
		2030	36,657	5,346	9,449	9,449	2,508	2,620	66,030
	High	**2020**	31,758	5,188	8,008	8,008	2,117	2,494	57,572
		2030	42,835	5,546	11,266	11,266	3,002	2,780	76,695
CEV			**Wind**	**Geo**	**Solar Thermal**	**Solar PV**	**Hydro**	**Biomass**	**Total**
	Low	**2020**	34,101	5,264	8,697	8,697	2,304	2,554	61,617
		2030	43,261	5,559	11,392	11,392	3,036	2,791	77,431
	Base	**2020**	56,256	5,979	15,214	15,214	2,645	3,127	98,433
		2030	74,150	6,557	20,477	36,102	5,505	3,589	146,379
	High	**2020**	65,842	6,288	18,033	18,033	4,841	3,374	116,412
		2030	92,683	7,155	25,928	40,928	6,986	4,067	177,748

Figure 21: BAU Carbon Emissions from Electricity Production – Base Case



Carbon Targets and CEV Fossil Generation Limits in 2030

The contribution of fossil energy to meeting the need is limited by the carbon budget. Table 8 shows the CEV carbon targets that limit carbon emitting resources in CEV cases. The carbon targets seek to bring the western electricity sector into compliance with the IPCC 2050 carbon reduction goal. Toward that end, the 2020 carbon target is based on WECC case PC8 from the 2010 study cycle which retires significant coal generation.[49] Note that the carbon targets for 2030 and 2050 are 167 MMT CO_2e and 60 MMT CO_2e, respectively.

Table 9 shows several combinations of coal and natural gas electricity production that are consistent with the 2030 carbon budget of 167 MMT CO_2e. These calculations are not based on lifecycle carbon emissions but are based on carbon emissions at time of production. The combinations are calculated assuming that coal carbon emissions average approximately 0.9 MT/MWh, natural gas plant carbon emissions average about 0.4 MT/MWh, and natural gas-fired CHP emits about half as much carbon per MWh as conventional gas fired generation. CHP is set at its maximum economic potential in each of the three CEV cases presented.

[49] The IPCC AR4 goal for 2020 is a 25 percent reduction below 1990 levels. For the western electricity sector this would translate into a goal of 220 MMT CO2e by 2020. Western Grid Group seeks to establish a WECC transmission planning case that achieves this goal but to date the most aggressive case modeled yields 283 MMT CO2e emissions and so we use that here.

Table 8: Western Electricity Sector Carbon Targets

Year	Emissions Goal (MMT CO2e)
2010	365 (actual)
2020	283
2030	167
2040	114
2050	60

Table 9 shows the trade-off between the total amount of fossil generation in billions of kWh and the amount of coal generation that continues to operate. As coal generation declines from 100 billion kWh to 80 billion kWh, the amount of conventional natural gas-fired generation increases from 125 billion kWh to 155 billion kWh, and thus the combined fossil generation of coal and conventional gas grows from 225 billion kWh to approximately 240 billion kWh. Given the carbon target, every kWh of coal taken out of production enables slightly more than 2 kWh of conventional natural gas-fired generation. Selecting a combination of coal and natural gas for 2030 should be determined by balancing the benefits of retaining base load coal versus the benefits of having a more flexible generation fleet. The example presented through the rest of this paper for 2030 assumes coal generation of 80 billion kWh, which leaves enough carbon emissions headroom to accommodate 155 billion kWh of natural gas. This level of coal represents a dramatic reduction from the approximately 280 billion kWh assumed in the WECC 2020 cases, but it allows for a relatively large amount of gas generation which enhances fleet flexibility.

Carbon Targets and Electric System Reliability in 2030

To sum up, the conventional generation fleet posited for the 2030 CEV cases includes nearly 230 billion kWh of large hydroelectric production, 70 billion kWh of nuclear, 80 billion kWh of coal generation, approximately 155 billion kWh of conventional gas, and 95 billion kWh of CHP. WECC base and reference scenarios have conventional generation contributing about nearly 80 percent of energy needs, and this proposed scenario reduces the conventional generation percentage below 70 percent. Nuclear, hydro and coal collectively decline from 60 percent of generation to 35 percent of generation. Changes like these are necessary to attain aggressive carbon reduction targets, but will require new reliability tools for system operators and an electric grid that is far more capable of regional resource sharing and trading.

The reliability tool box depends on widespread deployment of digital technology throughout the distribution and transmission systems of the West. With vastly improved system controls and real time information, demand response, price responsive tariffs, interruptible load, dispatchable distributed generation and electricity storage will each become readily available customer side of the meter tools. Furthermore, utility side of the meter tools such as continuously improving forecasting, implementing real time scheduling, regional resource sharing and trading, flexible gas generation and flexible hydro dispatch will be available to meet reliability requirements.

Effectively using regional resources to maintain reliability requires institutional evolution by system operators and regulators in the West to create a robust western grid that leverages regional resource diversity and uses advanced forecasting, real time scheduling, customer resources, energy storage and broad regional energy imbalance markets. Such a transformed western grid will be operated as if it were one control area and it will take “least cost” advantage of all regional and locally available resources to meet reliability requirements, including customer demand response and DG resources.

These issues will be discussed in more detail in Chapter 6.

Table 9: Sample Feasible Fossil Combinations At a 2030 Carbon Target of 167 MMT CO2e

Carbon Target	Coal Quantity	Coal Carbon	Gas Quantity	Gas Carbon	CHP Quantity	CHP Carbon
(MMT CO2)	(Bn kWh)	(MMT CO2)	(Bn kWh)	(MMT CO2)	(Bn kWh)	(MMT CO2)
167	100	94	125	54	94	19
167	80	75	168	72	94	19
167	60	56	212	91	94	19

CEV 2030: Three Carbon Reduction Portfolios

The three different CEV cases represent three different CEV portfolios that depend on demand reduction and renewable resources in different proportions to meet carbon reduction goals. The pathway that relies most heavily upon demand reduction and DG and thus limits the need for large scale renewable energy generation is the low demand case. One purpose of the low demand case is to demonstrate how much new large scale renewable resources will be needed to meet energy requirements in the presence of carbon constraints even if energy efficiency and distributed generation are used to the maximum extent possible. [50] The Base Case represents a pathway where the most aggressive demand reduction does not materialize so more central station renewable energy is needed. The High Case represents a portfolio where the most aggressive demand reduction does not materialize and gross demand drivers such as increased consumer demand for plug in electronic devices or increased air conditioning load (perhaps due to more extreme climate) drive gross demand higher. The High Case represents a case where much more large scale renewable energy development would be required to meet carbon reduction goals.

The need for additional large scale renewable resources is defined to be the residual need after renewable resource standards are met. Recent WECC work shows existing renewable standards require about 17 percent of energy to come from renewable sources in the western interconnection. Therefore the total central station renewable energy supply will be assumed to be the sum of the western renewable requirements plus the net need for low carbon energy after all conventional sources and the required renewable resources are taken into account.

Figure 22 shows the generation portfolio for 2030 under the base demand scenario, and Table 5 includes the quantities of electricity generation and energy efficiency by resource type for the CEV Base Case. The renewable energy required in 2030 to meet western RPS policy and standards is approximately 180 billion kWh, and the net need for additional low carbon generation is 230 billion kWh. Thus the total demand for central station renewable energy in 2030 is over 400 billion kWh, with roughly 340 billion kWh from sources that were not operating or under construction in 2010. The amount of demand-reducing efficiency resources for this pathway is 265 billion kWh.

[50] While it is possible that completely effective and safe carbon sequestration may allow some base load coal generation to be added back to the fleet someday or safety concerns related to nuclear generation may one day win back public support for new nuclear generation or tidal generation facilities may one day be developed that change the renewable mix, none of these speculative possibilities are considered likely prior to 2030. Therefore, for the purpose of this paper, the net need for low carbon is assumed to be filled by additional renewable generation.

Figure 23 shows the generation need by decade for the low demand case. The net need for additional low carbon resources is 85 billion kWh in 2030 for the Low Case, and the total need for central station renewable energy is 150 billion kWh plus the 85 billion kWh increment for a total of 235 billion kWh. Over 170 billion kWh of the 235 is new large scale renewable generation that is not currently operating or under construction. Efficiency resources in the Low Case pathway total 410 billion kWh.

Figure 24 shows the need for additional low carbon energy in 2030 for the high demand case at 300 billion kWh, a total resource need of over 490 billion kWh and the need for new large scale renewable energy that is not operating or under construction at 430 billion kWh. The efficiency resources in this High Case pathway total 285 billion kWh.

The three pathways all reach the generation carbon reduction goals shown in Figure 25. The large scale renewable energy required to meet the carbon reduction goals ranges from 170 billion kWh of new large scale renewable energy in the CEV Low Case to 430 billion kWh in the CEV High Case. Efficiency resources and DG in the low demand case are at extreme bounding levels; thus it is not possible to contemplate a low carbon scenario for 2030 that does not include at least 170 billion kWh of large scale renewable energy facilities and the associated transmission needed. Transmission planning should identify transmission necessary for the CEV High Case, but some transmission can be delayed or cancelled if the need does not materialize. It should be noted that if lifecycle carbon emissions are counted then even more high carbon resources need to be replaced with low carbon resources.

Figure 22: CEV Base Demand Generation Portfolios in 2030

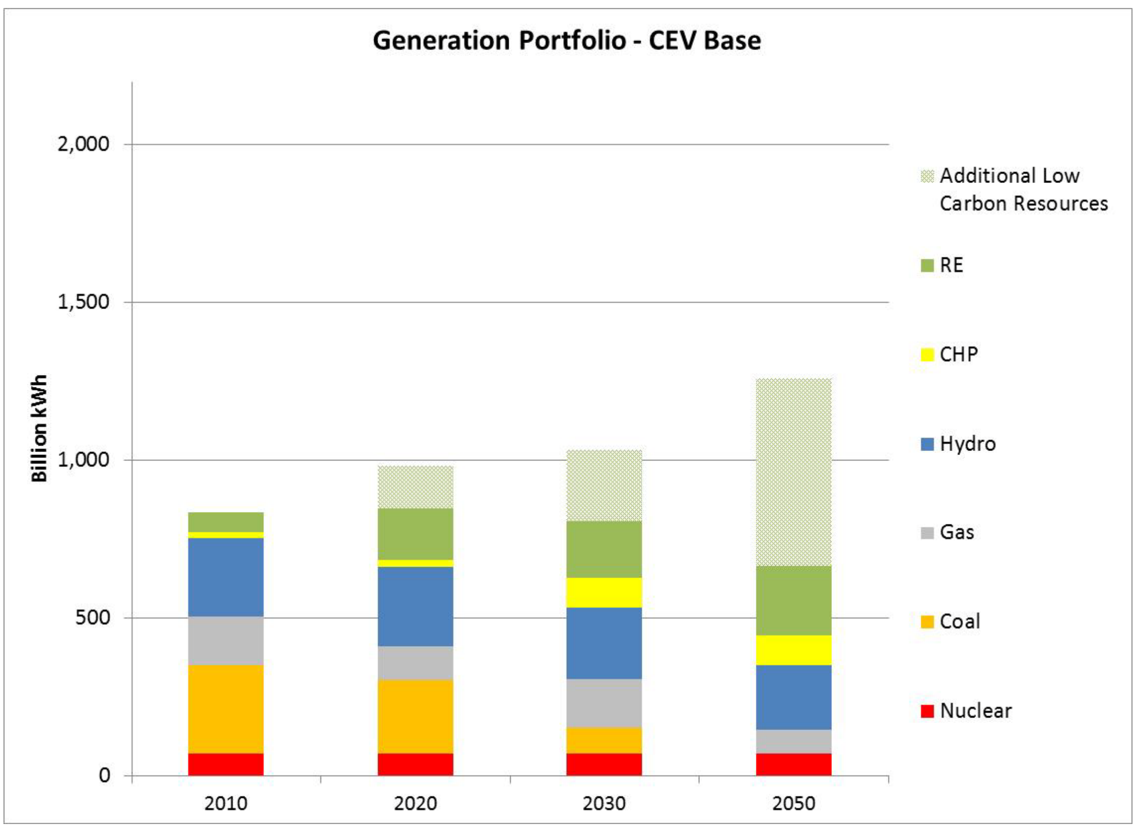


Figure 23: Low Demand Generation Portfolios in 2030

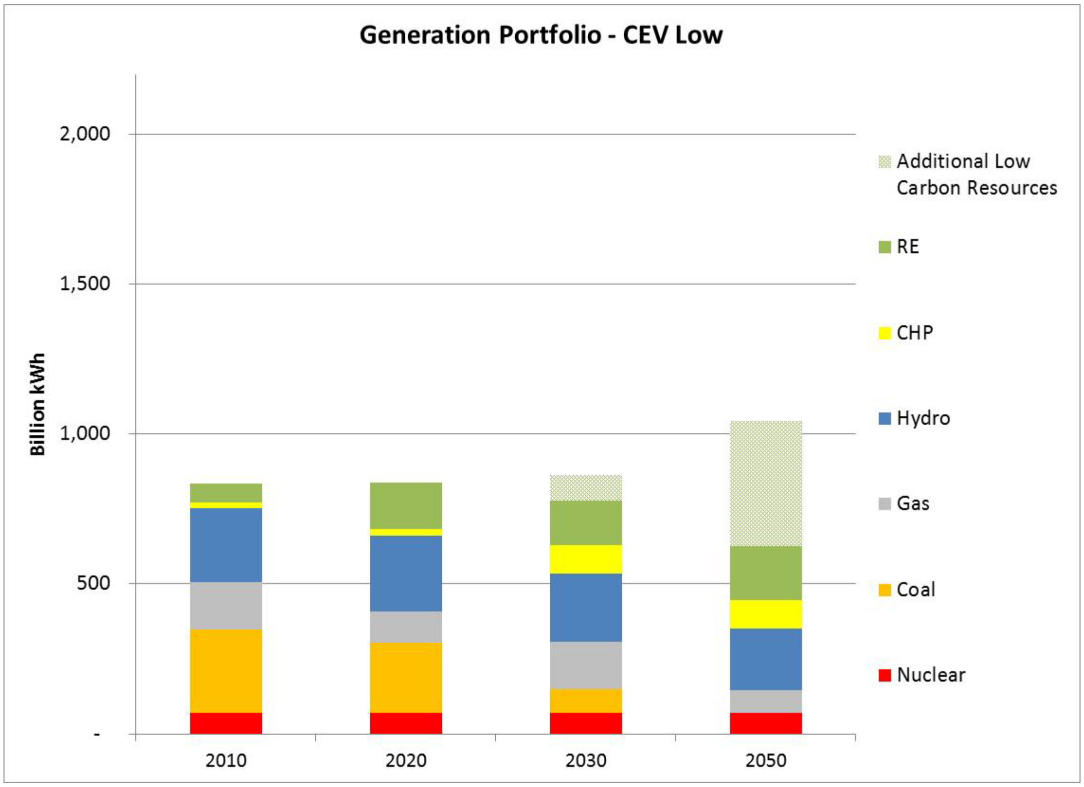
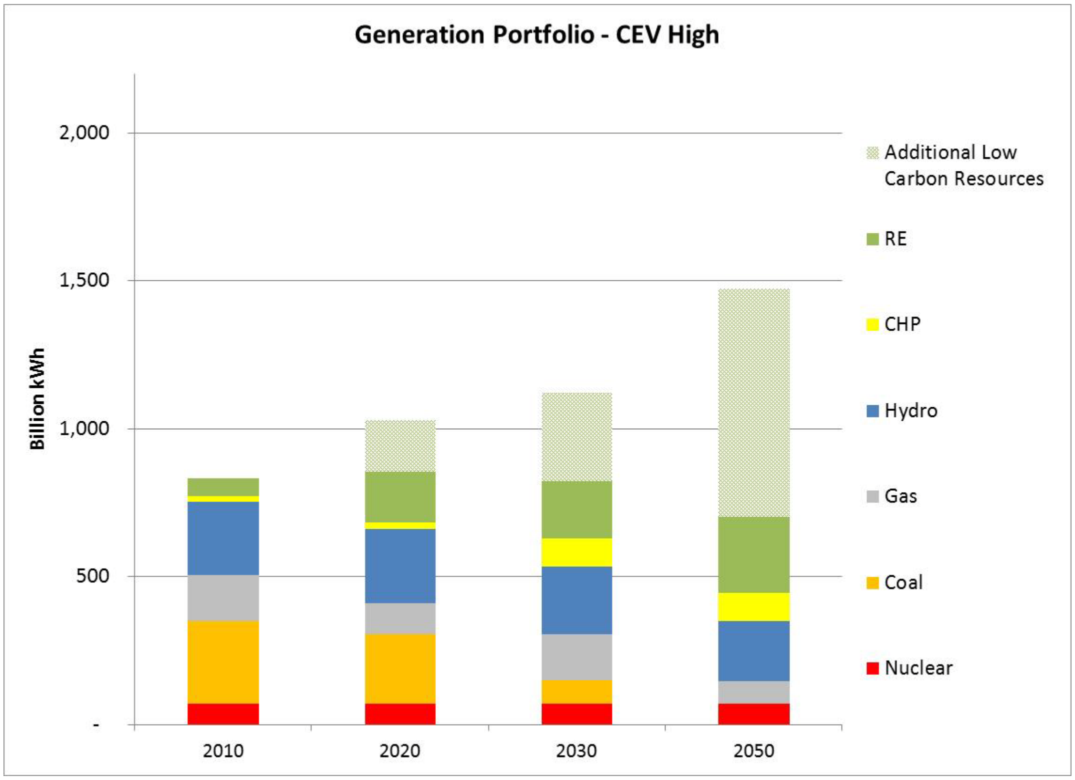


Figure 24: High Demand Generation Portfolios in 2030



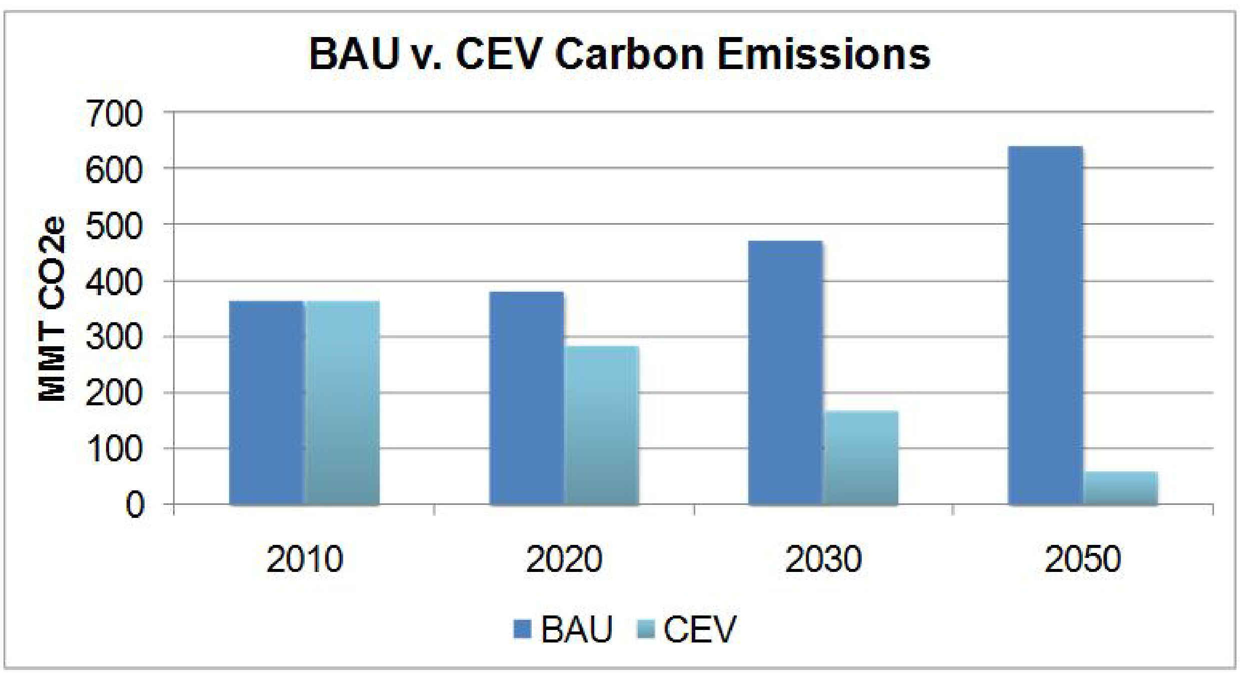
CEV 2050: Low Carbon Resource Needs

As the carbon target approaches 60 MMT CO2e in 2050, smaller and smaller amounts of fossil generation are possible. The carbon target effectively precludes the use of coal until proven, technically effective and cost effective carbon sequestration methods and technologies are developed and effectively implemented. Furthermore, the carbon budget constrains the amount of electricity produced from conventional natural gas generation to less than 80 billion kWh, assuming that 95 billion kWh of CHP is retained. Further de-rating of large hydro electric facilities reduces hydro generation to about 200 billion kWh, and nuclear is assumed to stay at 70 billion kWh.

Thus by 2050 total conventional generation (including CHP) will only be 445 billion kWh, or roughly 40 percent of electricity needs. Conversely, renewable energy and other low carbon resources will have to meet 60 percent or more of electricity needs. Table 6 shows CEV Low Case need for large scale renewable energy and other low carbon resources in 2050 is approximately 600 billion kWh. Therefore, even if demand reduction works exceptionally well, the need for low carbon resources in 2050 will exceed the 2030 CEV High Case need of 475 billion kWh.

Since the need for large scale renewables will exceed the CEV 2030 High Case sometime between 2030 and 2050, long term infrastructure plans should anticipate the need to deliver more than 475 billion kWh of large scale renewables. While nuclear, coal with effective sequestration, tidal power and other low carbon technologies may become viable to meet the low carbon needs some day, the prudent course of action is to plan to meet those needs with low carbon technologies like wind, solar and geothermal that are proven, viable and accepted by the public.

Figure 25: BAU vs. CEV Carbon Reduction from Generation



6. 2030 Renewable Portfolios and Resource Adequacy

Introduction

The BAU and CEV renewable energy portfolios presented in Chapter 5 indicate that significant increases of large scale variable generation are expected regardless of which trajectory occurs. While the portfolios presented in Chapter 5 were constructed to ensure the annual energy demand would be met, the portfolios were not tested to ensure that peak demand requirements would be met. This chapter assesses the resource adequacy of the constructed portfolios in 2030.

Large scale renewable energy production is projected to be over 60 billion kWh in the West in 2030 and the BAU large scale renewable energy portfolio in 2030 is projected to be between 205 and 225 billion kWh. The BAU approach to addressing how the increase in variable generation is to be handled is by adding significant new gas fired generation capacity. Since the BAU trajectory is assumed to operate the system in a similar fashion to how the system is operated today, resource adequacy assessment of the BAU portfolio relies on the current WECC resource adequacy methodology.

Chapter 6 Overview: 2030 Renewable Portfolios and Resource Adequacy

This chapter presents the Energy Portfolios presented in Chapter 5 in a resource adequacy (RA) context. The BAU trajectory assumes that system operations, system grid utilization, use of demand side resources and regional coordination do not substantially improve from current practice. The current WECC RA methodology is predicated on business as usual grid practices so the current methodology can serve as both a necessary and a sufficient condition test of BAU portfolio RA.

The table presented below shows the RA assessment of the BAU Base and High Cases. The Base Case is deficient in 2020 and the High Case is deficient in 2020 and 2030. The results mean that additional resources or changes in grid practices are needed for BAU Portfolios to meet resource adequacy need.

The current RA methodology is flawed for evaluating CEV cases for several reasons. The CEV trajectory contemplates significant changes in system operations, system grid utilization, use of demand side resources and regional coordination so the current RA methodology understates CEV RA.

The CEV assumes: information, communication and system control technologies are deployed and used to the maximum extent possible; grid utilization increases substantially; system operations are changed significantly to facilitate use of demand side, DG, and renewable technologies to meet reliability requirements; and, regional coordination allows the West to be operated as if it were one west-wide balancing area by 2030. The CEV assumptions imply effective imbalance markets so regional and demand side resources that have not been counted as dependable reserves in the BAU methodology, should be counted in a CEV methodology. Furthermore, improved forecasting, improved regional coordination and real time controls imply that capacity values should be increased in a CEV RA test for some resources like wind.

Thus the current RA assessment methodology can be used as a sufficient condition for assessing CEV portfolios but it is not useful as a necessary condition. In other words, a CEV portfolio passing the current RA test implies resource adequacy, but failing the current test does not necessarily imply inadequacy. The table below thus indicates that the CEV Low Case is resource adequate in 2020 and 2030 and the CEV Base Case passes the RA test in 2020. The other CEV cases are below the current RA threshold and are thus inconclusive. Conclusive results require quantification of the contribution of all CEV resources toward meeting RA requirements.

Chapter Overview (continued)

A Sketch Resource Adequacy Comparison

			Total Nameplate Capacity	Capacity Available at Peak	Peak Demand + 15% Planning Reserve Margin	Capacity Margin
BAU	Base	**2020**	236,137	213,356	218,250	12.8%
		2030	319,820	289,634	287,614	15.7%
	High	**2020**	239,208	214,409	227,527	9.2%
		2030	327,175	292,369	311,405	8.9%
CEV	Low	**2020**	236,343	209,078	192,172	23.8%
		2030	251,077	212,118	211,244	15.4%
	Base	**2020**	273,120	222,317	213,524	19.1%
		2030	289,131	219,847	244,920	4.8%
	High	**2020**	291,099	228,972	215,552	21.2%
		2030	321,125	231,745	262,236	3.4%

While the WECC resource adequacy results are reported for the CEV portfolios, the results cannot be relied upon because they do not reflect the changes in system operations and market structures assumed for the CEV trajectory. The CEV large scale renewable energy portfolio in 2030 ranges from 235 and 490 billion kWh depending on demand growth, and thus some CEV futures have significantly more variable generation than the BAU futures. However, unlike the BAU trajectory, the CEV trajectory is assumed to address the challenge of variable generation by adding new reliability tools to the system operators' reliability tool box. The new tools require installation of state of the art information, communications and control technologies as well as changes in system operations and market structure. Along with these tools, customer sited resources, demand response resources and regional resources become available to help address resource deficiencies. As a result, the current resource adequacy test needs to be modified to account for the addition of these capacity resources and thus CEV resource adequacy results necessarily understate resource adequacy.

This chapter describes in more detail how sample renewable energy portfolios were constructed and presents capacity and energy portfolios by resource type for 2030.

As elsewhere in this report, this chapter makes use of WECC's work where possible. The WECC 2020 Base Case includes a portfolio of over 60 billion kWh of renewable resources operating or under construction (Tables 10 and 11) and 110 billion kWh of new renewable resources to be added between 2010 and 2020 so a total of about 170 billion kWh is included in this WECC case (Tables 12 and 13). The WECC Base Case portfolio is used as a starting point for building all other portfolios. Any incremental need for renewable resources beyond 172 billion kWh is met using the Western Renewable Energy Zones (WREZ) Peer Analysis Tool data.[51]

[51] Resources in the Peer Analysis Tool database do not include existing resources so there is no risk of double counting those resources. However, since resources in the Peer Tool are used to fill the incremental 109 billion kWh shown in the WECC Base Case in Table 10 below, we have taken care to ensure that any incremental resources we add to build portfolios do not double count these WECC Base Case resources.

BAU and CEV Portfolios for 2030: Two Examples

This section presents and compares 2030 portfolios for the BAU Base Case vs. CEV Low Case and the BAU Base Case vs. CEV Base Case to illustrate how renewable resource portfolios were built. Table 10 and Table 11 show current renewable energy facilities by location and renewable energy resource type. The tables indicate that 17,850 MW exist or are under construction and these facilities are expected to generate 63 billion kWh when they are all operational. Tables 11 and 12 show the state by state portfolios presented by the WECC to meet the 2020 Base Case scenario. The WECC Base Case portfolio includes 54,000 MW of renewable resources generating 170 billion kWh of electricity.

Table 5 in Chapter 5 shows the total quantity of renewable resources needed for the two BAU cases and the three CEV cases, so the difference between the renewable resource needs identified in these respective cases and the 170 billion kWh identified in Table 13 represents the amount of renewable resource energy that needs to be added using the WREZ Peer Tool to build the 2030 BAU Base Case and CEV Low Case portfolios.

With respect to the BAU Base Case, Table 5 shows that 200 billion kWh of renewable resources are needed in 2030.[52] Thus the net need beyond the 170 billion kWh identified in Table 13 is a portfolio of about 30 billion kWh. The proposed portfolio built using the WREZ Peer Tool is shown in Table 14 on a kWh and MW basis.[53]

With respect to the CEV Low Case, Table 5 shows that 150 billion kWh are needed in 2030 to meet the existing state renewable policy or RPS requirements and an additional 85 billion kWh is needed to meet the net need for low carbon resources. Thus the CEV Low Case total need for renewable energy is 235 billion kWh. Thus the portfolio needed to complement the WECC portfolio must include nearly 65 billion kWh (235 billion kWh less 170 billion kWh). Table 14 below shows the CEV Low Case portfolio built using the WREZ Peer Tool to meet this need.

Figure 26a compares the overall portfolios between the BAU Base and CEV Low cases on a MW basis. Large differences in coal, renewable energy, gas, CHP and DG are evident. Gas generation capacities assume the persistence of the gas capacity factor of 27 percent observed in the WECC 2020 Base Case. Figure 26b shows gas capacity required if new gas added had twice the capacity factor as what is observed in the WECC Base Case. The actual average capacity factor for new gas may be higher than 27 percent but certainly would not exceed 54 percent. Thus BAU gas capacity additions exceed 35,000 MW even with a high factor. Figure 27 shows the magnitude of the incremental differences in renewable energy nameplate capacities required by the two cases.

While 2030 CEV Low Case renewable resource additions exceed the BAU Base Case, the difference is not as large as one might expect. The reason the difference is relatively small is that net demand for electricity is far lower in the CEV Low Case due to large CEV investments in energy saving and distributed generation.

Figures 28a, 28b and 29 provide the same comparisons for the BAU Base and CEV Base cases.

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[52] The BAU renewable resource need in 2030 is calculated assuming the same percentage of renewable energy will be needed to fulfill statutes in 2030 as was needed in 2020. Since some States have standards that continue to grow beyond 2020, the actual statutorily required renewable energy requirement will be somewhat higher than the 17 percent required in 2020.

[53] The incremental resources selected were the most cost effective remaining resources on a west wide basis according to the Peer Tool. An attempt was made to select resources that were not already included in the 172 billion kWh of renewables included in the WECC PC0 Base Case.

Table 10: Megawatts - Existing and Under Construction

	Wind	Solar	Geothermal	Biomass	Small Hydro	Total MW
AZ-NM-NV	394	85	15	30	30	554
Basin	1,176	-	397	13	-	1,586
CA-NO	1,175	5	1,003	405	789	3,377
CA-SO	1,608	475	1,017	203	330	3,632
NWPP	4,821	-	-	290	233	5,344
RMPA	1,090	30	-	-	-	1,120
Total US	10,263	595	2,432	941	1,381	15,613
Canada	1,069	-	699	245	225	2,238
Total US/Canada	11,332	595	3,131	1,186	1,606	17,850

Table 11: Billions of kWh - Existing and Under Construction

	Wind	Solar	Geothermal	Biomass	Small Hydro	Total MWh
AZ-NM-NV	1.2	0.2	0.1	0.3	0.1	1.9
Basin	3.7	-	2.9	0.2	-	6.7
CA-NO	2.2	0.0	5.8	2.5	3.0	13.6
CA-SO	4.4	1.2	7.3	1.3	1.3	15.4
NWPP	10.3	-	-	1.9	1.2	13.4
RMPA	2.8	0.1	-	-	-	2.8
Total US	24.7	1.4	16.0	6.1	5.6	53.8
Canada	3.1	-	4.7	1.6	0.6	10.0
Total US/Canada	27.8	1.4	20.7	7.7	6.2	63.7

Table 12: Megawatts of Renewable Energy (WECC 2020 Base Scenario)

Capacity	Wind	Solar CSP0	Solar CSP6	Solar PV	Biomass	Geothermal	Small Hydro	Total
Washington	4,965	0	0	0	261	0	216	5,441
California	7,051	5,487	150	4736	976	3,167	1199	22,766
New Mexico	901	0	161	240	73	15	0	1,390
Arizona	204	0	485	1742	38	0	30	2,500
Alberta	3,969	0	0	0	337	0	30	4,336
Colorado	3,265	0	254	785	0	0	0	4,303
Idaho	523	0	0	0	94	37	258	911
Wyoming	1,758	0	0	0	0	0	28	1,786
Nevada	150	75	637	146	26	679	0	1,713
British Columbia	1,105	0	0	0	542	0	90	1,737
Mexico	260	0	0	0	0	806	0	1,066
Montana	842	0	0	0	0	0	13	855
Oregon	4,526	0	0	20	98	220	108	4,973
Utah	323	0	0	0	0	202	0	525
WECC Total	29,841	5,562	1,687	7,669	2,444	5,126	1,972	54,301

Table 13: Billions of kWh of Renewable Energy Generation (WECC 2020 Base Scenario)

Energy	Wind	Solar CSP0	Solar CSP6	Solar PV	Biomass	Geothermal	Small Hydro	Total
Washington	12.6	-	-	-	1.5	-	1.1	15.2
California	18.2	10.6	0.3	9.7	6.6	21.8	4.6	71.9
New Mexico	2.8	-	0.5	0.5	0.4	0.1	-	4.4
Arizona	0.5	-	1.6	3.6	0.3	-	0.0	6.1
Alberta	12.2	-	-	-	2.5	-	0.1	14.8
Colorado	8.7	-	0.8	1.3	-	-	-	10.8
Idaho	1.4	-	-	-	0.5	0.3	0.9	3.1
Wyoming	6.7	-	-	-	-	-	0.1	6.8
Nevada	0.3	0.1	2.1	0.3	0.2	5.0	-	8.0
British Columbia	2.8	-	-	-	3.2	-	0.4	6.4
Mexico	0.6	-	-	-	-	5.4	-	6.0
Montana	2.6	-	-	-	-	-	0.0	2.6
Oregon	11.0	-	-	0.0	0.6	1.6	0.5	13.8
Utah	0.9	-	-	-	-	1.5	-	2.4
WECC Total	81.3	10.8	5.3	15.5	15.9	35.7	7.9	172.4

Table 14: Additional 2030 Resources Needed by for the CEV Low and BAU Base

	Wind	Geothermal	Solar	Hydro	Biomass	Efficiency & DG
BAU Base Case						
Billion kWh	19	2	9	2	1	64
MW	6,817	220	4,010	545	176	
CEV Low Case						
Billion kWh	37	3	14	4	3	457
MW	13,421	433	7,895	1,073	347	

Figure 26a: BAU Base vs. CEV Low Portfolios in 2030 (MW)

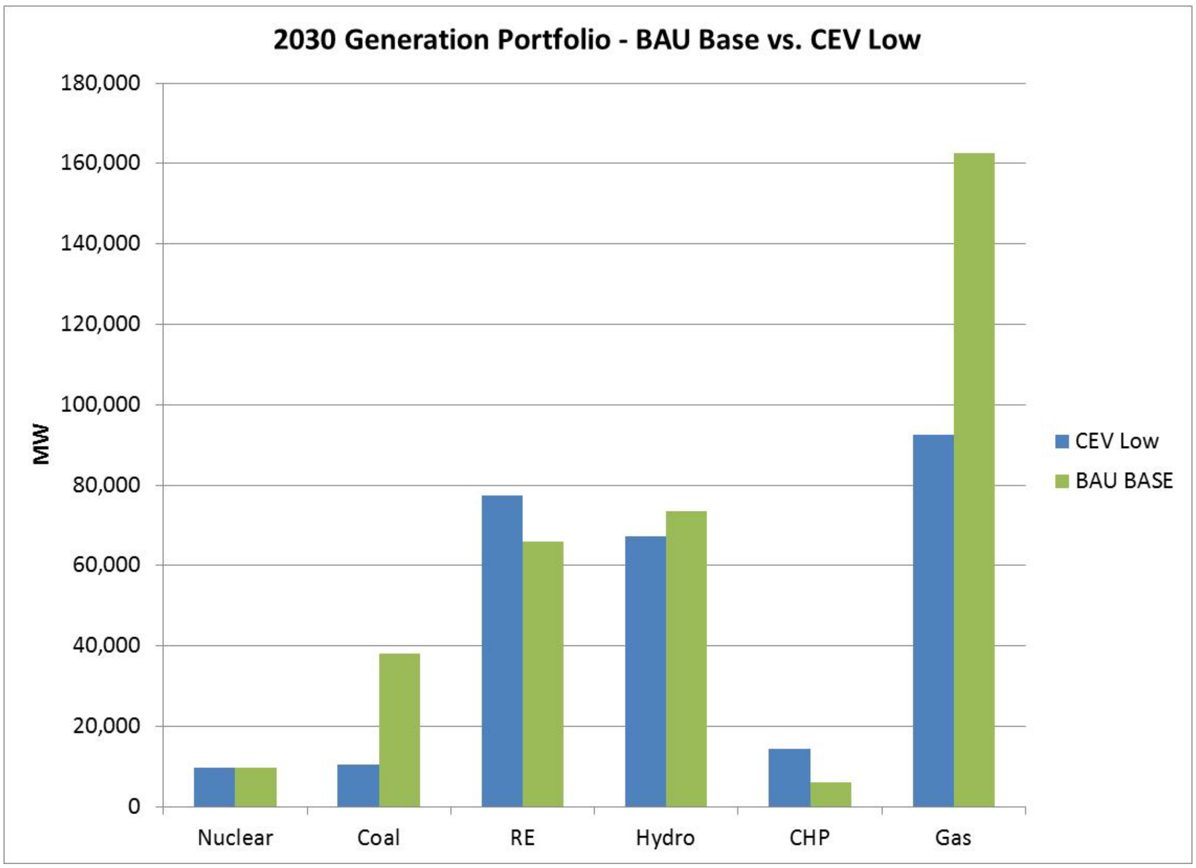


Figure 26b: BAU Gas Generation at Current and Double Capacity Factors (MW)

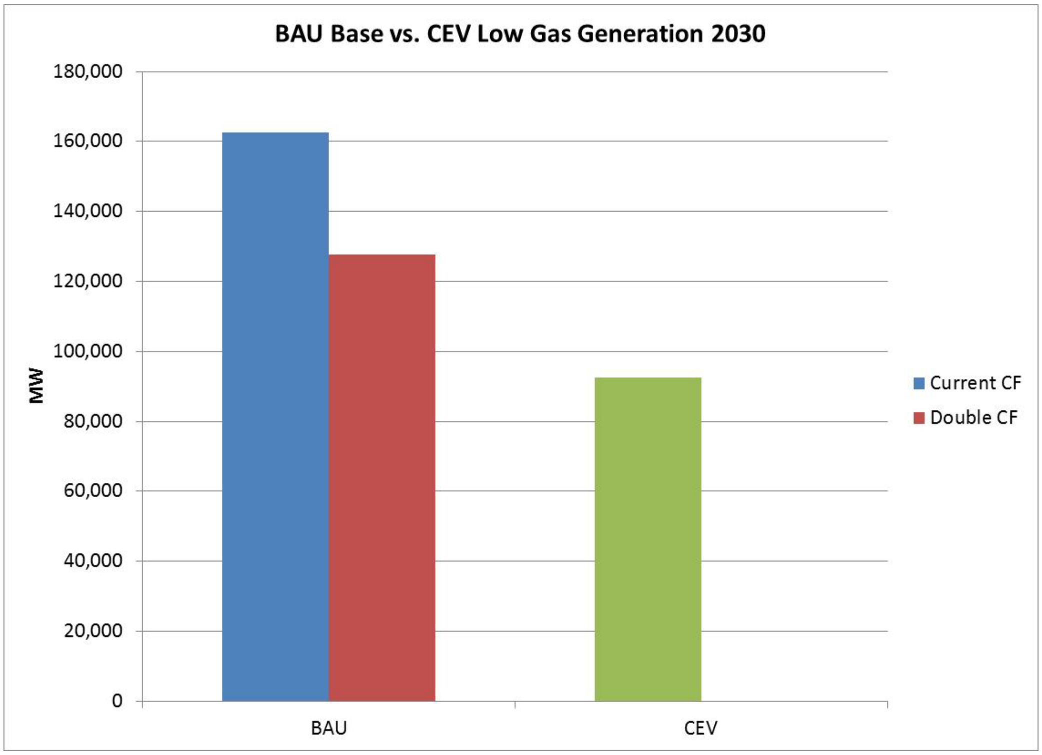


Figure 27: Large Scale Renewable Energy in 2030 BAU Base Case vs. CEV Low Case (MW)

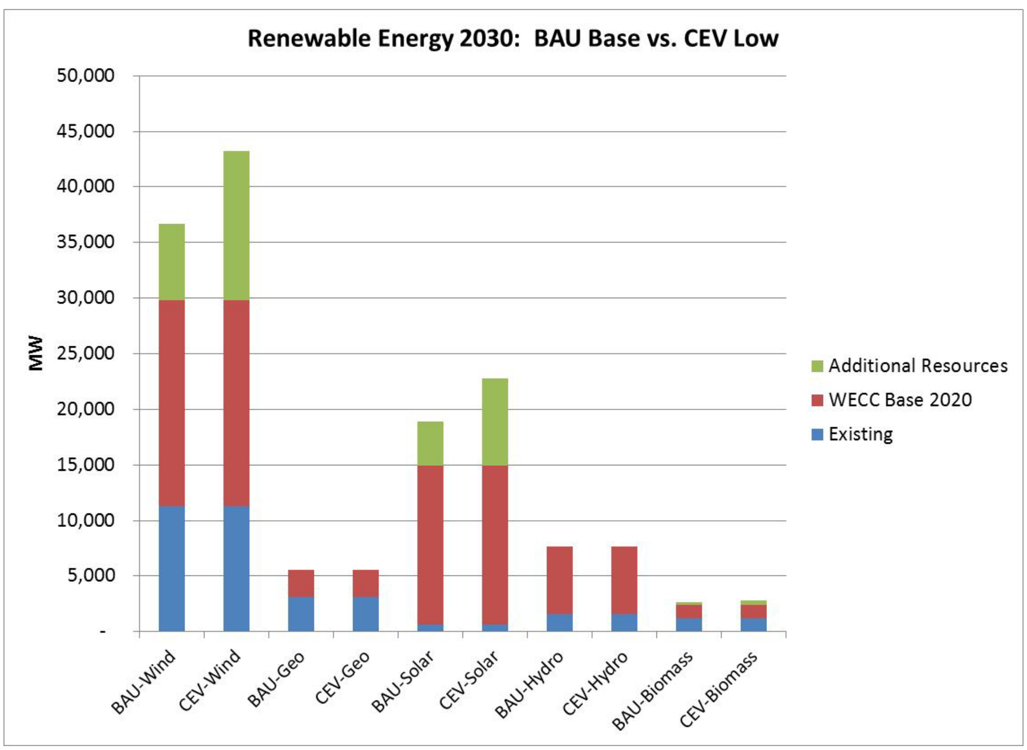


Figure 28a: BAU Base Case vs. CEV Base Case Portfolios in 2030 (MW)

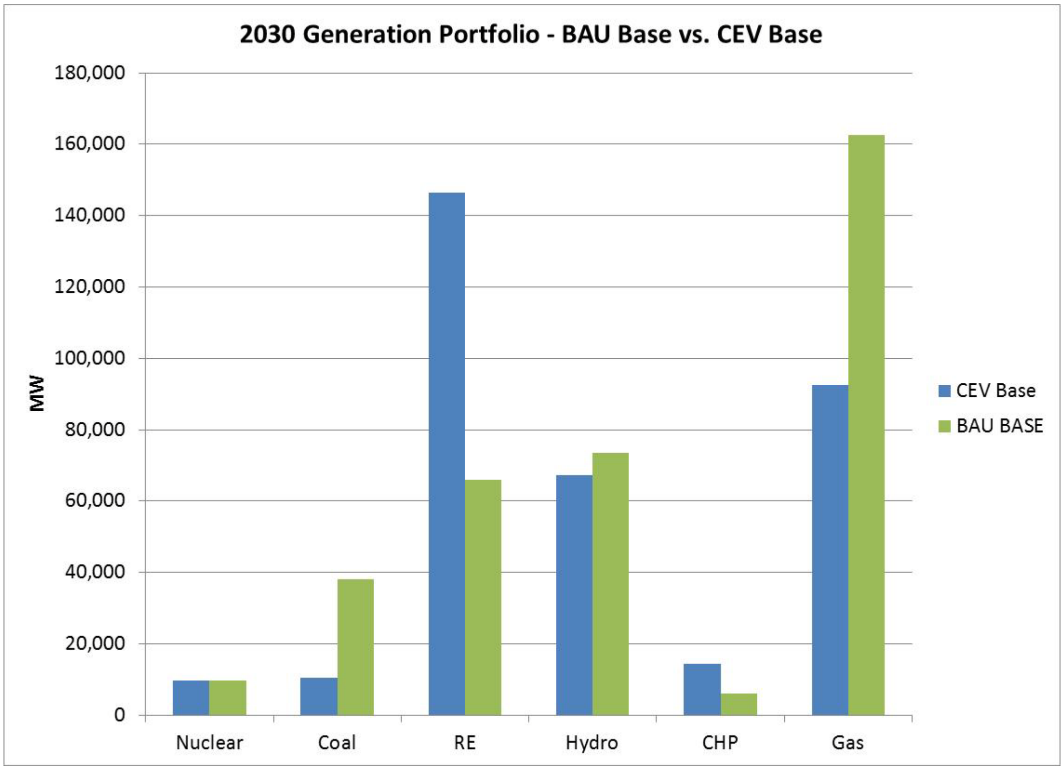


Figure 28b: BAU Gas Generation at Current and Double Capacity Factors (MW)

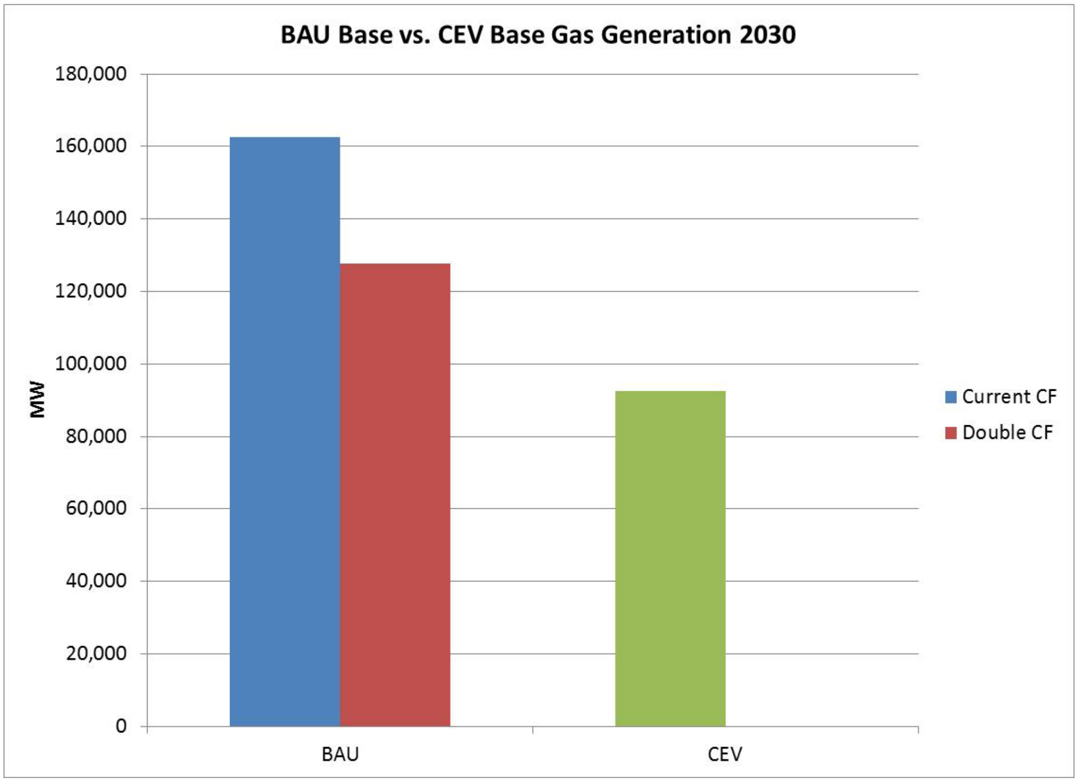
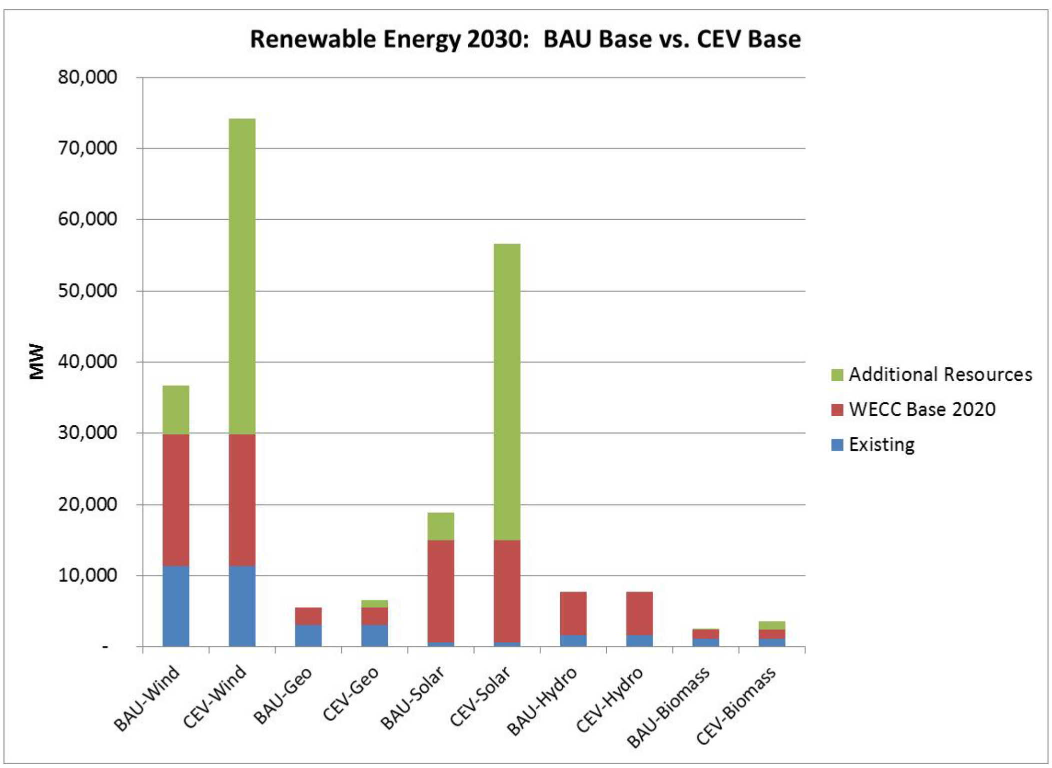


Figure 29: Large Scale Renewable Energy in 2030 BAU Base Case vs. CEV Base Case (MW)



Resource Adequacy Assessment: BAU vs. CEV

BAU Assessment is Straight Forward

The evaluation of the reliability of the BAU and CEV cases presented in this paper is resource adequacy. While resource adequacy is not sufficient for ensuring reliability, it is one test commonly used in industry and at WECC to assess the system's ability to protect reliability in a future time period.[54]

Assessing the resource adequacy of the BAU portfolios is straight forward because it is a simple application of the procedure used by WECC today. WECC uses the dependable capacity of resources to estimate available capacity at peak. The methodology and estimates of dependable capacity are based upon system operation assumptions that are reasonable for the BAU cases because the BAU cases assume that system operations, system grid utilization, use of demand side resources and regional coordination do not substantially improve from current practice. Since the current WECC resource adequacy methodology is predicated on business as usual grid practices, the current methodology can serve as both a necessary and a sufficient condition test of BAU portfolio resource adequacy.

CEV Assessment Using Current Methods is not Accurate

On the other hand, using the current resource adequacy assessment approach for the CEV cases is not appropriate. Assessing the resource adequacy of CEV cases is complicated by the fact that CEV cases assume significant changes in system operation. For example, CEV cases assume installation of advanced information, communications and control technology and implementation of operational practices that make optimal use of enhanced information, communication and control technologies. Recent work by NREL and others identify changes in western operation practices and coordination that can facilitate achieving reliability in aggressive renewable energy cases.[55] Some important changes that can facilitate meeting resource adequacy in CEV cases with less base load capacity include:

- Adoption of state of the art information systems and control technologies so that demand side resources can be used to meet capacity requirements;
- Improved coordination among balancing areas so that regional resources can be effectively used to support spinning reserve and sub-hourly reliability requirements;
- Improved planning and coordination among balancing areas to take advantage of regional and technological resource diversity;
- Improved forecasting to improve day ahead and hour ahead forecasts;
- Creating regional hourly and sub-hourly markets to facilitate use of regional resources to meet local resource needs;
- Replacement of retiring gas fired resources with more flexible gas fired resources; and,
- Modifying hydro power system and storage facilities dispatch to help meet reliability requirements.

With these changes, measuring resource adequacy in the CEV world will need to update peak demand forecasts and dependable capacity assessments to reflect the enhanced operational capabilities of the CEV systems. As a result, using the current resource adequacy approach for the CEV cases is akin to tying the hands of the CEV system operators behind their backs.

[54] More detailed reliability assessments that investigate local reliability conditions are beyond the scope of this paper.
[55] See the NREL Western Wind and Solar Integration Study (2010) for a specific list of recommendations on improving the system to meet reliability requirements 35 percent renewable energy on a west wide basis. Also see Gardner and Lehr, 2011, for a summary of operation and market structure issues regarding wind energy.

The next two sections explore the changes reflected in CEV system operations and market structure that should be assumed as one develops a methodology for assessing CEV resource adequacy.

CEV System Operational and Market Structure Policy Changes

System operation requires balancing of supply and demand for electricity and power plant dispatch to ensure reliability. The current western interconnection is balkanized among 38 Balancing Areas (BAs). The resources and power plants called on to run are determined largely by utilities (or other load serving entities) operating their own generation facilities and meeting any remaining need with bi-lateral contracts entered into between utility companies and with merchant generators, mostly on an individual service territory basis.[56]

This operational and market structure was developed under the assumption that large hydro, coal, nuclear and gas-fired plants would supply essentially all electricity and utility companies would own and operate their respective generation resources. The system as it currently exists was not designed to support large amounts of Variable Energy Resources (VER) such as solar and wind generation and it was not designed to use demand response and customer sited generation to meet reliability needs. The distribution system as it currently exists was not designed to accommodate large amounts of distributed generation resources. While these clean resources can be reliably integrated into our electric system, the western electric system as it is currently operated cannot effectively do so.

System Operations Policy Changes

Transitioning to an electric system that can effectively use VER, DG and demand response resources to ensure reliability will require a number of system operation changes.

The new operational mechanisms needed will minimize costs of balancing systems with large amounts of variable solar and wind power connected and will require the West to:

- Develop markets that clear on a 5-minute basis.
- Develop the Energy Imbalance Market being explored by WECC.
- Coordinate BA operations to share operating reserves and access to system flexibility on adjoining BAs.
- Use dynamic scheduling and pseudo-ties, to schedule variability of resources in one BA to another BA.
- Create incentives to encourage continuous improvement in weather forecasting for loads, for gas nominations and scheduling, and for use of state-of-the-art forecasting in operations decision-making and support systems to achieve efficient unit commitments as systems increase numbers and output of Variable Energy Resources.
- Eliminate penalties on Variable Energy Resources for over- and under-production relative to schedules, and allow VERs to net over- and under-production on a monthly basis.
- Coordinate Balancing Authority Areas (BAAs) across the West by consolidating them or “virtually consolidating” their operations to coordinate dispatch and system operation and to share operating reserves and system balancing requirements.

[56] Some load serving entities do not own generation and they rely on purchases from generators to meet all the needs of their customers.

- Develop policies to encourage use of demand resources to provide frequency regulation and create incentives for deployment of peak-shifting technologies.
- Implement programs for greater utilization of flexibility of existing gas-fired and hydro generation to provide system balancing.

Market Structure Policy Changes

Transitioning to an electric system that can effectively use VER, DG and demand response resources to ensure reliability will require a number of market structure changes.

The following market mechanisms will minimize costs of balancing systems with large amounts of variable solar and wind power connected and they include reforms to:

- Establish an Energy Imbalance Market: Encourage and support western utilities and BAAs to create and participate in an Energy Imbalance Market (EIM). A WECC-wide EIM will make greater use of existing transmission assets and reduce the cost of balancing the system.
- Implement state policies that support develop of a western regional market for renewable energy: A larger, more liquid market for clean energy will create more competition among suppliers, expand the pool of buyers, and reduce costs for consumers.
- Implement state policies that coordinate procurement among western power buyers: Such coordination will facilitate transmission development by matching the amount of renewable energy to be acquired each year to the capacity of transmission facilities being developed. Coordinated procurement can also help lay the foundation for development of a western regional market.
- Develop a market for ancillary services—the electrical functions that provide essential system balancing, storage and reliability services. Ancillary services are now mostly bundled with fossil generation. Clean, non-fossil resources have the potential to increase system flexibility and provide these services at lower cost. Markets that provide these services or clear and consistent payment policies covering ancillary services will enable them to be provided at lower cost.

A Sketch Resource Adequacy Test

This section presents sketch Resource Adequacy test results for the BAU and CEV cases under the assumption that none of the operations or market reforms suggested in the last two sections are implemented.

Reserve Margin Caveats

Before discussing these sketch results, it should be noted that the WECC methodology is criticized by some for asserting a planning reserve margin without adequate justification. Posited planning reserve margin requirements vary by sub-region of the WECC but they average about 15 percent. Some argue that 15 percent is much higher than necessary. Some claim that a loss of load probability analysis should be used to justify reserve margin values, and that a customer level willingness to pay for various service levels should be determined and provide the metric for system reliability. This could lead to study results that are specific to various customer and system circumstances which should determine the level of reliability customers want for standard service. Such analyses have not been done to date and it is conceivable that these analyses would indicate that 15 percent is too high.

Furthermore, the sketch resource adequacy assessment presented here follows WECC in not accounting for non-coincidence of peaks among sub-regions of the WECC. The peak demand values shown in Table

15 will be non-coincident peak values for each balancing area. Since peak consumption does not happen at the same time in different climate zones and different time zones in the West, the sum of the non-coincident peaks within and among sub-regions of the WECC certainly exceeds the WECC coincident peak. The amount by which the non-coincident peaks exceed any coincident peak is not provided in WECC data.

As WECC evolves toward an interconnection where greater functional coordination among balancing authorities and sub-regions move the WECC toward operating more like one coordinated balancing authority rather than 38 semi-autonomous balancing authorities, the coincident peak will become the regional target of significance. While local resource adequacy concerns will remain for some load pockets in the West, the evolution of WECC in the CEV future would be movement toward the use of all local and regional resources to ensure reliability in a coordinated fashion.

In addition, it should be noted that the capacity values at peak attributed to renewable resources were taken from the “Final Regional Gap” analysis developed by WECC’s Transmission Expansion Planning and Policy Committee (TEPPC) for the 2010 Study Cycle and these are also non-coincident values. There is disagreement among planners and stakeholders in the West regarding the proper capacity value should be deemed “dependable” and thus used to assess resource adequacy.

Presentation of Sketch Results

All of these caveats notwithstanding, resource adequacy of the BAU case and the CEV case can be compared by examining how each case meets capacity and energy targets. Resource additions were made to the BAU and CEV cases specifically to meet energy targets (recall Table 5) so both cases meet the energy targets.

A comparison of the capacity provided by each case is also necessary to determine resource adequacy. Table 15 below shows both the nameplate capacity for the resources assumed to be included in the cases to the capacity available from these resources at the time of peak.[57] These capacity values are then compared to a capacity level equal to the expected peak demand in the western interconnection plus a 15 percent planning reserve margin - the current average reserve margin in the western interconnection. The capacity margin column on the far right reflects the extent to which resource additions meet capacity targets.

The table shows that capacity margins below 15 percent exist for some of the BAU and CEV cases. The BAU results indicate that the energy portfolio for the BAU Base Case appears resource adequate but the energy portfolios for the BAU High Case is resource inadequate in 2020 and 2030. This means that the BAU High Case requires additional capacity resources to ensure resource adequacy.

The CEV Low Case exhibits reserve margins in excess of 15 percent in 2020 and 2030, and thus the CEV energy portfolios are clearly resource adequate. The CEV Base Case and High Case are resource adequate in 2020. In 2030, the CEV Base Case and CEV High Case energy portfolios fall below the 15 percent reserve margin threshold, but, as explained above this does not necessarily mean the CEV portfolios are capacity resource deficient.

The CEV assumes: information, communication and system control technologies are deployed and used to the maximum extent possible; grid utilization increases substantially; system operations are changed significantly to facilitate use of demand side, DG, and renewable technologies to meet reliability

[57] The capacity available at peak is called the “discounted capacity” and this calculation relies on the WECC discounted capacity values by resource type.

requirements; and, regional coordination allows the West to be operated as if it were one west-wide balancing area by 2030. The CEV assumptions imply effective imbalance markets so regional and demand side resources that have not been counted as dependable reserves in the BAU methodology, should be counted in a CEV methodology. Furthermore, improved forecasting, improved regional coordination and real time controls imply that capacity values should be increased in a CEV resource adequacy test for some resources like wind.

Recall that the balancing area peak demands are simply added up to derive a western peak demand. However, with the CEV system improvements peak demand of each balancing area will be reduced. Furthermore, the coincident peak demand in the West will be less than the sum of the 38 balancing area peak demands and, with the West operating as one balancing area, more regional resources will come available to address the coincident demand. As a result, the 2030 CEV Base Case and 2030 High Case results do not necessarily imply resource inadequacy.

Thus the current BAU resource adequacy assessment methodology can be used as a sufficient condition for assessing CEV portfolios but it is not useful as a necessary condition. In other words, a CEV portfolio passing the current RA test implies resource adequacy, but failing the current test does not necessarily

imply inadequacy. Determining CEV resource adequacy requires the development of a CEV methodology that captures the differences in CEV system operations.

Table 15: A Sketch Resource Adequacy Comparison

			Total Nameplate Capacity	Capacity Available at Peak	Peak Demand + 15% Planning Reserve Margin	Capacity Margin
BAU	Base	2020	236,137	213,356	218,250	12.8%
		2030	319,820	289,634	287,614	15.7%
	High	2020	239,208	214,409	227,527	9.2%
		2030	327,175	292,369	311,405	8.9%
CEV	Low	2020	236,343	209,078	192,172	23.8%
		2030	251,077	212,118	211,244	15.4%
	Base	2020	273,120	222,317	213,524	19.1%
		2030	289,131	219,847	244,920	4.8%
	High	2020	291,099	228,972	215,552	21.2%
		2030	321,125	231,745	262,236	3.4%

7. Comparing BAU and CEV Performance: Overview

BAU and CEV Investment Differences

The BAU and CEV trajectories meet energy and capacity needs with different resource portfolios. The BAU trajectories do not engage in significant demand reduction, continue to rely on significant amounts of conventional coal generation, rely on renewable energy only to the extent it is required by statute and meet incremental needs with new gas fired generation. The CEV trajectories reduce electricity consumption with energy saving efforts, reduce use of coal generation, and increase distributed resources and large scale renewable energy.

The resource portfolio differences between the BAU and CEV trajectories imply differences in grid infrastructure, operations and planning, and market structures. The CEV trajectory implies a different infrastructure: for example, a state-of-the-art information infrastructure is much more important and additional transmission to access high quality renewable resources is required. The CEV trajectory implies changes in grid operations and planning: advanced control systems and information systems are required to efficiently utilize distributed and regional resources to meet reliability targets and western regional planning is required to efficiently access remote, high quality renewables for regional benefit. The CEV trajectory also implies changes in market structures, including the business and regulatory models underlying grid development. These changes in market structures are needed because utility and non-utility electricity providers need proper incentives to induce private sector CEV investment and regulators face the challenge of designing regulation to properly align these incentives.

The BAU trajectory requires some transmission infrastructure additions, but operations and planning, and business and regulatory models can remain largely unchanged.

BAU Investment Follows Recent Trends

BAU trajectory is also predictable given its close alignment with recent performance. Recent load growth in the West has averaged about 2 percent per year since 1995 and peak demand growth has averaged about 2.5 percent per year.[58] The Western Electricity Coordinating Council (WECC) reports that as recently as 2006, 57 percent of electricity generation came from coal and natural gas generation, 30 percent from hydro electric generation, 8 percent from nuclear generation and about 4 percent from renewables. Furthermore, an examination of new generation installed in the WECC between 2000 and 2010 indicates that of the 78,000 Megawatts (MW) of capacity expansion, 54,000 were natural gas fired generation and about 3,000 MW were new coal facilities.

WECC projections of electricity demand and supply in the West over the coming decade from 2010 to 2020 show a persistence of BAU operation of the electric grid.[59] WECC information based on public utility resource plans for serving electricity needs in the West over the decade indicate that the growing need for electricity moderates slightly from the historical 2 percent growth per year to about 1.7 percent per year. While the percentage of fossil fueled generation moderates somewhat on a percentage basis, fossil generation grows from 500 billion kilowatt hours (kWh) of electricity supply to about 520 billion kWh. Renewable energy requirements in California and the West are projected to grow due to state statutory and policy mandates so that the renewable energy portion of demand

[58] WECC Electricity Transmission Primer, February 2010, is the basis for the numbers presented in this section.
[59] WECC PC0 (Base) Study Case results from the 2010 Study Plan are the basis for the discussion in the next two paragraphs.

becomes about 17 percent by 2020, but the combination of load growth and persistence of fossil generation produce carbon emissions for the electricity sector in 2020 that are somewhat higher than they were in 2010. Notably, coal fired generation is projected to increase from 280 billion kWh to 290 billion kWh in the WECC Base Case projection.

While BAU renewable generation increases substantially from 2010 to 2020 due to renewable energy requirements that require about 17 percent of energy needs to be met by renewable energy by 2020, continued reliance on fossil resources leads to carbon dioxide emissions growth from 365 MMT CO2 in 2010 to about 380 MMT in 2020.

Beyond 2020, the BAU cases show a western electricity sector that is characterized by relatively high load growth, relatively low demand reduction effort, relatively high growth in peak demand, relatively low demand response effort and continued dependence on coal and gas resources for electricity supply. The BAU cases assume that renewable energy is added to the point where minimum state statutes and policies are met and all residual demand is met by gas fired generation. The BAU cases and the national trends projected by the Department of Energy (DOE) are similar. Figure 30 below shows the national projection of fuel mix out to 2035.[60] West wide and nationwide this means that BAU cases and the DOE projection ensure that carbon dioxide emissions will grow as energy demand grows and thus the electricity sector will not contribute to carbon reduction but rather will produce additional carbon emissions.

CEV Investment Transitions to Clean Energy Resources

In contrast, the CEV trajectory reduces western electricity sector carbon emissions by reducing demand growth, transitioning away from coal fired generation and transitioning toward renewable energy sources of generation. The CEV trajectory also requires effort and investment to change the infrastructure, grid operations and planning and business and regulatory models underlying a CEV grid.

BAU and CEV Performance Differences

The remaining Chapters contrast the economic, environmental, energy security and public health performance of the BAU and CEV trajectories. The performance differences stem from direct effects resulting from the different investment priorities of the two trajectories as well as effects of investing in high and low carbon futures, respectively. For example, direct effects of investing in more distributed generation include costs (e.g., higher installation costs) and benefits (e.g., more jobs created per dollar invested). The induced climate change effect of investing in more low carbon resources include economic, environmental, energy security and climate change benefits of contributing to keeping carbon accumulation at levels that have reduced negative climate change impacts.

Chapters 8 through 11 present differences in economic, environmental, energy security, and public health performance in turn. Economic differences such as differences in jobs created and costs incurred are driven primarily by differences in portfolio composition but are also affected by other grid differences. Climate change impacts on the economic health of the West are also presented.

Environmental differences such as air quality, water supply quantity, land use, land productivity, species health are driven by the portfolio and infrastructure requirements differences. Climate change impacts on the environmental health of the West are also briefly explored.

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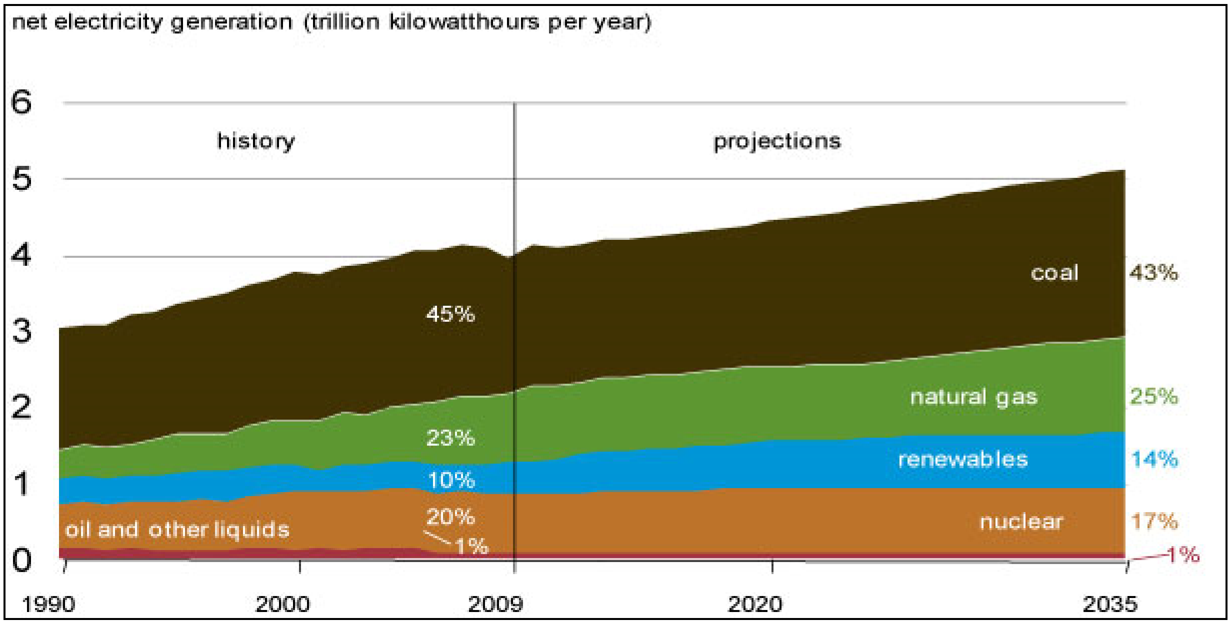
[60] DOE classifies large hydro production as renewable energy so much of the energy classified as renewable energy in the DOE figure is large hydro output.

Energy security differences such as exposure to fuel price volatility and fuel supply disruption, national competitiveness and access to diverse, distributed energy production. Climate change impacts on energy security are also introduced.

Public health differences include air quality, water quality and supply, adequate food supply, and climate change mitigation benefits.

Figure 30: US DOE 2035 Electricity Generation Resource Projection



DOE-EIA: Source: U.S. Energy Information Administration, *Annual Energy Outlook 2011, Early Release*, December 16, 2010.

8. Economic Performance

Introduction

The electricity sector has the potential to be an engine of economic growth in the West. More than 200 billion dollars will be invested in the sector over the next 20 years and these investments will support of millions of person years of employment.[61] However, BAU and CEV differences lead to CEV job creation advantages in excess of hundreds of thousands of person years of employment. BAU and CEV differences in job creation and other measures of economic performance differ for several reasons.

Chapter 8 Overview: Economic Performance

- **CEV Addresses Three Market Failures.** Economics teaches that accurate price signals and fair markets lead to highest value investment. The electricity sector is affected by externalities, public goods and market barriers so getting the highest value out of investment dollars right means recognizing the impact of these market imperfections. BAU does not address market failures, so BAU over-invests in high emitting resources and under-invests in electricity saving resources, customer sited resources and regional resources.
- **BAU and CEV Dollar Investment Differences.** The BAU and CEV trajectories invest in different portfolios and the net investment required by CEV portfolios is higher in most cases in 2030.
- **BAU and CEV Cost Differences.** While most CEV cases require more investment, the BAU portfolios are more expensive for consumers unless one assumes the cost of natural gas and the cost of carbon stay low for the foreseeable future. BAU portfolios have far more fossil generation and thus have higher operating and carbon costs. The CEV portfolios include projects with higher initial capital investment thus most CEV scenarios have higher fixed costs. CEV portfolios cost less unless natural gas prices stay stable and low. If one includes the costs of unpriced externalities, CEV portfolios are even less costly.
- **BAU and CEV Job Creation Differences**. Job creation differences between trajectories arise due to differences in investment portfolios, differences in import replacement, differences in electric service quality and cost, and differences in rates of innovation. Coal and gas generation create fewer jobs per kWh of generation than renewable generation and energy savings. Job creation in electricity using sectors will occur if quality of electric service per kWh spent is higher in CEV relative to BAU. Job creation due to innovation within the electric sector is likely to be greater in CEV relative to BAU.
- **BAU and CEV Risk Differences**. CEV represents a credible commitment by the West to carbon reduction and therefore represents an insurance policy that partially mitigates risks associated with climate change. The social cost of carbon ranges from $20 per ton to well over $100 per ton, depending on the severity of climate change outcomes. The CEV reduces the probability of higher social cost outcomes by creating a context for mutual commitment among regions and sectors for carbon emission reduction.

BAU and CEV Investment Differences

[61] Construction jobs are counted in annual Full Time Equivalent jobs.

BAU and CEV trajectory's respective efficacy in creating growth and jobs will depend on the trajectory's relative capacity to invest in the highest value projects. Economic theory teaches that maximizing social welfare requires that the competitive market get the prices of goods and services right. Failure to get the prices right causes investment dollars to flow into lower value projects and economic growth and job creation to suffer.

Getting prices right in the electricity sector means that three sources of market failure must be addressed. The three market imperfections are environmental externalities, public goods and market barriers. The first section of the chapter starts by comparing the relative capacity of the BAU and CEV trajectories to address these sources of market failure.

The section continues by using the BAU and CEV resource portfolios developed in Chapters 5 and 6 to estimate investment cost differences. Investment cost differences are then used to estimate cost of service. Annual fixed cost differences are based on first year revenue requirements and annual variable cost differences are based on fuel and carbon cost differences.[62] The section concludes by summarizing BAU and CEV cost differences.

BAU and CEV Job Differences

The second section addresses the BAU and CEV trajectory's relative capacity for creating jobs. The section begins by addressing how differences in investment portfolios yield differences in job creation.

Investment Creates Jobs

Electricity investment creates jobs: *direct jobs* for those who build and operate the capital; *indirect jobs* for those who work in electricity sector support industries; and, *induced jobs* for those who become employed as a result of the increased spending of those who became directly or indirectly employed.

The BAU and CEV trajectories require different portfolio investments and thus produce differences in direct, indirect and induced job creation. Fixed factors and results from other studies produce estimates of the direct, indirect and induced job impacts.

Improved Electric Service Creates Jobs

Since electricity is an important and often essential input to commercial and industrial activity, reliable, reasonably priced and secure electricity service affects western businesses ability to be profitable and compete in the global marketplace. In addition, lower cost of service for a given quality of electric service leaves money in consumer's pockets which increases customer disposable income and thus can be expected to increase consumer spending.[63]

The quality and cost of electricity service differs for the BAU and CEV trajectories, thus the electricity using agricultural, commercial and industrial sectors growth and job creation potential will also be affected by the electricity sector development trajectory. The difference in fixed and variable cost between the BAU and CEV trajectories is approximated and the relative cost impact of the trajectories on consumers is discussed. BAU and CEV quality of service differences are also discussed.

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[62] The first year revenue requirement gives an upper bound fixed cost estimate because fixed cost revenue requirements decline as assets depreciate.

[63] CGE and IO models sometimes allow for changes in the price or cost of electric service and include these impacts in the induced employment projections. However the price or cost differences are not always modeled and the quality of electric service is normally assumed to be held constant even if price or cost is modeled.

Electric Sector Innovation Creates Jobs

The electricity sector is also a potential source of innovation for the West and innovation is an economic engine in its own right. Innovation that causes reductions in the cost of technologies over time is sometimes included in CGE and IO modeling efforts. However, introduction of new generation technologies and effects of advanced information, communications and system control technologies on grid operations and efficiency constitute structural changes that are not adequately included in these models.

Technology cost reductions, introduction of new technologies and improvement in grid operations and efficiency can improve quality of service and reduce cost of service and thus can produce the benefits of improved electricity service discussed above. In addition, these technological advances constitute potential goods and services that the West can export. Finally, innovation in the electricity sector can spawn innovations outside the electric sector. All three of these potential innovation outcomes can produce economic growth and create jobs but they are difficult to quantify.

BAU and CEV Risk Differences

The BAU and CEV trajectories have very different carbon emission profiles and thus their respective effect on carbon accumulation and climate change is very different. As noted by Weitzman (2011), the economic consequences of climate change are potentially very costly and thus ensuring against these dramatic consequences is justified. People may disagree on the probability that climate change will lead to dramatic, negative consequences but even if one believes the costly impacts have a low probability of occurring Weitzman argues that insuring against the risk is necessary. Failure to insure against plausible high impact, negative events has negative economic consequences.

The final section of the chapter discusses the relative value of the BAU and CEV alternatives as insurance policies. The western electricity sector is caught in a prisoners' dilemma with every other geographic region and economic sector that puts individual incentive to burn more fossil fuel at odds with the common good of reducing global emissions. It is hard to imagine a global policy strategy that could succeed in limiting carbon accumulation that does not include each region and each sector committing to do their fair share in reducing their own carbon emissions.

The BAU cases do not include a commitment to reduce carbon emissions and thus climate change impacts reflect a failure locally and globally to reach a cooperative agreement to limit carbon accumulation.

The CEV cases reflect an electricity sector in the West that commits to do its fair share to reduce carbon emissions. Commitment to do one's fair share can transform the single period prisoners' dilemma problem into a repeated game where mutual commitment verified over time can lead to cooperative outcomes that lead to mutually beneficial carbon reduction.

Methodology for Evaluating Differences

This chapter describes how the electricity sector trajectory affects investment, electricity cost, and job creation. Several studies completed to date use computable general equilibrium (CGE) or input-output (IO) models to produce job estimates. While these modeling efforts have value, they include many simplifying assumptions that preclude certain BAU and CEV differences from being modeled. In addition, CGE and IO models include assumptions that are adequate for near term results five to ten years out but are not adequate for modeling results 20 to 40 years into the future where significant structural change will occur. In addition, the complexity of CGE and IO models means that some assumptions are hidden and thus transparency is a problem.

To understand the difficulty of using CGE or IO models to evaluate situations with significant structural change, consider the usefulness of using CGE or IO models in 1990 to examine the economics of the telecommunications sector in 2011. The models would not have captured the structural changes of transforming telecommunications from a market with no cell phones and predominantly monopoly carriers to the telecommunications market we have today. Thus the most interesting economic implications of the transformation of telecommunications would be absent or incorrectly specified.

CGE and IO modeling efforts are useful for tracing out some consequences of investment differences so work performed by others is referenced in this analysis. However, the focus of this analysis is to provide qualitative and quantitative comparisons that highlight the most important BAU and CEV differences.

The approach taken in this chapter is to present the key drivers that affect economic performance and job creation without relying on complex models. The chapter first quantifies investment cost and cost of service differences between the BAU and CEV trajectories. The chapter next identifies four sources of job creation and presents a quantitative and qualitative analysis of the relative job creation performance of BAU and CEV trajectories based on these four sources of job creation.

This approach is transparent and simple thus facilitating discussion among stakeholders regarding basic assumptions. In addition, by using this approach, three important job creation effects inadequately addressed in CGE and IO models (innovation, structural change and insurance against high impact long term risks) can be addressed.

BAU and CEV Investment Differences

Consequences of Failing to Correct Market Failures

The electric sector is affected by externalities, public goods and market barriers. Each of these factors cause market failure and require regulation to correct. Market failures cause price distortions, institutional problems and market impediments and each of these consequences impose costs on investors and consumers and limit job creation.

Externalities

An externality arises when the private costs or benefits to the producers or purchasers of a good or service differs from the total social costs or benefits entailed in its production and consumption. The electricity sector produces external effects, such as carbon, sulfur dioxide (SO_2), nitrogen oxide (NOx), mercury and particulate emissions. The cost of each of these externalities is not fully reflected in the cost of electric service and thus prices of electricity produced from fossil generation are typically below the true price because fossil generation externalities are higher than renewable energy generation externalities.[64]

Global climate change is one consequence of the failure to address external costs. Climate change is largely the result of market failures, namely those involving externalities and public goods. In the case of climate change, those who emit CO_2 into the atmosphere impose global costs (and some benefits) on

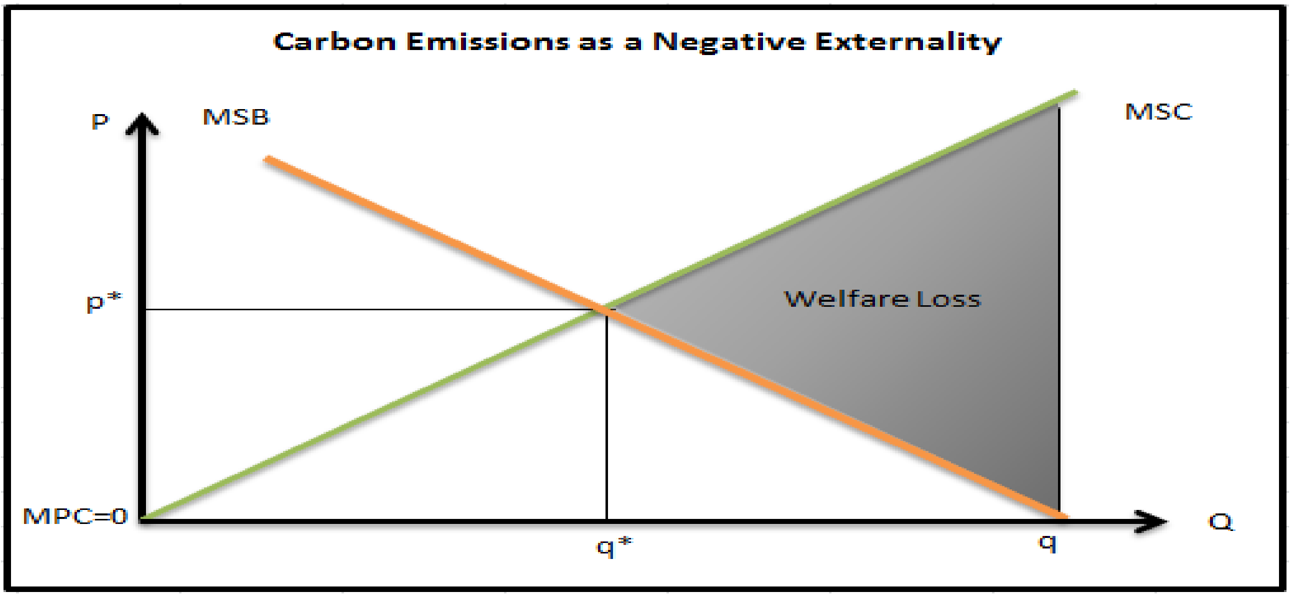
[64] IPCC (2011), p. 161, reports, “RE sources and the technologies using them for electricity generation have mostly lower external costs per produced electricity than fossil fuel-based technologies. However, case-specific considerations are needed as there can also be exceptions.”

current and future generations. Markets are concerned with private not social costs, so those who emit are not financially liable for the damages caused by their actions. They face no incentive to alter their behavior.

As a result, emissions continue to increase past the socially optimal level until the marginal social benefit (MSB) of another unit of emissions is equal to 0. This generates a welfare loss in the global economy, as evidenced in Figure 30.

If the true costs of carbon are taken into account and borne by the emitters, the quantity of emissions decreases to the socially optimal level (q*), and the price increases to the socially optimal price of carbon (p*).

Figure 30: Carbon Emissions as a Negative Externality



A Department of Energy (DOE) Interagency Working Group declared in 2010 that the social costs of carbon in 2010 should be assumed to be $21 per ton. Coal fired generation emits slightly less than one ton of carbon per MWh and gas fired generation emits slightly less than ½ of one ton for each MWh. So the cost of coal fired generation is about $20 per MWh too low and gas fired generation is about $10 per MWh too low if one accepts a $21 per ton carbon price.

However, others do not agree that the $21 per ton is representative of the social costs of carbon. Ackerman and Stanton with the Stockholm Institute recently showed that using the same modeling framework as DOE but varying assumptions in accordance with a range of climate science opinions yields 2010 estimates that range from $28 to $893 per ton.[65]

Failure to capture the full cost of other emission sources in high emitting generation sources further compounds the price distortion problem.

The BAU portfolios are built under the assumption that the full costs of externalities will continue to be ignored and thus BAU portfolios will over-invest in high emitting generation sources and under-invest in low emitting resources by definition. Thus BAU investment does not reflect actual prices, resource misallocation results and economic performance suffers as a result.

[65] Ackerman and Stanton. 2011. Climate Risks and Carbon Prices: Revising the Social Cost of Carbon.

Public Goods

In addition to under-pricing carbon emissions, the market fails to generate the correct price for and quantity of emissions abatement efforts/policies. This is because emissions abatement is a public good. Access to the benefits it generates cannot be restricted to those who pay, and one person's use of it does not impact on any other individual's ability to benefit from it. In the absence of intervention, the market does not provide the optimal quantity of emissions abatement. Additionally, there is little incentive for private investors to do so because they can free-ride on the investments of others.

Thus investment in carbon abatement is a prisoners' dilemma problem where each emitter has an incentive to under-invest in abatement even though it would be in the mutual benefit of all emitters to do their respective part.

Game theory demonstrates that a prisoners' dilemma can be overcome with commitment. The under-investment in abatement at a point in time is a single period prisoners' dilemma and as long as carbon emitters look at the problem as a short term, single period decision, under-investment will continue. However, if the climate game can be transformed into one where emitters perceive the repeated interaction, long term nature of the problem, then the problem can be overcome with commitment strategies. For example, if emitters commit to reduced emissions and if the compliance with the commitment can be verified then the prisoners' dilemma can be overcome.

The CEV is thus the statement of the West's commitment to reduce carbon emissions in the electricity sector. The implementation of the CEV can be verified so it is a credible commitment. While the West acting alone cannot solve the carbon accumulation problem, the West can do its part to transform the climate game by making a credible commitment to carbon reduction.

Conversely, BAU approaches indicate the West's failure to commit to long term carbon emission reduction and thus BAU approaches do not open the door to mutual commitment strategies.

Market Barriers

The other market failure that affects investment choices in the western electricity sector is the presence of market power. Public utilities are natural monopolies and utility regulation was implemented to mitigate market power. However, well-intentioned local and state regulatory efforts have led to artificial barriers that limit regional exchanges of electricity and ancillary services. These artificial barriers distort electricity prices, making the value of locally produced electricity look less expensive than regionally produced electricity. Regulatory policies reinforce the utility's incentive to perpetuate market barriers if utilities are not required to compare customer side of the meter solutions and regional solutions with local utility build solutions for meeting electricity needs. The consequence of these artificial barriers is another distortion in prices that impedes the flow of investment dollars to the least cost, highest social value investments.

The vitality of economic growth and job creation in the electric sector depend on capital being invested in the highest value projects, and accurate identification of highest value projects requires that market failures be corrected. Evaluating the cost differences between BAU and CEV portfolios is a useful exercise that tells part of the story about the relative job creation potential of BAU and CEV trajectories. A sketch comparison of the impacts of these cost differences will be provided in the next section. However, another significant difference between the trajectories that should not be ignored is that the CEV trajectory corrects market failure and gets the prices right, while the BAU trajectory does not correct the market failures.

Economic theory indicates that failing to get prices right and allowing barriers to persist causes investment dollars flow to less valuable projects and thus some investment dollars are wasted.

The CEV trajectory gets prices right, addresses the public good problem and overcomes market barriers. The BAU trajectory gets the prices wrong, fails to commit to long term carbon reduction and allows market barriers to persist. The consequence of these differences is that the BAU trajectory spends investment capital on lower value projects and fails to protect consumers by failing to overcome market barriers.

Investment Cost Differences

Overview

The BAU trajectory requires significant investment in coal plant retrofits and coal plant replacements. About 1/3 of the coal fleet in operation today requires environmental control retrofits in the next 10 years and about 50 percent of the fleet would be more than 50 years old in 2030 if it were still operating. BAU also invests heavily in new natural gas generation to meet incremental needs. The gas facilities expansion will require accompanying investment in natural gas system infrastructure. This analysis does not quantify the electric transmission and gas infrastructure requirements caused by new gas generation because a model that completely characterizes the location of gas generation would be needed and that specification is beyond the scope of this project. A complete analysis of the BAU trajectory would include these investment costs.

The CEV invests more heavily in demand reduction, distributed generation and large scale renewable energy. All investment costs are estimated except the potential costs associated with distribution system upgrades caused by high DG penetrations. A complete investment cost estimate should include these distribution system cost upgrades but unbiased information on the upgrade cost is not currently available.

Generation Investment Differences

Investment comparisons will focus on investment cost differences between the BAU and CEV generation portfolios. Two 2030 comparisons will be presented: a comparison of the BAU Base Case to the CEV Low Case and a comparison of the BAU Base Case to the CEV Base Case.

Table 16 shows the generation capital investment differences between the BAU Base Case and the CEV Low Case. The MW quantities were taken from Tables 6 and 7, and the costs per MW are referenced in the table by technology. All dollar values are rounded to the nearest $10 billion, unless they are under $10 billion. The BAU Case includes $160 to 290 billion more coal and gas generation investment and the CEV case includes $129 billion more CHP, renewable energy and DG investment. Therefore, the BAU Base Case requires between $31 and $161 billion more investment in generation than the CEV Low Case. The large difference is primarily due to the fact that the level of demand in the CEV Low Case is far below the BAU Base Case.

The range of coal plant replacement costs reflects a low end where all coal is assumed to be conventional and a high end where all coal is assumed to be carbon sequestration ready. Since safe, effective carbon sequestration has not been proven at the scale of typical coal power plants, the high end of the range is termed “carbon sequestration ready” because there is no proof that being ready will imply effective capture and sequestration.

The relatively small differences in renewable energy generation between the two cases is driven by the fact that renewable standard requirements are high enough that relatively few additional central station renewable facilities are required if energy saving and DG efforts are highly effective.

The large investment in DG is sensitive to assumptions about the timing and cost reduction assumptions in DG between 2010 and 2030. The assumption made to produce the investment cost difference shown is that DG will be steadily deployed between 2010 and 2030 and the cost trajectory will decline linearly from $5.90 per Watt in 2011 to $2 per Watt in 2030. If DG drops to $2 per watt more quickly and if all DG investment happened at $2 per watt then the DG cost difference would decline from $84 billion to $48 billion.

Table 16: Itemized Net BAU Base Case 2030 Investment Cost Relative to the CEV Low Case

	BAU (MW)	CEV (MW)	BAU – CEV (MW)	Net BAU Cost (Billions of $)
Coal	38,000	10,467	27,533	$90-200[66]
Gas	162,672	92,479	70,193	$90[67]
CHP	5,936	14,460	-8,524	-$20[68]
Wind	36,657	43,261	-6,604	-$10[69]
Geo	5,346	5,559	-213	-1[70]
Solar CSP	9,449	11,392	-1,943	-$8[71]
Solar PV	9,449	11,392	-1,943	-$6[72]
DG	4,000	28,000	-24,000	-84[73]

Table 17 shows the generation capital investment differences for the BAU Base Case versus the CEV Base Case. The BAU Base Case incremental investment in coal and gas generation is $180 to 290 billion and the CEV Base Case incremental investment is about $240 billion. The CEV Base Case requires $80 billion more investment than the BAU Base Case if conventional coal generation is assumed and $30 billion less if carbon sequestration ready coal generation is assumed.

[66] $16 Billion for retrofits to address Flue Gas Desulphurization (FGD), Selective Catalytic Reduction (SCR), Activated Carbon Injection (ACI) (to address Hg), and bag houses to control excess particulate emissions (PM). 20,000 MW of coal plant that will be 50 years old by 2030 is replaced at the cost reflected in the WECC pro forma. The range reflects the E3 recommended cost for conventional coal of $3,750 as the low end and the E3 cost of sequestration ready coal at $9,000.
[67] Gas capacity assumed to be 1/3 CT and 2/3 CCGT, with costs taken from WECC pro forma at 1,100 and 1,300 per kW, respectively.
[68] CHP capital cost taken from WECC pro forma tool, and applied assuming 75% of capacity is > 5 MW ($1,600/kW), and 25% is < 5 MW ($3,700/kW).
[69] The DOE 20% Wind Energy by 2030 report, Table B-10 shows capital cost declining from 2010 to 2030 from $1,650/kW to $1,480/kW. We assume the average of these costs, or $1,565/kW under the assumption that wind will be added uniformly over the period.
[70] The WECC E3 Pro Forma shows geothermal cost at $5,500/kW.
[71] The DOE 2030 Solar Vision Draft Study has CSP capital cost declining from $4,900/kW in 2010 to $3,000/kW in 2030, so an average of $3,950/kW was chosen.
[72] The DOE 2030 Solar Vision Draft Study has Utility Scale PV declining from $4,060/kW to $1,900/kW in 2030, so an average of $2,980/kW was chosen.
[73] The DOE 2030 Solar Vision Draft shows PV Residential and Commercial ranging from $5.90/W to $2.00/W between 2010 and 2030, so an average of $3.50/W was selected.

Table 17: Itemized Net BAU Investment Cost in 2030 Relative to the CEV Base Case

	BAU (MW)	CEV (MW)	BAU – CEV (MW)	Net BAU Cost (Billions of $)
Coal	38,000	10,467	27,533	$90-200
Gas	162,672	92,479	70,193	$90
CHP	5,936	14,460	-8,524	-$20
Wind	36,657	74,150	-37,493	-$59
Solar CSP	9,449	20,477	-11,028	-$44
Solar PV	9,449	36,102	-26,653	-$79
DG	4,000	14,000	-10,000	-$35

Investment in Energy Saving

The CEV Cases devote far more resources to energy saving than the BAU Base Case, and the quantity of that investment difference is important.

McKinsey reports that the investment required to implement all cost effective energy efficiency in the nation to achieve 23 percent savings by 2020 is $464 Billion with the West representing 18 percent of the national total, or about $84 billion. Since the CEV Base Case achieves 19 percent efficiency by 2030, it is reasonable to apply McKinsey's figures to estimate that about $65 billion of energy saving investment would be required.[74] Since the CEV Low Case achieves 31 percent reduction by 2030, a proportional adjustment to the investment estimate yields $115 billion.

Therefore, the CEV Base and Low Cases would require about $65 billion and $115 billion of additional energy saving investment by 2030 relative to the BAU Base Case.

Investment in Electricity Transmission

The BAU Base Case and CEV Low Case require significant and similar investment in electricity transmission and distribution facilities to access remote renewable resources. Accessing the most likely resource development zones to fill the need for these cases would cost about $20 billion over the next twenty years.[75] The CEV Base Case requires significantly more renewable energy generation and the estimated cost of accessing the Base Case resources is $38 billion. Therefore, the CEV Base Case includes an incremental transmission investment of $18 billion.

Other Investment Differences

The BAU Base Case requires transmission to access gas generation facilities and gas distribution facilities. The location of gas plant expansion is beyond the scope of this study so a specific investment of additional transmission cost to access incremental gas generation is not estimated. However, the amount of additional gas generation required by the BAU Base Case is significant, at more than 70,000 MW so the transmission cost associated with this incremental gas generation is also significant. The gas transmission and distribution system expansion required to serve the additional gas generation also represents a significant BAU Base Case cost not captured here.

[74] 19/23 of $84 billion is about $65 billion, and 31/23 of 84 billion is about $113 billion.

[75] The transmission estimates required to build to meet renewable resource needs are described in Chapter 9 in the context of land use requirements.

Investment costs associated with implementing the CEV not explicitly captured here include investing in the information and communications infrastructure and improving the distribution system to accommodate high penetrations of DG. The incremental cost associated with transmission and information, communications and control infrastructure are assumed to be the costs of integrating variable generation resources. The transmission portion of this cost is quantified. The incremental information, communications and control systems investment is not quantified here but should be included in a complete analysis of comparative costs.

It is highly uncertain how much incremental investment in information, communications and control systems investment would be required by the CEV cases and it is beyond the scope of this paper to estimate those costs. It is also unclear how much investment in local distribution systems might be required as customer sited distributed generation achieves much higher penetration rates. Updates to this study should consider these potential distribution system costs.

Summary of Investment Cost Differences

Table 18 summarizes the investment differences between the BAU Base Case and the CEV Low Case. The BAU Base Case requires a net incremental investment over the CEV Low Case of $46 billion by 2030 for those factors that are quantified if carbon sequestration ready coal is assumed, and the CEV Low Case costs $64 billion more than BAU Base if conventional coal is assumed.

Table 19 summarizes the investment differences between the BAU Base Case and the CEV Base Case. The CEV Base Case requires a net incremental investment of $33 to $143 billion by 2030, depending on whether carbon sequestration ready technology is installed.

The tables also present “other factors requiring investment,” but do not attempt to quantify these other factors. Future work should investigate these potential impacts.

Table 18: Summary of BAU Base Case 2030 Investment Cost relative to the CEV Low Case (Billions of Dollars)

	BAU Base Case	**CEV Low Case**	**BAU Net Cost**
Generation	$180 to 290	$129	$51 to 161
Transmission	$20	$20	0
Energy Savings	0	$115	$-115
Net Investment	$200 to 310	$264	$-64 to 46
Other Factors Requiring Investment	Electric Trans for Gas Generation; Gas Delivery Infrastructure	Info/Control systems; Electric Distribution System Improvement	

Table 19: Summary of BAU Base Case 2030 Investment Cost Relative to CEV Base Case (Billions of Dollars)

	BAU Base Case	**CEV Base Case**	**BAU Base Net Cost**
Generation	$180 to 290	$240	$-60 to +50
Transmission	$20	$38	$-18
Energy Savings	0	$65	$-65
Net Investment	$200 to 310	$343	$-33 to -143
Other Factors Requiring Investment	Trans for Gas Generation; Gas Delivery Infrastructure	Info/Control systems; Electric Distribution System	

		Improvement	

Cost of Service Differences

The initial investment required by the CEV cases is larger than the investment required to continue BAU delivery of electricity if BAU coal plant replacements are not built to be CCS ready. Any extra investment will manifest itself in electricity rates as the infrastructure is made operational. The operating costs of continuing BAU include fossil fuel and carbon cost premiums and these premiums also show up in rates in the near term, but more significantly, the uncertainty over the magnitude of fuel costs in the future introduces long term risk for future consumers.

Annual Revenue Requirement Differences

One way to quantify the annual cost of electricity capital investment is to assume investment is made by utilities and to calculate a first year revenue requirement. A typical fixed charge rate for utility capital investment is about 16 cents per dollar of investment if capital lasts 30 years and 17.5 cents per dollar of investment if capital lasts 20 years.[76] Table 20 below shows the first year revenue requirement for capital investments assuming BAU investments last about 30 years on average and CEV investments last 20 years on average as suggested by the WECC E3 Pro Forma. These represents an upper bound fixed cost differences on the annual fixed charge cost to consumers for utility sponsored projects.[77]

Table 20: BAU Base Case First Year Revenue Requirement Relative to CEV Low and Base Cases (Billions of Dollars per Year)

	Net Investment	First Year Revenue Requirement
Net Cost of BAU Base Case vs. CEV Low Case	$-64 to 46 billion	$-14.2 to +3.4 billion
Net Cost of BAU Base Case vs. CEV Base Case	$-33 to -143 billion	$-10.4 to – 28 billion

The results presented in Table 20 indicate that the BAU Base Case annual fixed cost relative to CEV annual fixed costs ranges from 3.4 billion more expensive to 28 billion less expensive.

Fuel and Carbon Cost Differences

The BAU Base Case in 2030 produces 220 billion kWh more gas generation and 200 billion kWh more coal generation than the CEV Base Case. This means that BAU operating cost will be higher than CEV operating cost because fuel costs will be higher and carbon costs will be higher. Tables 21 and 22 show annual fuel cost increment for several prices for delivered natural gas and coal.[78]

[76] 17.5 cents per dollar of investment is consistent with 50 percent equity/50 percent debt capital structure with cost of debt at about 8 percent, cost of equity at 12 percent, state and federal tax on equity at 40 percent and depreciation rate of 5 percent. The cost to consumers decreases with investment tax credits, so the 17.5 cent example is a proxy for a case where tax credits do not persist. 16 cents results if the depreciation rate is 3.5 percent rather than 5 percent.
[77] First year costs are highest because as the investment depreciates the net investment declines and the fixed charge rate is applied to the net investment.
[78] The gas generation heat rate is assumed to average 8,000 for these calculations, and the coal generation heat rate is assumed to average 10,000.

Table 21: BAU Base Case 2030 Gas Cost Premium Relative to the CEV Low and Base Cases (Billions of Dollars per Year)

Gas Price ->	$4 per MMBTU	$8 per MMBTU	$12 per MMBTU
BAU has about 220 Billion kWh more gas generation per year than CEV Cases	$7	$14.1	$21.1

Table 22: BAU Base Case 2030 Coal Cost Premium Relative to the CEV Low and Base Cases (Billions of Dollars per Year)

Coal Price ->	$1.60 per MMBTU	$2.00 per MMBTU	$2.40 per MMBTU
BAU has about 200 Billion kWh more coal generation per year	$3.2	$4	$4.8

In addition to fuel costs, carbon costs are a possible cost of fossil generation that will materialize if carbon trading or taxation is implemented in the West. Table 22 below shows the amount of carbon expense associated with carbon cost of $20, $40 and $60 per ton.[79]

Table 23: BAU Base Case 2030 Carbon Cost Premium Extra Carbon Costs (Billions of Dollars per Year)

Carbon Cost ->	$20 per ton	$40 per ton	$60 per ton
Annual Cost of 220 TWh of Gas Generation	$1.9	$3. 8	$5.7
Annual Cost of 200 TWh of Coal Generation	$3.8	$7.5	$11.3

The additional annual fuel and carbon costs of the BAU Base Case therefore range from about $16 billion per year to $43 billion per year.

Combined Fixed Charge and Operating Cost Impacts on Consumers

Combining fixed and operating costs results yields Table 24 below.

Table 24: BAU Total Net Cost per Year Relative to CEV Low and Base Cases in 2030 (Billions of Dollars per Year)

	Operating Cost Difference Range	Fixed Charge Cost Difference Range	Combined Cost Difference Range
Net Cost of BAU Base Case vs. CEV Low Case	$+16 to +43	$-14.2 to +3.4	$+1.8 to +46.4
Net Cost of BAU Base Case vs. CEV Base Case	$+16 to +43	$-10.4 to -28	$-12 to +15

[79] The calculations assume 0.91 tons of carbon emission per MWh of coal generation and 0.43 tons of carbon emission per MWh of gas generation.

BAU

The annual cost of BAU is larger for the entire range of possibilities contemplated for the CEV Low Case and the BAU Base Case is larger for most possibilities for the CEV Base Case. The BAU Case has much higher kWh sales than the CEV Cases and so the BAU cases may result in lower rates per kWh. So, while the annual electricity bill paid by consumers under the BAU trajectory is higher, the cost per kWh could well be lower.

Potential sources of consumer cost increase in this period that increase the relative cost of BAU include rate increases to pay for coal plant replacements, gas plant and gas infrastructure, and required renewable energy. Increasing fuel price uncertainty implies magnified price volatility exposure risk. Clear manifestation of adverse carbon consequences leads to increased carbon price increase risk. Excessive commitment to fossil fuel technologies leads to the possibility of stranded investments if fuel and carbon prices escalate significantly. Failure to invest in information technology, infrastructure expansion, resource sharing mechanisms such as EIM, and failure to diversify risk expose consumers to large potential rate increases.

Potential sources of potential relative benefit for a BAU trajectory include lower costs if fuel prices stay stable and low, carbon prices stay stable and low and no carbon sequestration ready investment is required.

CEV

The CEV Low Case offers lower costs to consumers over a wide range of gas, coal, and carbon costs. The CEV Low Case is lower than BAU costs even if the BAU trajectory invests nothing in carbon capture and sequestration.

The CEV Base Case offers lower costs to consumers for most plausible gas, coal and carbon costs, but extremely low gas, coal and carbon costs could render a slight cost advantage for consumers for the BAU trajectory.

The cost per kWh of the CEV cases could well be higher than the BAU Base Case because the volume of sales is much lower for CEV.

Sources of potential relative consumer cost increases include costs associated with delayed improvement in renewable technologies, delayed attainment of energy efficiency goals, significant delay in construction of necessary infrastructure.

Potential sources of relative benefit include lower costs associated with favorable technological change in renewable technologies, lower costs associated with efficient resource sharing in the West, lower costs associated with diverse resource integration due to successful information architecture, carbon mitigation benefits in the West owing to the electric sector doing its part to reduce carbon emissions, and economies of scale in renewable energy manufacturing that lead to substantial price decreases.

BAU vs. CEV Cost of Service Impact Summary

BAU can keep consumer costs in check if fossil fuel prices stay stable and low, if carbon prices stay stable and low and if no carbon capture and sequestration investment is required. BAU maintains system reliability in the manner established in the West for the last 50 years so relatively little learning is required by system operators. BAU does not take advantage of regional resource sharing so integration costs, ancillary services costs and new resource procurement costs will stay higher than necessary due to artificial barriers between balancing areas.

CEV can keep consumer costs in check by reducing demand growth, taking full advantage of customer side of the meter resources to meet energy and capacity needs, diversifying resources, reducing fossil fuel price risk, reducing carbon price risk, promoting regional cooperation in meeting integration, ancillary services and new energy requirements, and by building a robust regional information, distribution and transmission infrastructure. The CEV requires system operators and planners to add new tools to their reliability tool box and thus the CEV imposes significant pressure to learn to operate the system in ways that are less familiar in the West than they are in some other electric systems in the world such as Denmark, Ireland, Germany and Spain. The CEV incurs upfront costs to build the robust and adaptive infrastructure. Due diligence is needed to ensure the costs incurred to build the information, distribution and transmission necessary are reasonable.

BAU and CEV Job Creation Differences

Job growth in the electricity sector comes from investing in the highest value projects by getting the prices right, investing in new demand side and supply side technology and facilities, investing in new information, distribution and transmission system infrastructure, and replacing import intensive technologies with import-replacing technologies.

Job impacts analyses that encompass all four of these sources of job growth could be theoretically accomplished with macroeconomic general equilibrium models if the models use prices that reflect all externalities, capture the effects of innovation, capture structural changes over the next 20 to 40 years and characterize the western electric sector with sufficient granularity so that all four effects can be identified. Computable General Equilibrium (CGE) models executed to date have not adequately captured these four effects. Such a general equilibrium analysis is beyond the scope of this project.

An input-output analysis such as IMPLAN could be crudely accomplished with the information available that could approximate direct, indirect and induced employment effects of investment changes but such an analysis has not yet been performed. Furthermore, there are limitations to such an input-output analysis in this context that should be considered before such a task is executed.[80]

This section will approximate relative job creation impacts caused by investment differences using the person year multipliers suggested by Wei, et al.[81] In addition, the section will provide quantitative and qualitative comparisons of job creation stemming from cost differences, structural changes, and innovation.

Investment Driven Job Growth

BAU

BAU creates electric sector jobs through investments in coal, gas and required renewable energy. BAU job creation differences relative to CEV cases stem from increased investment in coal and gas facilities.

[80] IMPLAN is a fixed coefficients model and thus does not capture any change in technology or any other structural change thus using such an approach for a 20 to 40 year impact analysis is a stretch. In addition, IMPLAN requires a price forecast for the two scenarios and a price forecast requires either a general equilibrium model or a sensitivity analysis approach that explores outcomes for a range of potential prices.
[81] Wei, Max, Shana Patadia and Daniel Kammen, 2009. "Putting Renewables and Energy Efficiency to Work: How Many Jobs can the Clean Energy Industry Generate in the US," Energy Policy, November 2009.

Table 25 shows that investment in coal plant offer about 22,000 person years of employment if retrofitted and replacement facilities are not carbon sequestration ready and about 57,000 person years if facilities are made carbon sequestration ready.[82]

Table 25 further indicates that the 219 billion kWh of extra gas generation in the BAU Base leads to 24,090 additional person years of employment relative to CEV cases.[83]

Table 25: Sources of Relative BAU Job Creation
(Billions of kWh and Person-Years of Employment)

	BAU-CEV (TWh)	Total Person-yrs.
Coal		
W/O Carbon Capture & Storage	198	21,780
W/ Carbon Capture & Storage	198	57,420
Gas	219	24,090

CEV

The CEV direct and indirect job growth associated with additional renewable energy and DG investments that exceed BAU levels can be computed as shown in Tables 26 and 27 below. The tables present ranges of potential jobs created for the investment levels specified in Tables 16 and 17, and the generation differences specified in Table 6. The CEV Low Case generates about 190,000 more person years of employment than the BAU Base Case. The CEV Base Case generates about 180,000 more person years of employment than the BAU Base Case.

Table 26: Sources of CEV Low Case Relative Job Creation
(Billions of kWh and Person-years of Employment)

	CEV - BAU (TWh)	Total Person-yrs.
Biomass	1	231
Geothermal	2	380
Small Hydro	2	561
Wind	18	3,059
Solar CSP	4	955
Solar PV	4	3,613
DG	48	42,108
EE	345	131,000
CHP	56	6,160

The CEV investment difference in transmission is $18 billion between the CEV Base Case and the BAU Base Case. The Brattle Group estimates that every $1 Billion in additional transmission investment creates 13,000 one year Full Time Equivalent (FTE) direct, indirect and induced jobs.[84] Thus the $18 billion in additional investment equates to about 13,000 FTE per year if the $18 billion is spread equally over an 18 year period out to 2030.

[82] Wei, et al, 2009, report that coal generation facilities employ 0.11 person years for every million kWh of generation. If the equipment is sequestration ready then 0.29 person years are created for every million kWh. Employment numbers assumes about 27,000 MW of coal generation will need to be retrofitted or replaced by 2030.
[83] Wei, et al, 2009, indicates gas generation creates 0.11 person years of employment for every million kWh of generation.
[84] WIRES and The Brattle Group., Economic and Employment Benefits of Transmission Infrastructure Investment in the U.S. and Canada, May 2011

Table 27: Sources of CEV Base Case Relative Job Creation (Billions of kWh and Person-years of Employment)

	CEV - BAU (TWh)	Total Person-yrs.
Biomass	6	1,307
Geothermal	9	2,161
Small Hydro	12	3,183
Wind	102	17,365
Solar CSP	24	5,421
Solar PV	57	49,563
DG	24	21,054
EE	200	76,000
CHP	56	6,160

Import Replacement can Drive Job Growth in Some States

Fossil fuel related job growth includes job growth that occurs in fuel producing regions rather than the region in which the energy facilities are constructed. Natural gas and coal producing states will lose jobs under a CEV future unless renewable generation and/or renewable generation manufacturing is located in those states. If renewable generation or manufacturing is located in those states then they may gain jobs under a CEV trajectory because renewable generation requires more labor per unit of energy that fossil generation.

In most western states much of the CEV job growth has the potential to occur closer to the placement of facilities and efficiency programs. Efficiency investments are much less capital intensive and thus most expenditure can support local labor. DG, wind and large scale solar have the potential of providing focused local employment if the renewable technologies are produced within the West. Installation of the technologies can be achieved with local labor but establishing manufacturing facilities locally adds local job potential. Therefore, CEV employment opportunities are larger and they have the potential of having greater local multiplied effects due to the local nature of the labor activities. Replacing fossil fuel dependent generation with EE and RE generation thus can be viewed as an import replacing, local economic development initiative.

Job Growth, Electricity Cost Reduction and Improved Electric Service

If households and businesses spend less on energy for a given quality of service then income is freed up for other local expenditures. Since much of the expenditure on energy dollars flows out of the local economy to fossil fuel producing regions, reducing the energy bill of consumers and businesses through demand reduction and CHP policies can spur local job growth. Conversely, the expense that comes with large upfront investments, like those required by the CEV can increase cost initially and thus reduce local expenditures on non-energy goods and services.

Since the CEV includes elements that decrease cost and elements that increase cost, the relative job creation capability of CEV relative to BAU depends on whether the ultimate effect on cost is to increase bills relative to BAU or decrease bills relative to BAU.

Uncertainty in gas, coal and carbon prices along with uncertainty in the pace of technological change in renewable energy industries mean that the cost difference and thus the job producing potential associated with cost reduction is uncertain.

Job Creation Benefits of Innovation

Technology cost reductions, introduction of new technologies and technological improvement in grid operations and grid efficiency can improve quality of service and reduce cost of service. Thus the innovation focus of CEV relative to BAU can produce the benefits of improved electricity service discussed above. In addition, technological advances constitute potential goods and services the West can export. Third, innovation in the electricity sector can spawn innovations outside the electric sector. Taken together, these three benefits of innovation can produce significant long term job benefits.

While cost reduction and efficiency improvement innovations are sometimes studied, the second two benefits are usually ignored. For example, Google recently sponsored research that investigates the benefits of innovation in clean energy technologies.[85] The study is nationwide and focuses on cost reduction in clean energy technologies. The study estimates that innovation and clean energy policy changes could produce between 1.1 and 1.9 million more jobs and save households more than $900 per year relative to a BAU future.[86] Thus the job creation benefits of pursuing a CEV future over a BAU future in the West appear significant.

The Google study lists "synergies/efficiencies" among the sources of innovation but it is not clear whether effects of advanced information, communications and system control technologies on grid operations and efficiency is fully captured. CGE and IO models typically leave out this sort of innovation because it constitutes a structural change in the electric sector and in the relationship of the electric sector to other sectors. CGE and IO models are not well-suited to exploring structural change. Structural change is a double edged sword because the cost of changing institutions from ingrained habits can be difficult and expensive. Thus while the job creation benefits identified by the Google study and other CGE or IO based studies may understate the job creation benefits of innovation, one should also acknowledge potential hidden costs that impede structural change.

Even the Google study does not investigate the second two effects of innovation on job creation. The potential job creation benefits of becoming a technology leader in the electric sector is emphasized by a recent Pew study, however.[87] With the G20 slated to spend $2.3 Trillion on clean energy technologies over the next twenty years, leaders in technology development, demonstration and deployment stand to benefit handsomely. Projecting how much of the $2.3 Trillion pie the West could garner if it becomes a technology leader is a speculative exercise, but the opportunity associated with becoming a clean power leader should be recognized even if the potential benefits are uncertain.

Third, most studies, including the Google study do not consider the potential innovation spillover benefits that may be enjoyed from leading in the electric sector. Generation technology innovation, electricity storage innovation, and electricity system communications, information and control system innovations each have the potential of spilling over from the electric sector to other sectors and the potential for additional job creation benefits of spillover should not be ignored.

Taken together, the three potential sources of job benefits arising from electric sector innovation appear substantial. The CEV trajectory emphasizes use of emerging generation technologies, use of storage, information, communications and control technologies to meet reliability requirements and use of advanced technologies to create an effective interface with electric transportation. As a result, the

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[85] "The Impact of Clean Energy Innovation: Examining the Impact of Clean Energy Innovation on the United States Energy System and Economy," June 2011, Google.

[86] Ibid, p. 2. It should be noted that the Google study includes the benefits of transportation electrification in these job numbers.

[87] "Global Clean Power: A $2.3 Trillion Opportunity," The Pew Charitable Trusts and The Clean Energy Economy, 2010.

CEV trajectory has innovation-based job creation potential that exceeds the BAU innovation-based potential.

BAU and CEV High Impact Risk Differences

The economic performance differences between BAU and CEV trajectories highlighted thus far present expected economic outcomes without addressing uncertainty and risk. While some results are presented as ranges to reflect possible discrete differences in assumptions, the consideration of potential high impact events has not yet been discussed. High impact events are important to evaluating relative economic performance because high impact events represent unusually large risks or unusually large opportunities. A complete evaluation of development alternatives should include consideration of an alternative's capacity to protect society against high impact negative events and to preserve the potential of enjoying high impact positive events.

While some disagree that climate change will have serious, high impact negative consequences, everyone acknowledges that climate change impacts could be negative and profound. This section focuses on the benefit of protecting against high impact, negative carbon accumulation consequences.

The BAU trajectory results in increased carbon emissions and does not offer a path to overcoming the carbon game prisoners' dilemma described earlier. The CEV trajectory ensures the West's electricity sector does its part to reduce climate emissions, and this commitment creates the opportunity for mutual commitment strategies that could slow carbon emissions globally. As a result, the CEV trajectory represents an insurance policy against high impact, negative climate change outcomes.

The value of the CEV insurance policy depends on the potential magnitude of the climate change risk as well as the potential value of climate change mitigation. Many economists have put great efforts into quantifying the economic impacts of climate change. The efforts include CGE and IO analyses that show jobs, GDP and sector impacts that contrast business as usual versus low carbon futures. The results of these studies are summarized in a series of tables over the next several pages.

Table 28: BAU vs. CEV Social Costs of Carbon

COSTS OF CARBON	
BAU	**CEV**
Social Cost of Carbon: The "social cost of carbon" (SCC) is a measure of the incremental damage resulting from one additional ton of GHG emissions, expressed in present value terms. It captures the full economic cost to society, now and in the future, of emitting a ton of greenhouse gasses in the present. Stern estimates that the current SCC with BAU is $85 per ton (in 2000 dollars) if non-market impacts and the risk of catastrophes are taken into account.[88] An interagency group estimates the SCC in 2010 to be between $21 and $35 per ton (in 2007 dollars); however, the estimate rises to $65/ton when considering high risk low probability temperature increases.[89] Others have recently used the same model with modified assumptions based on recent climate science results to show that the SCC ranges from $28 per ton to nearly $900 per ton.[90] *Market Cost of Carbon:* There is no market for carbon, and, thus, the market cost of carbon is $0.	*Social Cost of Carbon:* At the optimal level of abatement, the marginal cost of abatement (MAC) will equal the SCC. The SCC depends on the desired level of carbon stabilization. Stern estimates that along a trajectory towards 550 ppm CO_2e and a trajectory towards 450 ppm, the SCC would be $30 per ton and $25 per ton, respectively. The interagency group believes the SCC to be $21 per ton in 2010, no matter the scenario. *Market Cost of Carbon:* According to Stern, the social cost of carbon should reflect the price of carbon. Thus, he estimates that the optimal market price of carbon ranges from $25 to $30 per ton, as this will lead to stabilization levels between 450 and 550 ppm CO_2e. Ackerman and Stanton suggest $28 per ton as a minimum but argue that much higher levels of carbon cost may be appropriate.

[88] Stern, 2006
[89] Keohanem, pp. 13-16
[90] Ackerman and Stanton, 2011, Stockholm Institute.

Table 29: BAU vs. CEV Climate Change GDP Impacts

GDP	
BAU	**CEV**
• A survey of 3 prominent Integrated Assessment Model (IAMs) concludes that by the end of the century expected temperature increases of between 1.1-6.4° C will lead to damages ranging between approximately 4 and 17 percent of GWP. These estimates should be viewed as lower bounds because they fail to account for non-market amenities and catastrophes. • The IPCC estimates damages of 1.5-3 percent of GWP annually for a doubling of GHG concentrations relative to preindustrial levels and 11 percent of GWP for a temperature increase of 6° C.[91] • The Stern Review estimates that the risks and impacts of a BAU scenario over the next two centuries are equivalent to an average reduction in global per-capita consumption of at least 5 percent, now and forever. When accounting for non-market impacts, such as those on the environment and human health, feedback effects and the unequal distribution of climate change impacts around the globe, the cost estimate for a BAU scenario increase to 20 percent.[92]	• The average estimate of costs to the U.S. economy of reducing GHG emissions through a cap-and-trade program is under 0.6 percent for the period between 2010 and 2030 relative to a BAU scenario.[93] • In the same time period, the estimates of the cost of emissions abatement on the word economy range from 3 to -2 percent (net gains) of GDP relative to BAU.[94] • Out to 2050, Stern estimates of the annual costs of stabilizing at 550 ppm and 450ppm CO_2e to be 1 percent and 2 percent of global GDP relative to BAU, respectively. • Other 500-550ppm stabilization cost estimates for 2050 range from -2 (net gains) to 4 percent of global GDP with an average of 1 percent. (Stern , p. 267) • Annual cost estimates for more stringent 350ppm stabilization scenarios, range between 1 to 3 percent of world GDP.[95]

[91] Answer Testimony of Nathaniel Keohane before the Public Utilities Commission of Colorado, September 17, 2010
[92] Stern
[93] Keohane
[94] Keohane, p. 18
[95] Ackerman, Frank et al. *The Economics of 350: The Benefits and Costs of Climate Stabilization.*

Table 30: BAU vs. CEV Climate Change Jobs Impacts

JOBS	
BAU	**CEV**
• The average employment over the life a facility (jobs/MWa) is 1.01 for coal-fired facilities and 0.95 for natural gas-fired facilities. The majority of these jobs are in fuel processing and operations and management (O&M). [96] • The average U.S. employment associated with a scenario in which fossil fuels continue as usual out to 2020 is 83,369.[97] • In the absence of AB32 and energy efficiency measures beyond those which currently exist in the state, it is estimated that 181,000 new jobs will be generated in California by 2020.[98] • ASES projects that a BAU scenario will generate 1.3 million jobs in the U.S. by 2030.[99]	• When compared to the fossil fuel-based energy sector, the renewable energy sector generates more jobs per megawatt of power installed, per unit of energy produced, and per dollar of investment. The average employment over the life of a facility (jobs/MWa) ranges from 6.96011.01 for solar PV, 0.7-2.78 for wind, and 0.78-2.84 for biomass.[100] • The average U.S. employment associated with a 20 percent RPS by 2020 is 240,850.[101] • It is estimated that by 2020, policy to mitigate climate change in California will generate 403,000 jobs relative to the baseline.[102] • ASES projects that aggressively pursuing efficiency and renewable energy projects could generate 4.5 million net jobs in the U.S. by 2030.[103]

[96] Kammen, Daniel et al. Table ES-1
[97] Kammen, page 11, Table 3
[98] Roland-Holst, David, October 2008.
[99] UNEP, p. 100
[100] Kammen et al., Table ES-1
[101] Kamen et al. Table ES-2
[102] Roland-Holst, October 2008.
[103] UNEP, p. 100

Table 31: BAU vs. CEV Climate Change Sector Impacts

SECTORAL IMPACTS	
<u>CA:</u> It is estimated that a BAU scenario will put assets at risk and lead to damages in many CA sectors (2006 USD billions).[104] • *Public Health:* damages per year: 3.8-24 • *Water:* assets at risk: 5; damages: 0.6 • *Energy:* assets at risk: 21; damages 2.7-6.3 • *Transportation:* assets at risk: 500 • *Agriculture, Forestry & Fisheries:* assets at risk: 113; damages: 0.3-4.3 <u>Global:</u> • *Agriculture:* Warmer crop yields associated with a BAU scenario will increase crop yields by 5 percent in Northern Europe. Overall, it will lead to a decrease in yields that cause a 20 percent increase in global agricultural prices.[105]	*Renewable Energy*: Investment in renewable energy will generate net job growth. *Transportation*: Transitioning the sector away from fossil fuels will require replacing or modifying 250 million vehicles and 240,000 aircrafts.[106] Buildings: It is estimated that the costs to upgrade or retrofit existing buildings to save energy are minimal.[107] *Agriculture:* A large portion of future renewables will likely be biofuels, which can cause harm to the environment and lead to increased food shortages and prices. When removing these jobs from the mix, ASES' estimate for jobs created by the renewable energy sector drops from 1.3 million to 290,000[108] Additionally, the sectorial impacts of a BAU scenario can be avoided by transitioning to a clean energy economy.

[104] Roland-Holst, Davis and Fredrich Kahrl. November 2008
[105] Hisas
[106] CNA
[107] UNEP
[108] Ibid

Table 32: BAU vs. CEV Climate Change Competitiveness Impacts

COMPETITIVE IMPACTS	
BAU	**CEV**
If the U.S. continues to rely heavily on fossil fuels, it may lose out on investment opportunities and fail to remain competitive in renewable energy markets. Under a BAU scenario, $1.7 trillion will be invested in clean energy globally over the next 10 years. In the U.S., existing policies will lead annual investment in renewables to increase 73 percent relative to 2010 levels. This is less than the projected increase under a CEV scenario. By continuing on with BAU, the U.S. is potentially losing $97 billion in renewables investment through 2020[109].	The U.S. has a lot to gain by adopting a CEV strategy. With policies that emphasize clean energy, it is projected that $2.3 trillion will be invested in clean energy around the world over the next 10 years. By adopting a CEV plan, the U.S. has an opportunity to attract some of this investment and could increase cumulative investments to $53 billion annually by 2020, a 23 percent increase relative to 2010 levels. Compared to BAU, a CEV scenario will lead to additional investment of $97 billion over the next 10 years.[111]
Our dependence on fossil fuels also posits problems for national security. The U.S. sends hundreds of billions of dollars overseas annually because over 50 percent of U.S. oil is derived from imports. This leaves American businesses and government agencies, like the DOD, vulnerable to unpredictable price volatility. Every $10 increase in the price of a barrel of oil costs the DOD $1.3 billion.[110]	By investing in renewable energy technologies, the U.S. can ensure that it is at the forefront of this expanding sector. This will reduce our dependence on foreign nations, making us less vulnerable to oil price swings that could negatively impact our nation's economy and security.

9: Environmental Performance

Comparing the environmental performance of BAU and CEV cases includes evaluating direct environmental impacts caused by criteria air pollutants, land impacts and water impacts, as well as evaluating potential impacts on land, air, water and wildlife associated with climate change.

Direct impacts of BAU include continuing high levels of mercury, sulfur dioxide, nitrous oxide and particulate emissions from coal and gas power plants.

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[109] PEW. Global Clean Power: A $2.3 Trillion Opportunity. 2010.
[110] CNA. p. 3
[111] PEW
"climate policy ramp" that begins with small, slow steps. We investigate whether, with slightly different assumptions, DICE might recommend beginning abatement more rapidly, and stabilizing at 350 ppm CO2. Pg. 6 ECON of 350

The electric utility industry is one of the leading producers of criteria pollutant air emissions as well as the largest producer of carbon emissions. U.S. power plants are responsible for approximately 66 percent of SO_2 emissions, 19 percent of NOx emissions, 72 percent of mercury air emissions, and 39 percent of CO2 emissions produced in the U.S.[112] These emissions are produced predominantly from coal and natural gas fired power generation plants.

Chapter 9 Overview: Environmental Performance

BAU vs. CEV Direct Impacts:

- **Criteria Pollutant Impacts**: BAU portfolios have more coal and natural gas fired resources and therefore the BAU portfolios have higher levels of criteria pollutants.
- **Water Use Impacts**: BAU Base Case water use is more than twice the water used in the CEV Low and Base Cases.
- **Land Use Impacts**: CEV large scale renewable energy build outs directly use between 600,000 and 1,500,000 acres of land. BAU requires less land for generation and transmission footprints but uses far more land for fuel exploration and production.

BAU vs. CEV Potential Climate Change Impacts:

The CEV cases represent a credible commitment by the West to do its part to reduce carbon emissions to the IPCC 2050 target. If the West and other regions and sectors fail to make these commitments then the sources cited declare that there will be impacts on:

- **Temperature and precipitation**: Failing to limit carbon accumulation will lead to changes between 2 and 11.5 degrees by 2100. Jointly making commitments could limit carbon accumulation below 450 ppm could limit temperature increases to 2 additional degrees Celsius by 2100. For every degree Celsius change, southwest runoff will decrease 3.3 to 6.1 percent and northwest runoff will increase 1.2 percent.
- **Ecosystem Processes & Biodiversity**: Physical changes in the environment such as increased temperatures and changes in precipitation will result in increases in sea level, drought, wildfires and flooding will affect ecosystems and human activities. These changes directly affect many species through affecting their habitats.
- **Water Supply**: The arid southwestern U.S. is projected to experience longer and more severe droughts from the combination of increased evaporation and reductions in precipitation.

Criteria pollutant emissions and carbon emissions affect human health and have significant impacts on the environment. The human health impacts will be addressed in Chapter 11.

Policy decisions regarding the types of new resources to develop and whether or not to continue to rely on resources that are in use today should be considered in light of the direct impact that these resources will have on the environment now and in the future. This section provides a summary of the direct environmental and climate change impacts of the BAU and CEV portfolios.

[112] Benchmarking, June 2010, National Academy of Sciences

Direct Environmental Impacts of BAU and CEV

SO_2, NOx, and mercury air emissions for the BAU and CEV portfolio cases depend directly dependent upon electricity produced from coal and natural gas fired resources. While best available retrofit technologies and best available control technologies mitigate the rate of emission of these criteria pollutants per kWh of electricity produced, the number of kWh of fossil generation can serve as a proxy for relative quantity of emissions.

In the BAU cases the current quantity of coal fired power plant generation is assumed to persist as aging plant is retrofitted or replaced with new facilities. Natural gas fired resources persist and grow as they are the incremental resource of choice to meet growing needs in the BAU cases. While investment to mitigate emission of criteria pollutants is assumed pursuant to expected EPA air quality requirements, these actions only mitigate and do not eliminate criteria pollutant emissions per kWh of generation. Table 33 shows electric generation by resource type for each of the five cases. The table shows that the BAU cases maintain coal energy production for each of cases and have increasing levels of natural gas fired energy to meet incremental energy needs.

The CEV cases reflect decreasing levels of coal and natural gas fired energy production as renewable resources and energy efficiency are used to address incremental energy requirements. The coal and gas resource columns in the table show that fossil generation is much smaller for the CEV cases in 2030 and 2050 so criteria pollutant emission levels will be much smaller for the CEV cases.

CO_2e emission levels at time of production are estimated for each resource type using average coal and gas emission rates per kWh. Electricity output levels are thus used to derive GHG emission levels.[113,114] Figure 25 in Chapter 5 provides a comparison of CO_2e emission levels for the 2010-2050 BAU and CEV portfolio cases. As can be seen from the graph, the CEV portfolios result in decreasing levels of CO_2e through 2050, whereas, the BAU portfolios have increasing levels of CO_2e through 2050.

[113] Gas exploration produces methane emissions and the Global Warming Potential of methane was recently upgraded. In addition, gas from fracked wells produces methane 'burbs' which further increases the GHG emissions from gas. Neither of these effects is included in the CO_2 estimates associated with burning natural gas for electric generation so the GHG estimates for gas generation are likely too low.

[114] CO_2 emissions are not life cycle emissions estimates. Future enhancements of this work should include life cycle estimates but it should be noted that including life cycle emissions will require fewer high carbon resources than what is reported here for the CEV cases.

Table 33: Generation by Resource Type

Generation in Billions of kWh by Resource Type by Case										
			Nuclear	Coal	Gas	RE	Hydro	CHP	Efficiency Resources	DG
BAU	Base	2010*	70	278	157	63	246	19	-	**
		2020	70	278	210	172	248	26	54	**
		2030	70	278	375	204	248	39	64	**
		2050	70	278	734	286	278	58	89	**
	High	2010*	70	278	157	63	246	19	-	**
		2020	70	278	210	181	247	28	56	**
		2030	70	278	498	224	248	39	71	**
		2050	70	278	1,036	345	278	58	109	**
CEV	Low		Nuclear	Coal	Gas	RE	Hydro	CHP	Efficiency Resources	DG
		2010*	70	278	157	63	246	19	-	1
		2020	70	233	106	201	252	22	208	20
		2030	70	80	156	237	227	95	409	48
		2050	70	-	76	601	204	95	767	93
	Base	2010*	70	278	157	63	246	19	-	1
		2020	70	233	106	295	252	22	108	20
		2030	70	80	156	388	227	95	264	24
		2050	70	-	76	780	204	95	587	47
	High	2010*	70	278	157	63	246	19	-	1
		2020	70	233	106	339	252	22	114	20
		2030	70	80	156	475	227	95	286	24
		2050	70	-	76	994	204	95	683	47

** BAU DG generation is assumed to be fully captured in the respective demand forecasts for the Base and High Cases.

Water Use Comparison BAU versus CEV

Water usage requirements by generation resources are increasingly becoming an important consideration in resource planning. As demand for water increases the resource will become scarcer and its cost will increase. In addition, policy makers are likely to continue to support low water use policies and low water use resources in future planning decisions. Consequently, understanding the water usage requirements of future resource portfolios is a key factor for policy makers.

The water consumption estimates for the BAU and CEV portfolio cases are provided in the table below.[115] The estimates were derived from water usage data and energy production data for the

[115] Argonne National Laboratories p. 85
CEC, California Energy Commission presentation, Environmental Aspects of Advanced Generation in California, IEPR Staff Workshop on RD&D of Advance Generation Technologies, p. 15

resources in each of the portfolios. Water usage values in gallons per MWh for plant operations were obtained from a number of sources including the BLM Solar PEIS (2010), U.S. DOE (2009), Western Resource Advocates (2010), Argonne National laboratory (September 2010) and California Energy Commission PIER (August 2010). Figure 30 below provides a presentation of relative water use by generation resource type produced by Western Resource Advocates.

Producing the water use estimates required a number of assumptions. Existing gas generation was assumed to be wet cooled, all new gas generation was assumed to be dry cooled, concentrating solar power was assumed to be 80 percent dry cooled and 20 percent wet cooled, and all coal generation was assumed to be conventional coal generation. Water use for carbon sequestration was not included.

Table 34 shows the relative water consumption in 100s of billions of gallons for each of BAU and CEV cases based on the electricity generation quantities shown in Table 33 and the assumptions just enumerated.

What stands out in the table is that the BAU cases have increasing water requirements through 2050 and the CEV cases have decreasing water requirements through 2050. By 2050 BAU water requirements are more than twice CEV water requirements. And relative to current (2010) water use, the CEV cases reduce water use for electricity generation by 50 percent. In other words, a CEV path to 2050 will free up "new" water for other uses between today and 2050.

Environmental Defense Fund, and Western Resource Advocates, 2010, Protecting the lifeline of the west— how climate and clean energy policies can safeguard water: EDF and DOE, 44 p.
U.S DOE, Concentrating solar power commercial application study—reducing water consumption of concentrating solar power electricity generation: DOE Report to Congress, p. 35
Bureau of Land Management, and U.S. Department of Energy p. 49

Figure 31: Water Use by Generation Technology[116]

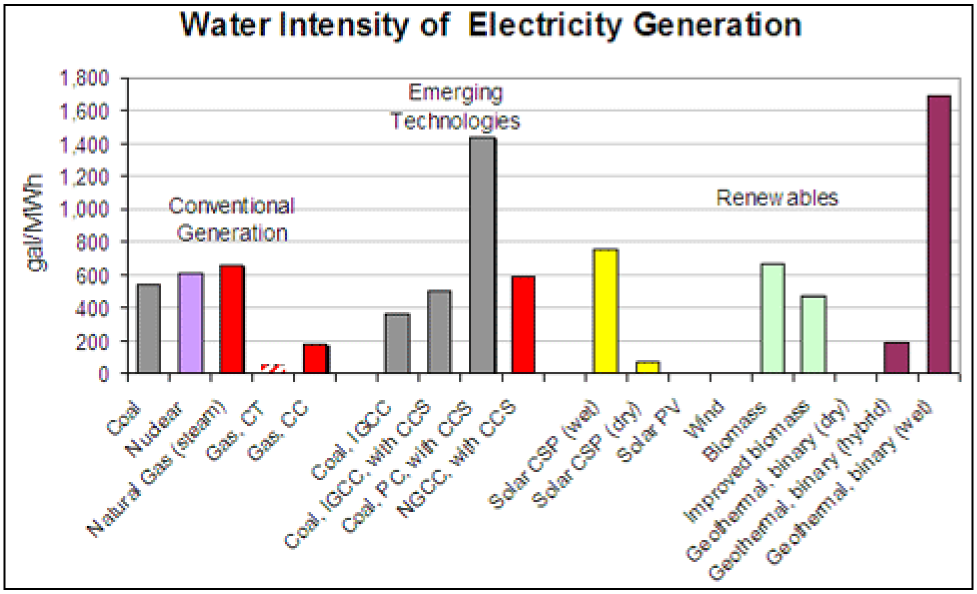

Table 34: BAU and CEV Water Use

			Relative Water Consumptions (100's Billions of Gallons)
BAU	Base	2010	3.14
		2020	3.48
		2030	3.91
		2050	4.84
	High	2010	3.14
		2020	3.49
		2030	3.92
		2050	4.46
CEV	Low	2010	3.14
		2020	3.02
		2030	1.89
		2050	1.49
	Base	2010	3.14
		2020	2.96
		2030	1.98
		2050	1.43
	High	2010	3.14
		2020	2.99
		2030	2.04
		2050	1.57

116 Western Resource Advocates, taken from http://www.westernresourceadvocates.org/water/waterenergy.php, July 2011.

BAU versus CEV Land Use Impact Comparison

Land use requirements are another key factor that should be considered when selecting future resource portfolios. Land use requirements affect permitting requirements, resource development timeframes and have wildlife and other land resource impacts. Estimates of land use requirements for CEV portfolio cases are provided in the tables that follow. Land use requirements for BAU portfolio cases will be discussed relative to land committed to gas and coal resource development.

CEV Land Use Requirements

The incremental resources used to meet future demand for the CEV portfolios are energy efficiency, CHP and renewable resources. Land use requirements for these resources include land for the resource footprint, transmission access to the resource and to integrate the resource into the electric system, substations and other land requirements. All land use calculations presented for the CEV cases estimate the amount of land that will become disturbed by the development and thus not available for other uses.

High concentration renewable energy resources are typically in locations remote from loads and transmission access to these remote locations is limited. Some transmission will be available on existing transmission facilities and on transmission lines that have 'freed-up" capacity due to coal plant retirements, so new transmission does not need to be built to access all remote renewables. The land required to achieve the CEV Low and High Cases are provided in Tables 35A and 35B below. The assumptions used to produce these estimates are included in the technical appendix.

The land use estimates in Tables 35A and 35B include the disturbed land footprint associated with units of generation facilities only. For example, the footprint for wind projects is based on an estimate of the number of acres disturbed by each wind turbine and then multiplied by the number of turbines. Since wind projects with large numbers of contiguous turbines may have cumulative impacts on some species in some locations, the "resource footprint" provided in the table may understate the land impact for some large wind projects.

The CEV directly developed amount in the West beyond currently impacted lands will be between 600 thousand and 1,500,000 acres by 2030. The large scale renewable energy requirements for 2050 shown in Table 33 indicate that CEV renewable energy requirements range from about 600 billion kWh to about 1,000 billion kWh. Specific development portfolios were not built for these 2050 cases because changes in technology, scientific breakthroughs and public preferences could take the portfolios in very different low carbon directions between 2030 and 2050. Therefore, land projections are highly speculative for this period.

However, if one assumes that large scale renewable energy fills the low carbon resource need out to 2050 then a rough estimate of the number of acres required would range from 1,500,000 acres to 3,000,000 acres based on the fact that Table 35B shows a portfolio of about 500 billion kWh would require about 1,500,000 acres.

Even at the upper end of these 2050 estimates, 3,000,000 acres represents approximately ½ of 1% of the land in the west or an area about one eighth of the size of the Mojave Desert. These acreages, however, could be increased somewhat depending upon how well prairie-grouse habitats are avoided since those species are more sensitive to vertical structures like turbines and towers.

Table 35A: Land Impact Estimate for CEV Low Case (235 Billion kWh RE 2030 Portfolio)

Land Use For Transmission and RE Resource Footprint

PC 235 (Incremental)	Resource Capacity Added (MW)	Land Use for Regional Transmission Projects (Acres)	Land Use for Trunk Lines (Acres)	Land Use For Collector Lines (Acres)	Land Use for Feeder Lines (Acres)	Land Use for Substations (Acres)	Land Use For RE Resource Footprint (Acres)	Land Use By RE Type (Acres)
Large Scale Solar Thermal	7,900	0	19,000	10,000	8,000	700	67,000	105,000
Large Scale Solar PV	9,900	0	19,000	10,000	8,000	700	79,000	117,000
Wholesale Solar DG (2-20 MW)	0	0	0	0	0	0	0	0
Small Scale DG Roof Top	0	0	0	0	0	0	0	0
Wind Mountain	14,300	95,000	0	20,000	11,000	2,400	90,000	218,000
Wind CA/BJ	4,800	0	5,000	17,000	2,000	200	26,000	50,000
Wind SW	4,300	0	5,000	15,000	2,000	200	23,000	45,000
Wind Northwest	5,400	0	5,000	16,000	2,000	200	28,000	51,000
Geothermal RE Requirements	2,400	0	5,000	15,000	1,000	200	2,400	24,000
Biomass RE Requirements	1,400	0	3,000	1,000	800	100	2,000	7,000
Hydro RE Requirements	1,300	0	3,000	1,000	1,000	100	200	5,000
Totals	43,800	95,000	64,000	105,000	36,000	5,000	318,000	622,000
Land Use Adjustment For Transmission Capacity Available From Coal Plan Retirements								34,300
Total Land Use to Develop RE (Acres)								587,700
Square Miles								918
Rhode Islands								0.5

Table 35B: Land Impact Estimate for CEV High Case (467 Billion kWh RE 2030 Portfolio)

Land Use For Transmission and RE Resource Footprint								
PC 467 (Incremental)	Resource Capacity Added (MW)	Land Use for Regional Transmission Projects (Acres)	Land Use for Trunk Lines (Acres)	Land Use For Collector Lines (Acres)	Land Use for Feeder Lines (Acres)	Land Use for Substations (Acres)	Land Use For RE Resource Footprint (Acres)	Land Use By RE Type (Acres)
Large Scale Solar Thermal	21,300	0	52,000	26,000	23,000	1,900	181,000	284,000
Large Scale Solar PV	26,800	0	52,000	26,000	23,000	1,900	215,000	318,000
Wholesale Solar DG (2-20 MW)	0	0	0	0	0	0	0	0
Small Scale DG Roof Top	0	0	0	0	0	0	0	0
Wind Mountain	33,600	218,000	0	46,000	26,000	5,600	211,000	507,000
Wind CA/BJ	8,300	0	9,000	29,000	3,000	400	44,000	85,000
Wind SW	15,600	0	17,000	53,000	6,000	700	83,000	160,000
Wind Northwest	11,100	0	11,000	33,000	4,000	400	59,000	107,000
Geothermal RE Requirements	2,700	0	5,000	17,000	2,000	200	2,700	27,000
Biomass RE Requirements	3,800	0	7,000	4,000	2,300	300	6,000	20,000
Hydro RE Requirements	3,200	0	6,000	3,000	2,000	200	500	12,000
Totals	105,100	218,000	159,000	237,000	91,000	12,000	802,000	1,520,000
Land Use Adjustment For Transmission Capacity Available From Coal Plan Retirements								34,267
Total Land Use to Develop RE (Acres)								1,485,733
Square Miles								2,321
Rhode Islands								1.2

BAU Land Use Requirements

The incremental resource for the BAU portfolios is natural gas fired generation resources. Land use requirements for these resources include land for: the generation footprint, transmission access to the generation facilities, and natural gas transmission lines, gathering pipelines, processing equipment, storage and LNG infrastructure.

Estimates of the overall land use requirements for natural gas fired generation to meet required resource levels for BAU cases would thus need to take into account the following factors: existing right of way can be used in many cases for new gas transmission infrastructure; gas generation resources can be located at existing plant locations or can replace other types of fossil fuel resources at existing sites; and, natural gas fired resources, unlike renewable resources, do not have to be located at the source of energy and are typically located close to the load and existing electric and gas transmission infrastructure. These factors require more specific assumptions about the location of gas generation than is possible in this sketch comparison of BAU and CEV portfolios so land use estimates for the BAU cases are not presented here.

However, the amount of land use required simply for gas exploration and production is significant. As of March 1, 2011, approximately 38 million acres were under lease for off-shore oil and gas development. Of these, roughly 10.5 million acres are under active leases, 3 million with approved exploration plans and 7.5 million with approved development plans. The Bureau of Land Management (BLM) reports that as of March 14, 2011, over 38 million acres were under lease for onshore oil and gas activities. Only 43 percent of the onshore acres leased were for production and exploration.

The BAU Base Case increases gas fired generation from 157 billion kWh in 2010 to 375 billion kWh in 2030 which more than doubles gas fired generation. Nationwide gas used for electric generation is about 33 percent of annual gas consumption so more than doubling gas demand for electric generation would increase annual gas demand by more than 33 percent. Given the number of acres devoted to offshore and onshore oil and gas development, it is safe to say that impacted land will run into the multi-millions of acres.

DOE further reports that coal mining disturbs approximately 1 million acres of land per year for electricity generation in the U.S.

Comparing BAU and CEV Land Impacts

Comparing these impacts with those from additional development of fossil fuels is difficult to do rigorously. Impacts from initial development of natural gas to be used for power generation may be more intense but of shorter duration once the bulk of the infrastructure is removed potentially allowing some recovery of the land. Mining associated with coal extraction is also very intense and of a longer duration.

It is important to acknowledge that all energy development has impacts on land, water, and wildlife. As we visualize these impacts, it also is important that we understand the tradeoffs associated with each fuel source. Yes, the land impacts to produce enough renewable energy to achieve the clean energy goals are significant. If, however, we conduct BAU continuing to impact land with fossil fuel developments, then the land and water ecosystems as we know them will change dramatically.

For instance more than 10 million acres of sagebrush in Nevada alone is at risk of being replaced with cheat grass dominated habitats and the earth warming will exacerbate these impacts.[117] The National Forest Service projects that more than 3.6 million acres of lodgepole pine forest will be dead by 2013 and accelerated loss of acres is expected in the future due to beetles that are thriving with warmer temperatures.[118]

Fuel Cycle Land Impacts

The land impacts calculated above reflect electricity production land impacts but they do not provide a complete comparison of fossil, nuclear and renewable energy technology land impact. Fthenakis and Kim (2009) examine the direct and indirect impacts of renewable and conventional fuel cycles. They find ground mounted PV systems in areas with high insolation levels transform less land than surfaced mined coal. Coal impacts land in the mining, benefication and electricity generation stages. In the coal mining stage, the U.S. average total land transformation (land altered from a reference state) is 400 m^2 per GWh for surface mining and 200 m^2 per GWh for underground mining. Operating a 1000 MW coal power plant in the U.S. leads to further land transformation of 9.1 m^2 per GWh. Additionally, there is indirect land transformation from the materials and energy used to mine and operate coal power plants. In contrast, the fuel cycle for ground-mounted solar PV in high isolation areas, such as the Southwestern U.S., leads to direct land transformation of only 164 m^2 per GWh.

The land occupation of surface coal mining (the duration over which the area of transformed land returns to its original state) ranges from 1,290 m^2 per GWh per year to 25,200 m^2 per GWh per year in the U.S. This is less than solar PV plants with a long lifespan. However, biomass farming has the highest level of land occupation at 380,000 m^2 per GWh per year. This is followed closely by nuclear, which has land occupation of 300,000 m^2 per GWh per year.

Climate Change Impacts on the Environment

The environmental impacts discussed thus far are direct environmental impacts that do not incorporate any exacerbating consequences attributable to climate changes. The purpose of the rest of this chapter is to separately discuss these additional impacts resulting from climate change.

Rising temperatures and changes in precipitation are presented herein as two major changes in the physical environment. However, the effects of these physical changes are not mutually exclusive. For example, drought results from changes in precipitation (decreases), but is also likely attributable to and would certainly be exacerbated by high temperatures.

The carbon targets selected to build the CEV cases rely on the IPCC AR4 recommendation that keeping the concentration of carbon below 450 parts per million (ppm) is necessary to limit the risk of severe, irreversible effects of climate change. IPCC AR4 argued that as concentrations grow above 450 ppm, there is substantial risk that temperature increases would exceed 2 degrees Celsius and the land, ecosystem and species impacts would become increasing severe and irreversible. Figure 31 produced by the Union of Concerned Scientists summarize the potential effects of temperature increases exceeding 2 degrees Celsius.[119]

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[117] Pacific Northwest Research Station Science Findings, March 2007, "Sagebrush in Western North America: Habitats and Species in Jeopardy."
[118] Bruce Melton (2008). "North America's Mountain Pine Beetle Pandemic," October 2008.
[119] Union of Concerned Scientists. .

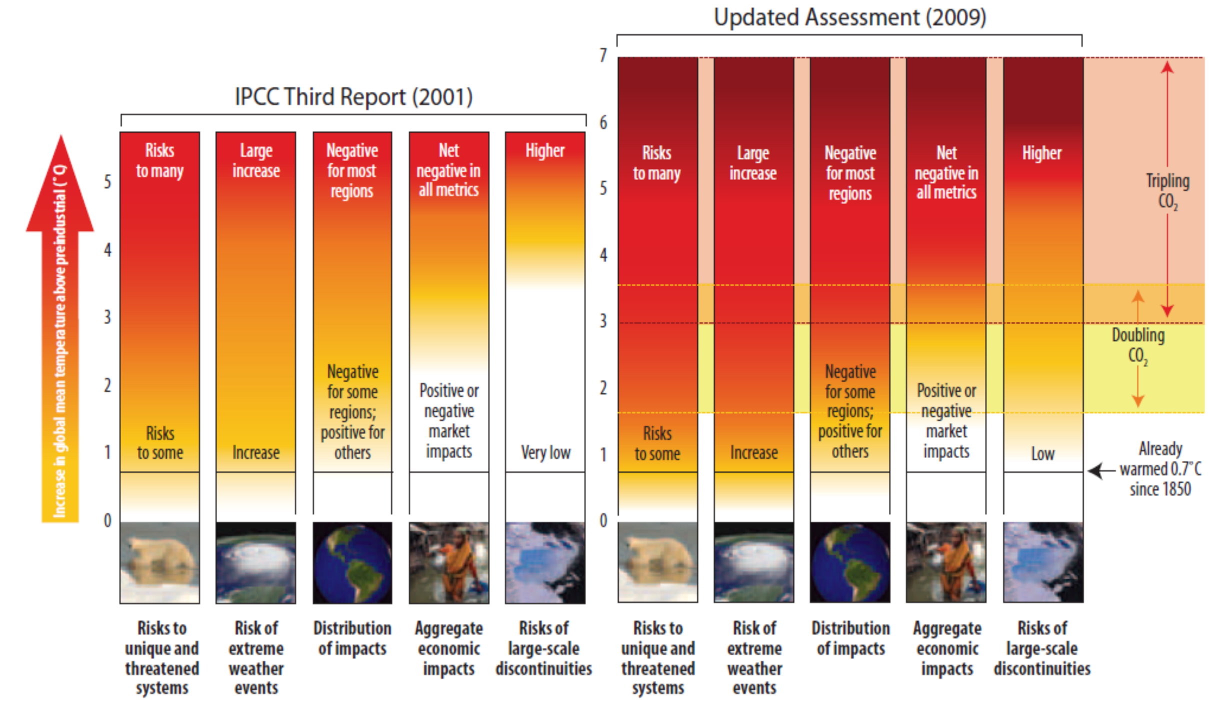
The IPCC AR4 further argued that reducing CO_2 emissions significantly is necessary to keep concentrations of carbon from rising above 450 ppm. The emissions reduction goal selected by the IPCC AR4 to keep accumulation below 450 ppm includes a 2050 target of reducing carbon emissions to 80 percent below 1990 levels by 2050 for developed economies. While an 80 percent reduction target is dramatic, scientific evidence emerging since AR4 has led James Hansen and many other scientists to argue that more aggressive emission reductions to stabilize carbon at a 350 ppm target.[120] Western Clean Energy Advocates (WCEA) endorsed the notion that western electricity sector planning should contribute its share to the global reduction requirement recommended in AR4.[121]

WCEA recognizes that setting a goal for the western electricity sector is not sufficient to stabilize global carbon emissions. However, WCEA stakeholders agreed that western states and provinces should act now to plan to meet their pro rata share of the goal as the West rather than waiting for the nation and the world to establish and implement carbon taxing and trading institutions. Given the potentially severe consequences of failing to address climate change, the western electricity sector should step forward to “do its part” toward meeting the global reduction goals.

Furthermore, setting the electricity sector target at the electricity sector pro rata share of emissions is a reasonable starting point. The WCI target leaves 2020 emissions in the West above 1990 levels, so the WCI goal is modest. However, on a state by state basis, some WCI partner states have adopted goals similar to the IPCC AR4 goals (California and Oregon) while other states have adopted more modest goals.[122] Western Climate Initiative (WCI) economic modeling of cap and trade completed in 2010 showed that electricity sector emissions reduction would contribute approximately its pro rata share of total western emissions.[123]

[120] Ackerman, et al. pp. 11-15.
[121] Western Clean Energy Advocates
[122] Ibid, p. 4.
[123] Western Climate Initiative, Updated Economic Analysis of the WCI Cap-and-Trade Program, July 13, 2010 Stakeholder Call, p. 12, shows that the electricity sector contributes 31% of the total emissions reduction in the West, and the electricity sector is currently responsible for about 33 percent of the West’s carbon emissions.

Figure 32: Effects as Temperature Increases Exceed 2 Degrees



Source: Adapted from Smith et al. 2009; Schneider 2009.

Continuing BAU electricity generation and consumption patterns in the West lead to increasing carbon emissions over time and thus the BAU trajectory clearly leaves the western electricity sector failing to do its part toward reducing carbon emissions. Potential implications of the world and the western electricity sector following BAU policies lead to the climate impacts that are described next.

Increased Temperature Impacts

The global average temperature since 1900 has risen by about 1.5°F. By 2100, it is projected to rise another 2° to 11.5°F.[124] The U.S. average temperature has risen by a comparable amount and is very likely to rise more than the global average over this century, with some variation from place to place regardless of the stabilization target. The average temperature in the Southwest has increased 1.5°F since 1960-1979; this is among the most rapid temperature increases reported on a regional basis in the U.S. and significantly higher than the global average.[125] By the end of the century, average annual temperature is projected to rise approximately 4°F (IPCC low emissions scenario) to 10°F (IPCC high emissions scenario) above the historical baseline, averaged over the Southwest region.[126]

The global warming trend observed in temperature measurements is confirmed in observations of sea ice and glacier melting. Reduced coverage of ice and snow on land allows more heat to be absorbed by land, which increases melting, resulting in a feedback loop. In the western U.S., increased temperatures

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[124] U.S. Global Change Research Program (USGCRP). 2009. Global Climate Change Impacts in the United States. Thomas R. Karl, Jerry M. Melillo, and Thomas C. Peterson, (eds.). Cambridge University Press, Cambridge, UK.

[125] Wehner, 2005

[126] USGRCP, 2009

are manifested in declines in spring snow pack, shorter ski seasons, reduced flows of major rivers (e.g., Colorado River), increased wildfire, and rises in sea level.

Developed areas along the western U.S. coastline will be vulnerable to increased landslides exacerbated by sea-level rise and the resultant increase in beach erosion. Coastal areas along the Puget Sound in Washington are especially vulnerable to rises in sea level, which are projected to rise locally up to 50 inches (approximately 4 feet) this century in areas that are concurrently experiencing rapid subsidence.[127]

Snowpack acts as natural water storage available for the warm season. With increasing temperatures, more precipitation falls as rain than snow and accumulated snow melts earlier. Earlier snow melt results in drastic changes to the timing of runoff; stream flow increases in winter and early spring and decreases in late spring, summer, and fall. Furthermore, increases in rain (rather than snow) result in increased winter stream flows and flooding as well as increased drought risk in summer from decreased water availability in snowpack. Related to the changes in runoff timing is the decrease in flow to major rivers.

Rising air temperatures increase evaporation and produce drier conditions (especially when accompanied by reduced precipitation, see subsection below). Drier conditions are exacerbated by earlier spring snowmelt. In the western U.S., the result has been an increase in the frequency of large wildfires and the length of the fire season.[128] Areas of the western U.S. particularly vulnerable to increases in the extent of wildfire include the Pacific Northwest and forested regions of the Sierra Nevada Mountains.[129]

Catastrophic forest wildfires have led to erosion, as soils are sterilized by extreme heat, and erosion has caused millions of dollars of damages to western municipal water collection systems. The water impacts of climate changes with regard to forests and water supplies are early indicators of how damaging and expensive climate change will be for the West.[130]

The 450 ppm stabilization target has the potential to keep the global temperature increase at or below approximately 3.5°F (1.9 °C) from pre-industrial levels and 2°F (1.1 °C) above the current average temperature.[131] Many concerns have been raised about dangerous climate repercussions occurring at temperature increases beyond these levels, which would likely occur under a business-as-usual scenario. Even an increase of 1°C, which is anticipated under the 450 ppm stabilization target, is predicted to increase the areas burned in parts of the western U.S. by 200 to 400 percent.[132] Additional warming (3°C to 4°C) is expected to result in the loss of approximately 250,000 square kilometers of wetlands and drylands, many millions more people at risk of coastal flooding from sea level rise, and approximately 9 of 10 summers hotter than the warmest summer experienced between 1971 and 2000.[133]

Changes in Precipitation Impacts

Future changes in precipitation are more difficult to predict than changes in temperature. The distribution of global precipitation is dictated, in part, by atmospheric circulation patterns, which are

[127] USGRCP, 2009
[128] Westerling et. al., 2006
[129] NRC, 2010
[130] The Denver Water system is currently spending millions of dollars to recover from forest fires and the resulting erosion. See: http://www.denverwater.org/Recreation/WatertonCanyon/FAQs/
[131] USGRCP, 2009
[132] NRC, 2010
[133] Ibid

influenced by temperature. Therefore changes in temperature, as described above, will result in changes in precipitation. Generally, higher latitudes are projected to receive more precipitation while drier zones located outside of the tropics are expected to both expand toward the poles and receive even less precipitation. As temperatures increase, precipitation events will be concentrated into heavier events with longer intervening dry periods.

In the United States, precipitation has increased 5 percent over the past 50 years.[134] In the western U.S., increases in the amount falling in very heavy precipitation events (heaviest 1 percent of all daily events) has increased 16 percent in the Northwest and 9 percent in California, Nevada, and the Southwest.[135] The current trend of less frequent but more intense precipitation events in the West is projected to continue. It is expected that northern areas will become wetter and southern areas, particularly in the Southwest, will become drier. Precipitation also generally decreased during the summer and fall in the Southwest, while winter and spring, which are the wettest seasons in most western states that depend on mountain snowpack, have had increases in precipitation. This trend of increased extremes of wet winters and dry summers is expected to continue and elevates the risk of droughts and floods.

In some northern areas of the western U.S., rising temperatures will result in more precipitation falling as rain and less as snow. However, any potential increase in water availability may not be realized due to projected increases in evaporation rates and runoff. Excessive runoff from heavy rain events that persist for weeks to months in large river basins often results in flooding.

Longer periods between rain fall combined with higher temperatures dry out soils and vegetation, causing drought and reducing soil productivity that depends on retained moisture. This is exacerbated by the incidence of earlier snowpack melt in the western U.S. The Southwest, in particular, is expected to experience increasing drought as changes in atmospheric circulation patterns cause the dry zone just outside the tropics to expand farther northward into the United States. The combination of drought and high temperatures has led to serious insect infestations in western U.S forests, in particular the piñon pine forests of the southwest, the lodgepole forests of the mountain West, and the ponderosa forests at lower elevations in mountains and foothills.

For every degree (°C) of temperature change above the current average temperature, the following changes in precipitation are anticipated.[136]

- A 3 to 10 percent increase in extreme precipitation (heaviest 15 percent of daily rainfall)
- the relative change in runoff would range from a decrease of 3.3 percent in California to 6.1 percent in Arizona and an increase of 1.2 percent in the Northwest

Although it is generally believed that local precipitation response scales with global mean surface temperature, inherent uncertainties due to several factors influencing local precipitation make accurately predicting changes in precipitation difficult. Extrapolating the NRC-modeled predictions above, it is expected that the predicted changes in precipitation (i.e., increased and more intense rainfall precipitation with drier intervening periods) and resultant runoff and drought would be exacerbated under the business-as-usual scenario as compared to the 450 ppm stabilization target adopted in the CEV.

[134] Karl et al., p. 27
[135] USGRCP, 2009
[136] NRC, 2010

Ecosystem Process Change Impacts

Physical changes in the environment (i.e., increased temperatures and changes in precipitation) and the resultant increases in sea level, drought, wildfires and flooding will affect ecosystems and human activities.

Society relies on ecosystem goods (e.g., food, building materials, medicines) and services (e.g., carbon capture, water filtration and flow regulation, local climate stabilization). The provision of these goods and services is made possible by healthy ecosystem processes, including photosynthesis, decomposition and nutrient recycling, and water cycling. These processes are affected by climate and the concentration of atmospheric carbon.

In general, temperature increases speed plant growth rates, decomposition rates, and nutrient cycling, although this is also influenced by availability of water. In the western U.S. where water is scarce, forest growth is expected to decrease and become increasingly vulnerable to insect infestation, which will adversely affect associated ecosystem processes. Particularly important forest ecosystem goods and services likely to be adversely affected by climate change are availability and quality of raw materials for wood and paper products, water collection systems and carbon sequestration. In the U.S., forests currently offset approximately 20 percent of U.S. fossil fuel carbon.[137] Degraded forests and the reduced functionality of this "carbon sink" coupled with increased carbon emissions under the BAU scenario would exacerbate the effects of climate change.

Biodiversity Impacts

Biodiversity, defined as the variety of all forms of life, maintains the ability of ecosystems to provide goods and services. Biodiversity is affected by climate and natural disturbances (e.g., fire); trophic interactions between competitors, predators, and prey; parasites and diseases; and human disturbances (e.g., development and habitat degradation). In conjunction with these stressors, climate change is exerting major influences on ecosystems and biodiversity, which have manifested in shifts in the timing of seasons as well as species distribution and abundance.

Evident shifts in the timing of the seasons have occurred over the past decade and are projected to continue. In the U.S., spring begins an average of 10 to 14 days earlier than 20 years ago.[138] Many plants and animals respond to a longer growing season by changing the timing of activities associated with the arrival of spring and onset of autumn such as flowering, leaf fall, breeding, and migration. A major concern for the wildlife species affected by climate change is the potential for disparity between the species and resources. For example, migrating species may arrive earlier at breeding grounds before vegetation has sprouted or insect food species have emerged or species may be forced to move into areas where adequate resources do not occur.

The geographic ranges of species are determined by climatic factors, including the temperatures and water stresses in which they can endure. Projected shifts in some species distribution and abundance scale approximately with temperature.[139] In the western U.S., species are generally shifting northwards in latitude and upward in elevation in response to climate change.[140] Distance to the nearest cool refuge

[137] USGRCP, 2009

[138] NRC, 2010

[139] Ibid.

[140] Graham and Grimm, 1990; IPCC, 1998

is of critical importance to a species being affected by climate change. Poor dispersers and cold-blooded species that have a maximum dispersal distance that is shorter than the distance to the cool refuge could be in danger of losing local populations or potentially extinction of entire species; man-made barriers (e.g., roads, development) exacerbate this risk. The habitats of some mountain species and coldwater fish, such as salmon and trout, are very likely to contract in response to warming. Invasive plant species are better adapted to the effects of climate change than most native plants because they can disperse easier, tolerate a wider range of environmental conditions and some respond with greater growth rates in the presence of excess carbon dioxide. Although some species have been able to shift their range in response to climate change, the long-term impacts of these shifts at the ecosystem level have not been assessed. Examples of species and resource assemblages in the western U.S. affected by climate change are presented in the technical appendix include coniferous forests, desert tortoise, sage grouse, and salmon.

The scope of future extinction events (e.g., types of species, geographic regions) caused by climate change will vary under differing stabilization targets. The Intergovernmental Panel on Climate Change estimated that if a warming of 3.5 to 5.5°F occurs as expected under a BAU scenario, 20 to 30 percent of species that have been studied would be in climate zones that are far outside of their current ranges, and would therefore likely be at risk of extinction.[141] The rate of temperature change under a BAU scenario in the next few decades could be higher than most species have experienced over past millennia. The species affected under a 450 ppm scenario would be those that are relatively more sensitive to the effects of rising temperatures and effects would occur under a more limited geographic scope than the BAU scenario.

Water Supply Impacts

Given that movement of water through the atmosphere and oceans is the major mechanism for redistribution of global heat, increased temperatures are expected to result in dramatic changes to the water cycle. For every 1°F increase in temperature, the water holding capacity of the atmosphere increases approximately 4 percent.[142] Altered patterns of atmospheric circulation and water holding capacity cause changes in precipitation that result in concentrated precipitation events with drier interim periods and changes in the seasonal availability of water, as described above.

In the western U.S., the water supply is generally expected to decrease. Groundwater is an important agricultural, industrial, and domestic water supply in parts of the western U.S. and in most areas is closely tied to surface water availability for recharge. Changes in precipitation and alterations in vegetation communities can affect the rate of infiltration to groundwater aquifers. Further, groundwater levels directly affect stream flow levels as streambeds are a primary recharge site.

Existing stressors on water supply in the western U.S. include rapid population growth, aging water supply infrastructure, and ongoing water rights disputes. Reduced availability of precipitation coupled with higher evaporation rates and higher temperatures will further pressure water demands in the western U.S.

Warming in western mountains is projected to cause decreased snowpack, earlier spring runoff, more winter flooding and reduced summer flows, exacerbating competition for over-allocated water resources. Future projections for most snowmelt-dominated basins in the West consistently indicate

[141] IPCC, 1998

[142] USGRCP, 2009

earlier spring runoff, in some cases up to 60 days earlier[143]. Earlier runoff produces lower late-summer stream flows, which stress human and environmental systems through less water availability and higher water temperatures. For every degree (°C) of temperature change above the current average temperature, the relative change in runoff would range from a decrease of 3 percent in California to 6 percent in Arizona and an increase of 1 percent in the northwest.[144]

Hydropower production is expected to be reduced due to lower river flows in the Pacific Northwest and the Sierra Nevada Mountains as well as the Colorado River.[145] The relationship between hydropower generation and precipitation tends to be proportional, with a 1 percent change in precipitation resulting in approximately 1 percent change in power generation.[146] However, predicting the effects of climate change on hydropower generation is limited by uncertainties in precipitation projections. For example, recent projections of hydropower generation in the Sierra Nevada Mountains of California ranged from -10 percent to +10 percent and +2 percent to -30 percent in the Pacific Northwest, depending on the assumed precipitation projections.[147]

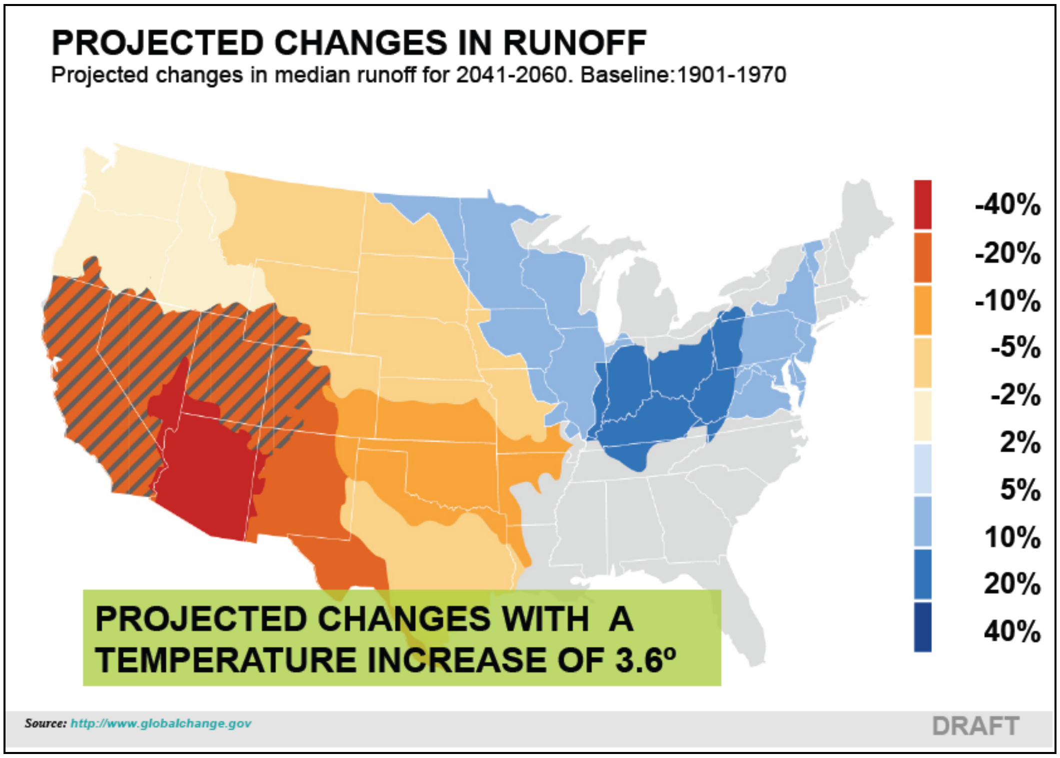
In addition, efficiency and operability of other thermal electricity generation technologies (e.g. fossil-fuel fired power plants) will be adversely affected by the projected reduced availability of water for cooling and increased temperatures of cooling water. In the western U.S, the use of cooling water for power plants in arid regions has proven to be a contentious environmental issue.

The arid southwestern U.S. is projected to experience longer and more severe droughts from the combination of increased evaporation and reductions in precipitation. Effects include:

- Hydropower production is expected to be reduced due to lower river flows, including the Colorado River, as discussed above.
- By 2050, it is projected that scheduled Colorado River water deliveries (at current levels) would be missed nearly 60 percent of the time with a 10 percent flow reduction, and 88 percent of the time with a 20 percent reduction. For long-term sustainability, a reduction of up to 20 percent of current scheduled deliveries would be required.[148]
- Lake Mead has a 50 percent chance of running dry by 2021 if climate change and future water use are not abated.[149]

Figure 33: Projected Changes in Water Runoff

[143] Stewart, I.T., D.R. Cayan, and M.D. Dettinger. 2004. Changes in snowmelt runoff timing in western North America under a 'business as usual' climate change scenario. Climatic Change 62(1-3): 217-232.
[144] National Research Council (NRC), 2010
[145] This issue is discussed more in the Technical Appendix.
[146] USGRCP, 2009
[147] Vicuña et al. 2008; Markoff et al. 2008
[148] Barnett T.P. and Pierce D.W. 2009. Sustainable water deliveries from the Colorado River in a changing climate. Proceedings of the National Academy of Sciences of the United States of America. http://www.pnas.org/content/106/18/7334.full.pdf+html
[149] Ibid


PROJECTED CHANGES IN RUNOFF
Projected changes in median runoff for 2041-2060. Baseline:1901-1970
-40%
-20%
-10%
-5%
-2%
2%
5%
10%
20%
40%
PROJECTED CHANGES WITH A TEMPERATURE INCREASE OF 3.6º
Source: http://www.globalchange.gov
DRAFT

10. Energy Security Performance

The 2009 U.S. Army Energy Security Implementation Strategy asserts, "Given the Army's reliance on energy, disruption of critical power and fuel supplies would harm the Army's ability to accomplish its missions. Such a risk exposes an Army vulnerability that must be addressed by a more secure energy position and outlook."[150] Just as the mission of the armed forces is affected by stable, reliable energy supplies, maintaining a high quality of life in the West is affected by energy security. Energy security in the West is, in turn, affected by the available of reliable and reasonably priced electricity.

Chapter 10 Overview: Energy Security Performance

Electric Generation Fuel Security:

Natural gas supply and price have been subject to volatility over the last 30 years and volatility is likely to continue. While hydraulic fracturing and new discoveries in North America are expected to increase natural gas supply, environmental and public health uncertainties surrounding fracking may limit its application. Furthermore, the natural gas industry is global and international events can affect supply and price in North America. Coal supply and price is likely to be stable until the full environmental, public health and carbon costs of coal are reflected.

Transportation Fuel Security:

Oil and gas supply is subject to market volatility and international tensions. Electrification of the transportation sector enhances energy security in the West but changes in the electric system will be needed to accommodate high penetrations of plug-in hybrid and electric vehicles. The CEV implements the information, communication and control system infrastructure that facilitates system flexibility and thus facilitates high penetration of electric vehicles.

Competitiveness and Energy Security:

Energy security in the West depends on the competitiveness of the U.S. energy sector in innovating and implementing state of the art electric industry technologies. Being on the leading edge of manufacturing electric industry technologies enhances security by reducing our dependence on international suppliers. Being on the leading edge of implementing state of the art technologies enhances the competitiveness of all electricity using industries and thus increases energy security by enhancing standard of living.

[150] U.S. Army, 2009, U.S. Army Energy Security Implementation Strategy, p. i

The purpose of this chapter is to explore the relative merits of BAU and CEV trajectories in providing an electric supply that enhances energy security for the West. The electric system affects energy security performance in the West in three ways and this chapter addresses each.

The three areas of energy security performance explored are the capacity of the electric system to provide energy security by: (1) ensuring that the fuel supplies necessary to run the electric system are secure; (2) facilitating transportation sector electrification and thus reduces western dependence on imported oil; and (3) supporting global competitiveness by providing western businesses with cost effective supplies and leading edge technology innovation.

Generation Fuel Supply and Energy Security

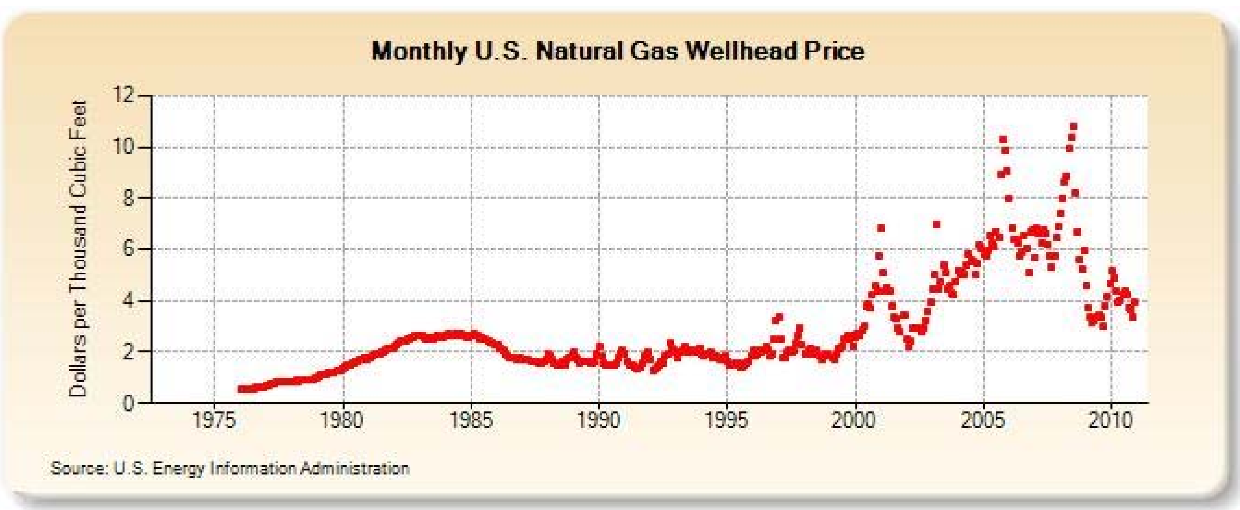
BAU and CEV generation portfolio differences indicate differenced in dependence upon fuel supplies. BAU relies on coal and natural gas to a greater extent. The U.S. has a large supply of domestic coal reserves, and prices for coal will stay down as long as externalities are not priced. Thus coal supply is likely to be uninterrupted.

BAU also relies on expanding natural gas use in the U.S. By 2030, the BAU natural gas requirements for electric generation in the West are more than double current requirements. While some express optimism that recent discoveries and hydraulic fracturing will lead to stable, low natural gas prices for decades, the environmental impacts of hydraulic fracturing on a large scale are not known and thus uncertainty persists.

Furthermore, natural gas has become a global market and history has shown that supply shocks and price volatility do occur. Figure 34 shows the recent history of natural gas wellhead prices in the U.S.

Generation sources that do not rely on fossil fuels do not face these supply interruption and price volatility challenges. Renewable energy sources face the challenge of overcoming variable generation issues and the CEV approach for addressing these challenges was discussed in Chapter 6.

Figure 34: Monthly Natural Gas Wellhead Price History



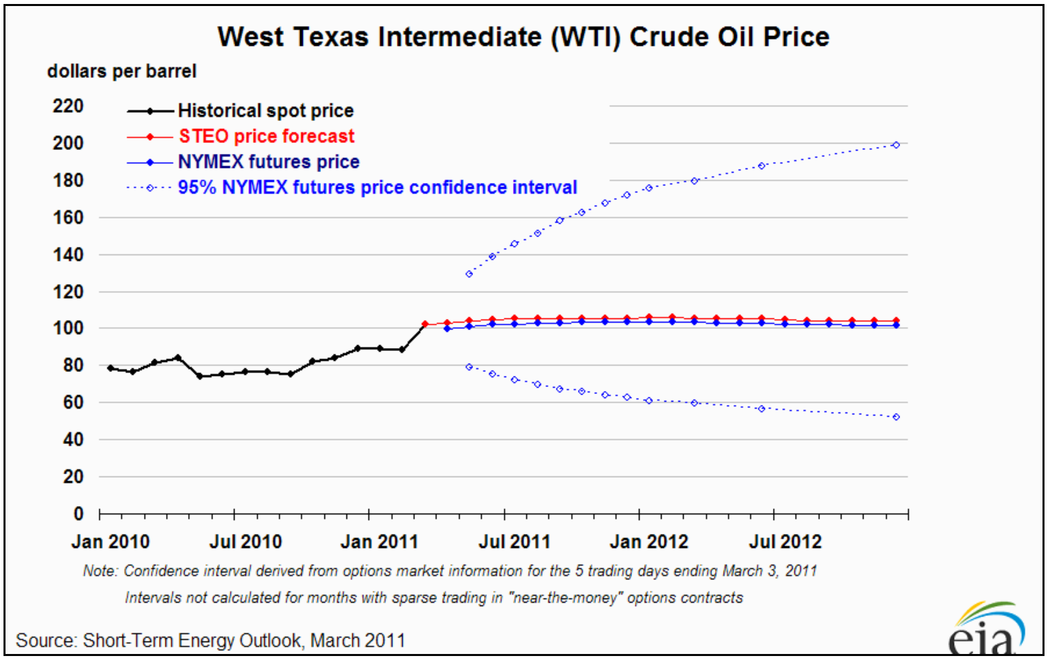
Electrification and Energy Security

Oil Dependence is a Source of Insecurity

Oil supply and price volatility can be expected to continue for the foreseeable future. Recent run-ups in the price of crude oil and gasoline shown Figures 35 and 36 below are reminders that the West is vulnerable to world events.

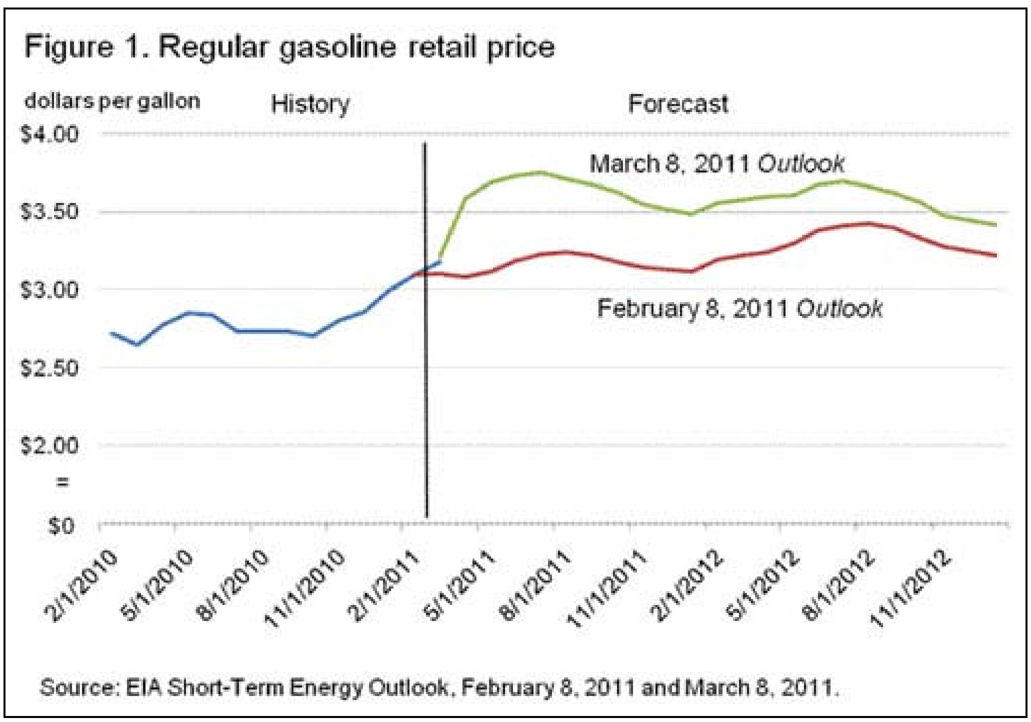
Note from Figure 35 that the price range shown for oil in July 2012 ranges from $60 to $180 per barrel, with an expected price at about $100. Figure 36 shows how the run-up in oil prices translates into gasoline prices. The high price and the wide range illustrate the vulnerability of being dependent on oil and gasoline.

Figure 35: Range of Projected Oil Prices



Source: U.S. Energy Information Administration, Short-Term Energy Outlook.

Figure 36: Recent Retail Gasoline Prices and Year Ahead Price Forecast



Source: U.S. Energy Information Administration, This Week in Petroleum, published Wednesdays after 1:00 pm EST.

Center for Naval Analysis Advisory Board Member quotes:

"The nation's heavy use of fossil energy leaves American unacceptably vulnerable to hostile nations and is detrimental to foreign policy." — ***CNA Military Advisory Board***

"Given the Army's reliance on energy, disruption of critical power and fuel supplies would harm the Army's ability to accomplish its missions. Such a risk exposes an Army vulnerability that must be addressed by a more secure energy position and outlook." ***— 2009 Army Energy Security Implementation Strategy***

"Using energy wisely is the cornerstone of building an Air Force capable of complete air domination, for today, tomorrow and beyond." — ***Air Force Energy Plan 2010***

"The Air Force continues to aggressively pursue cleaner sources of energy. Sustainable installations provide an operational advantage to our force and, needless to say, we are excited by the momentum in this arena." — ***Maj. Gen. Timothy, Air Force Civil Engineer***

"Addressing the consequences of changes in the Earth's climate is not simply about saving polar bears or preserving the beauty of mountain glaciers. Climate change is a threat to our national security. Taking it head-on is about preserving our way of life." —**retired Navy Vice Adm. Lee F. Gunn**

The Center for Naval Analysis Board includes retired military brass from each branch of military service and in 2009 they produced a report emphasizing the importance of energy independence to national security. In particular, several board members emphasize their concern over addressing dependence on petroleum products. The quotes above summarize the views of several board members.

The importance of managing the risk of fossil fuel supply and price is further evidenced by the active U.S. Department of Defense taking concrete action to diversify its electricity supply away from fossil sources. For example, the Department of Defense has begun placing potential for supply disruption and price spikes of fossil sources. One example of a recent installation is featured below.

A robust, sophisticated electric system with state of the art technologies will position the U.S. to accommodate high penetrations of electric vehicles and thus will speed our insulation from world petroleum politics.

Competitiveness and Energy Security

As emphasized in Chapter 8, the CEV trajectory depends on innovation and staying on the leading edge of technology. Chapter 8 emphasized the benefits of being an innovator in creating jobs. This section notes that being an innovator is also important to national security.

The CEV trajectory relies on new information, distribution and transmission infrastructure which keeps US on leading edge of electricity system technologies. These innovations have importance for maintaining our economic leadership, for developing greater energy security as we learn to use more resources that do not need fossil fuels and for spawning new innovations in sectors outside the electricity sector.

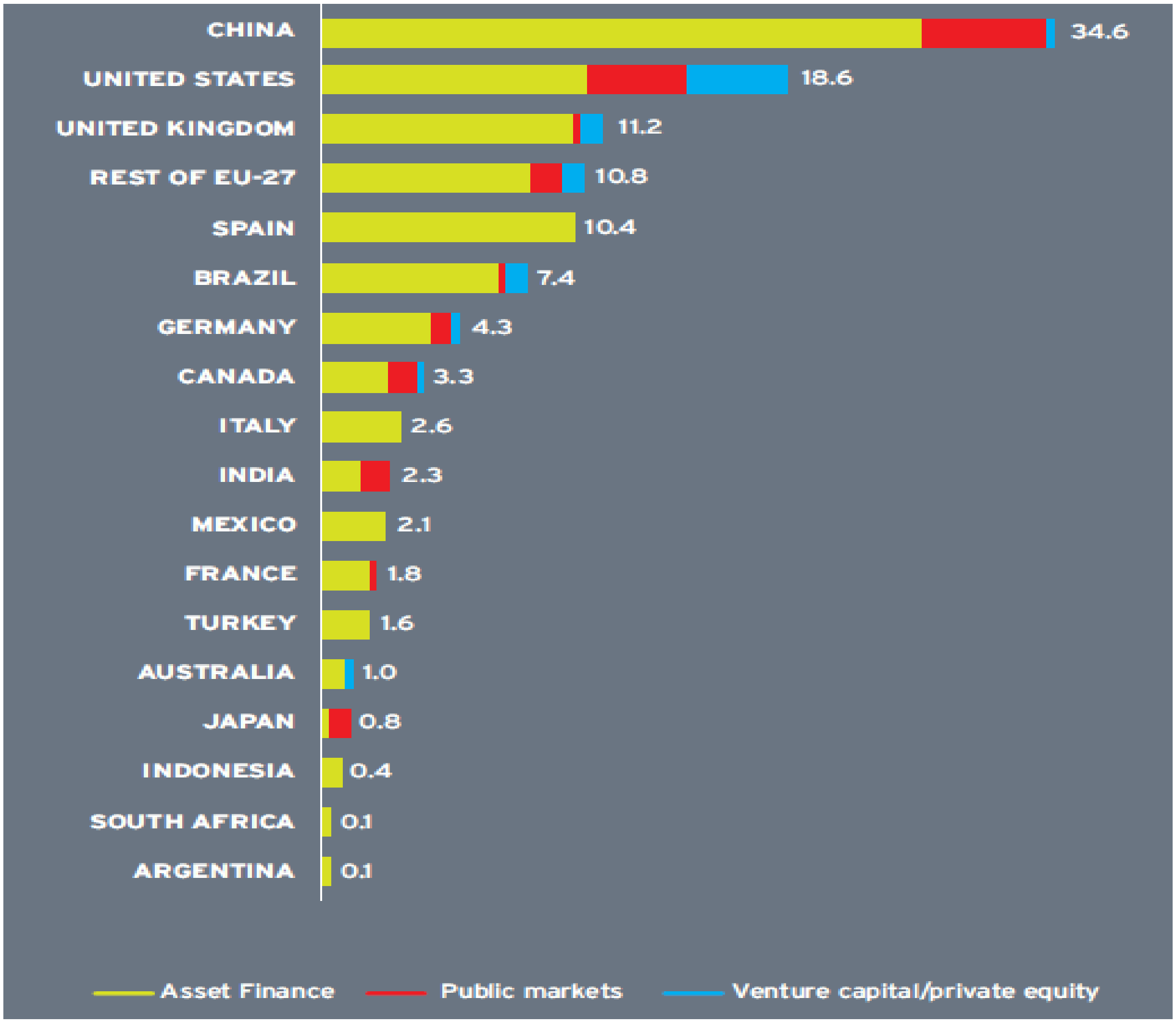
The Department is increasing its use of renewable energy supplies and reducing energy demand to improve operational effectiveness, reduce greenhouse gas emissions in support of U.S. climate change initiatives, and protect the department from energy price fluctuations.

- ***DoD's 2010 Quadrennial Defense Review Report***

The importance of obtaining and keeping a leadership position in renewable energy technologies is evidenced by the increasing importance of the clean energy sector in the world economy and the aggressive pursuit of the market by other nations.

While the West has increased its investment in clean energy technologies over the last few years and WECC expects about 17 percent of western energy needs to be met by renewable resources by 2020, the U.S. needs to re-focus its efforts on winning market share in the global clean technology sector competition. While the increased penetration of renewable energy is a good start, the U.S. fell out of the top ten countries in investment per capita in clean energy in 2009, and Figure 37 shows that United States has been passed by China in the total annual investment in renewable energy. The CEV increases U.S. investment in distributed generation, demand reduction and large scale renewable energy technologies which would give the U.S. industry an opportunity to reach a critical mass in size and scope that could improve its international competitiveness. Further, being on the leading edge of clean technology and smart grid implementation could provide U.S. industry with the opportunity to gain competitiveness through innovation.

Figure 37: Billions of Dollars of Investment in Renewable Energy Technologies, 2009.



Source: PEW Center Report, "A 2.3 Trillion Dollar Opportunity." Expand figure to the right so numbers are cut off.

11. Public Health Performance

The last three chapters have evaluated the economic performance, environmental performance and energy security performance differences between BAU and CEV development trajectories. Each chapter addressed the direct impacts of trajectory development as well as the climate change induced impacts. This chapter similarly looks at the direct public health impacts of development alternatives as well as the climate induced impacts. This chapter is similar to Chapter 9 except rather than focusing on the effects of BAU and CEV development trajectories on environmental performance, this chapter focuses on the public health effects of different trajectories.

Fossil emissions are a primary source of public health impacts in the electricity sector so this chapter will start by focusing on the direct impacts of fossil emissions on public health. The factors affecting public health include mercury poisoning, ozone depletion, decreased agricultural production, diminished water supply and quality and a host of other issues.

Chapter 11 Overview: Public Health Performance

BAU vs. CEV Direct Public Health Impacts:

Fossil fired electric generation has direct air and water quality impacts and these impacts affect public health. The relative public health impacts of the BAU and CEV trajectories are primarily driven by differences in generation. Conventional coal generation produces mercury emissions that affect air and water quality and, in turn, affect public health. Coal generation also emits SO_2, NOx and $PM_{2.5}$ fine particulate emissions and these particulates have impacts on public health.

BAU vs. CEV Potential Climate Change Induced Public Health Impacts:

- Water Quality and Supply: Climate change impacts vary by region within the West but it is likely that some regions will experience reduced water supply, increased drought, intense rainfall that contaminates some water supplies and eutrophic conditions in some locations due to reduced flows.
- Food Production: Climate scientists disagree on the impact of climate change on food production. In some regions of the world, CO_2 accumulations will encourage growth but in other regions heat stress and changes in ecosystems will stunt growth.
- Disease Impacts: Pathogens transmitted by food, water, or animals are susceptible to changes in replication, survival, persistence, habitat range, and transmission as a result of changing climatic conditions such as increasing temperature, precipitation, and extreme weather events.
- Heat Impacts: If carbon accumulation continues unabated, approximately 9 of 10 summers will be hotter than the warmest summer experienced between 1971 and 2000. Since heat is the leading cause of weather-related death in the U.S., increased weather related mortality is likely.

The second part of the chapter discusses how continuing high carbon emissions and the climate change will affect public health.

Public Health Impacts of Air Quality Degradation

Emissions levels vary greatly between BAU and CEV scenarios. BAU development of the western electric grid will keep coal fired generation at levels similar to present levels and will expand natural gas fired generation. Fossil generation has direct impacts on health by way of particulate air emissions and mercury emissions.

Coal fired generation is the largest source of mercury emissions, contributing 65 percent of all mercury emissions, and continued operation of coal fired generation without mercury mitigation will lead to continued mercury poisoning of lakes and wildlife.[151]

Exposure to mercury can lead to an array of health problems, including sensory impairment in vision, speech and hearing, lack of coordination, asthma attacks, respiratory disease, heart disease, and increased risk of cancer. It is especially harmful to pregnant women and young children because it penetrates the nervous system and causes developmental disorders. In young children, exposure can retard cognitive development and stunt lung growth. A fetus loses 1.5 IQ points for every doubling of mercury exposure. This is cause for concern, as roughly 16 percent of women of childbearing age have unsafe levels of mercury in their blood, and between 300,000 and 600,000 children are at risk for sever neurological and developmental disorders annually because of mercury exposure.[152]

Fine particulate matter is another concern. Fine particles consist of either soot emitted directly from combustion sources or formed in the atmosphere from power plant sulfur dioxide (SO_2) or nitrogen oxides (NOx) emissions. It is problematic because it can bypass the body's defensive mechanisms and become lodged deep in the human lung.[153] Because of this, It is estimated that small particulate matter (specifically, $PM_{2.5}$) from coal plants resulted in nearly 24,000 premature deaths, 38,200 heart attacks, 554,000 asthma attacks, 21,850 hospital admissions, 26,000 emergency room visits and 3,186,000 lost work days throughout the U.S in 2004.[154]

The American Lung Association reports that over 92 million Americans live in areas with unhealthy levels of particulate matter, and more than 52 million live in areas where these harmful levels persist year-round. This can lead to asthma attacks, lung tissue damage, stroke, heart attack, and premature death.[155] These problems are not exclusive to individuals with long-exposure. Even short-term exposure to fine particulate matter can lead to increased risk of heart attack.[156]

Life expectancy is shorter in cities with high levels of pollution. It is estimated that fine particulate matter reduces the average life span of the general population by a few years.

Conventional coal power plants have a large impact on mortality according to Figure 38 below, which reports the Clean Air Task Force findings on power plant mortality per 100,000 adults. The areas with the largest mortality risk are concentrated in regions with the highest concentration of coal plants.[157]

Reducing coal fired generation should provide benefits to public health. The Clean Air Task Force updated previously mentioned health statistics for 2010. Their study takes into account emissions

[151] NCS, p.38
[152] Natural Capital Solutions, P. 38
[153] Clean Air Task Force, p. 8
[154] NCS, p. 40
[155] Ibid.
[156] CATF, p. 8
[157] CATF, p. 11

reductions from regulatory changes. This includes the 2005 Clean Air Interstate Rule (CAIR), despite the fact that it was struck down in 2008, because the CAIR requirements remain in place until the Environmental Protection Agency (EPA) issues a replacement rule. With the new measures in place, the Task Force finds that the number of premature deaths is reduced to 13,200, hospitalizations to 9,000 and heart attacks to 20,000 in 2010.[158]

Though the decrease in health problems discussed in the report spans a six year period, the effects of coal reduction on public health will be immediate, as most fine particle-related deaths occur within two years of exposure.[159]

A recent Synapse study reiterated the benefits of reducing coal generation. It showed the health benefits of transitioning 30 percent of Utah's coal fired generation to clean energy sources. The benefits identified by Synapse include:

- Preventing 101 premature deaths each year
- Preventing 70 asthma related emergency room visits each year
- Saving about $850 million dollars over the life of the coal plants in reduced health care costs

Increased emissions, temperatures and associated air stagnation are also expected to increase ground-level ozone, which is a component of smog and a human health risk. Inhaling ozone has been demonstrated to decrease short-term lung function and damage lung lining, thereby increasing asthma-related hospital visits and premature death. Those who spend more time outdoors with physical exertion, namely children, outdoor workers and athletes, are the most susceptible to ozone-related health effects.

The rise in ground-level ozone and subsequent health risks can be avoided if clean energy sources replaces fossil sources. The map shown in Figure 39 projects changes in ground-level ozone at the end of the century relative to 1996-2000 for the high and low emissions scenarios. It is clear that the change in ground-level ozone is significantly higher in the higher emissions scenario, but more importantly, the map shows that ozone levels actually decrease overall when under a low emissions scenario.[160]

[158] CATF, p. 5
[159] CATF, p. 8
[160] Karl et al., p. 92

Figure 38: Power Plant Mortality Per 100,000 Adults[161]

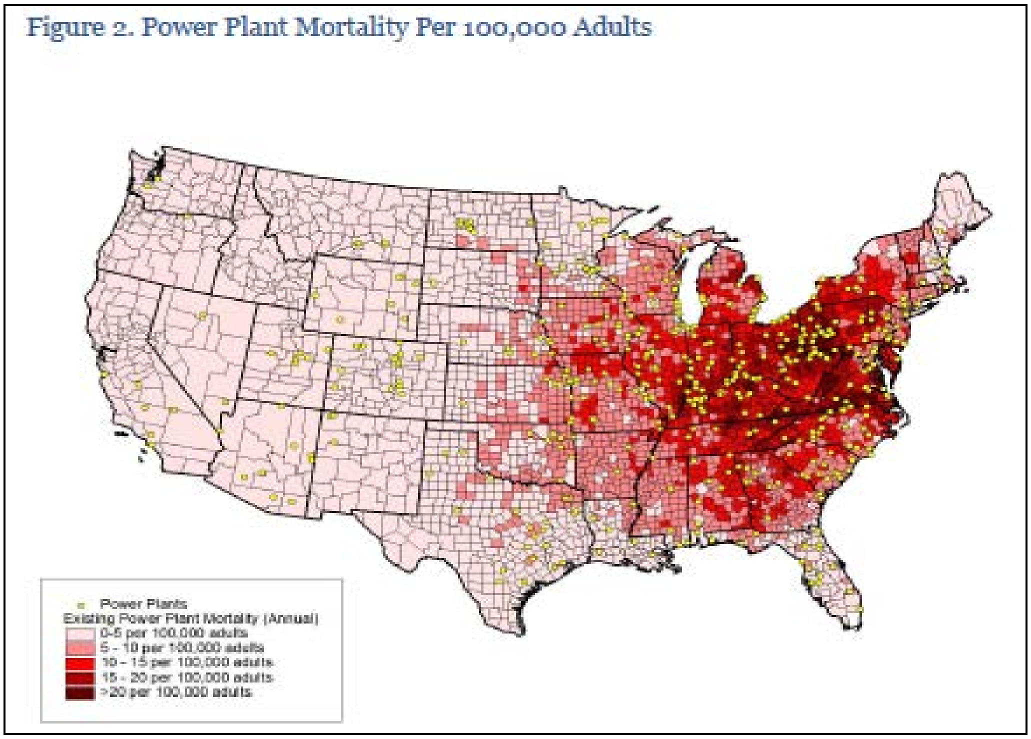
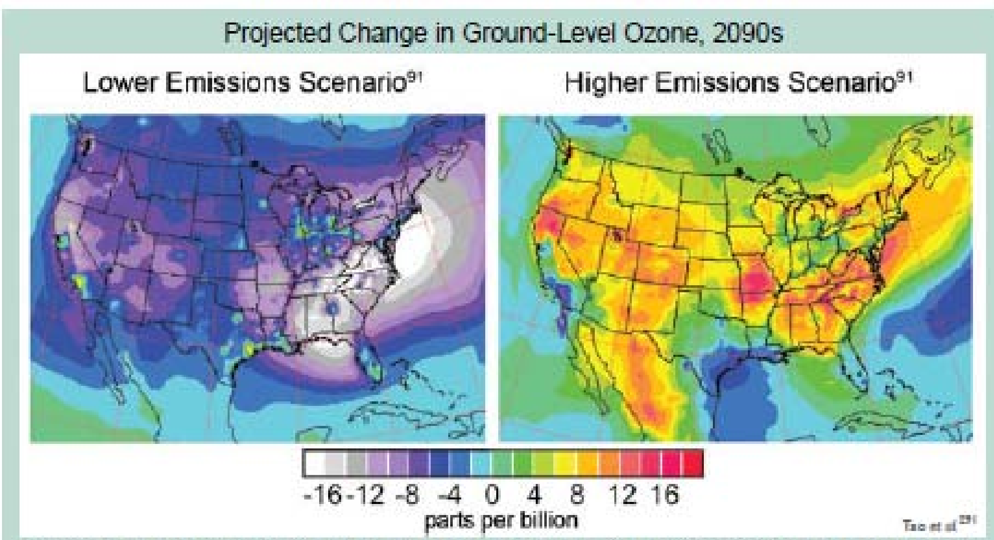


Figure 39: Projected Change in Ground Level Ozone, 2090s[162]



The maps show projected changes in ground-level ozone (a component of smog) for the 2090s, averaged over the summer months (June through August), relative to 1996-2000, under lower and higher emissions scenarios, which include both greenhouse gases and emissions that lead to ozone formation (some of which decrease under the lower emissions scenario).[91] By themselves, higher temperatures and other projected climate changes would increase ozone levels under both scenarios. However, the maps indicate that future projections of ozone depend heavily on emissions, with the higher emissions scenario[91] increasing ozone by large amounts, while the lower emissions scenario[91] results in an overall decrease in ground-level ozone by the end of the century.[391]

[161] CATF, p. 11
[162] Karl et al., p. 92

Public Health Impacts of Climate Change

As discussed previously in Chapter 9, a BAU scenario, in which carbon levels go unchecked, has had and will continue to have severe consequences for the global climate. This section covers some of the same ground as that covered in Chapter 9 but in this Chapter the focus is on impacts of climate change on public health.

In the 20th century, the U.S. department of the Interior reports that temperatures have increased throughout the Western U.S., particularly in basin areas, in which temperatures have increased approximately 2 degrees Fahrenheit. Globally, it is predicted that average temperature will increase by more than 5-6 degrees Celsius if emissions are left unchecked.[163] Such drastic changes in climate will have profound impacts on agriculture, water, pathogens and ultimately human health.

Direct impacts to human health from the physical effects of climate change include exposure to heat waves, hazard-related deaths from severe storms, respiratory ailments caused or exacerbated by air pollution and airborne allergens, and exposure to climate-sensitive infectious diseases. The effects of these human health risks will also be influenced by demographic characteristics including age and fitness level.

On its own, heat will lead to increased pollutants. Higher temperatures increase the natural emissions of volatile organic compounds (VOCs), accelerate ozone formation, and increase the frequency and duration of stagnant air masses that allow pollution to accumulate. This will further increase health problems associated with pollution. By 2050, it is predicted that warming will cause the number Red Ozone Alert days in the 50 largest cities in the Eastern U.S. to increase by 68 percent.[164]

Water Supply Degradation

Water is the driving force for all life on earth. It is essential for economic development, food production, and above all else human health. Continuing on a business as usual trajectory will increase emissions and temperatures in such a way as to dramatically impact the quality, quantity, and location of the earth's water sources.

As previously discussed in Chapter 9, water resources in the West have already felt the effects of climate change. There is a long-term downward trend in snowpack and shifts towards earlier spring runoff. For example, there is currently, an 11-year drought in the Colorado River Basin has left two main reservoirs of the river, which provides water to 30 million individuals and 1.4 million acres of farmland, at 55 percent of total capacity.

If climate change persists as projected, these problems will be amplified. The west will be drier and hotter. As a result, the duration and intensity of droughts will increase.

Climate change is also expected to increase the incidence of heavy rain events in some areas, leading to increased risk of waterborne disease, and reduce rainfall in the southwest region. As this is the region with the highest projected rate of population growth to 2025, future water levels may not be sufficient to meet demand.[165]

[163] U.S. Department of the Interior. p. vii
[164] Karl et al., p. 94
[165] Karl et al., p. 50

In addition to impacting supply, climate change could potentially alter water temperature, flow, runoff rate and timing, all of which affect water quality. Surface water ecosystems may experience decreases in their ability to remove pollutants and improve water quality.[166] If water temperatures rise, algae will increase and lead to eutrophic conditions in lakes and poor water quality and ultimately affecting public health.

Food Production Productivity

It is estimated that a BAU scenario, in which temperatures increase by 2.4 degrees Celsius, will have positive impacts on agricultural production in some areas of the world, such as Central and South Asia and northern Europe, where warmer climate is expected to increase crop yields by 5 percent. However, the overall impacts on crop yields from a BAU scenario are negative, as the decreases in agricultural output in other, more populated regions of the world will more than offset these gains.[167]

The IPCC reiterated the notion that impacts of climate change on agriculture would vary by region. They claim that climate change would likely be harmful to agriculture in the tropics and beneficial to colder regions in the Northern Hemisphere. However, they and many other scientists argue that increased carbon dioxide would offset the problems caused by temperature increases. The reasoning is that increases in CO_2 will increase yields for some crops because CO_2 is the primary fuel for plant growth. This is known as the carbon fertilization effect.

More recent research by scientists at the University of Illinois argues that the IPCC overestimates the positive impact of CO_2 on crop yield. They find that additional CO_2 increases soy bean crops by roughly 15 percent, half the amount purported in previous research. Additionally, they find no bump in yields for corn. They conclude that the benefits of CO_2 will not outweigh the negative effects of climate change on agriculture.[168]

When temperatures move beyond a certain threshold (84 degrees for corn and 86 degrees for soybeans), yields decline drastically. Thus, the predicted climate for the U.S. at the turn of the century could cause crop yields to decrease by 30 percent or more.[169]

This decrease in food production, coupled with increases in population will lead to increases in food prices in the future. In fact, Scientists estimate that a 2.4 degree C increase in temperature will lead to a 20 percent increase in global agricultural prices. This will have the greatest impact on those in developing countries, who spend a larger proportion of their income on food than those in developed countries. As a result, the share of hunger could increase to one in five people.[170] A further temperature increase to 3 degree Celsius increase would cause 1-3 million people to die from malnutrition.

Observed Disease Impacts

Pathogens transmitted by food, water, or animals are susceptible to changes in replication, survival, persistence, habitat range, and transmission as a result of changing climatic conditions such as increasing temperature, precipitation, and extreme weather events. Examples include: tick populations carrying Rocky Mountain fever shifting from south to north; food poisoning outbreaks from *Salmonella* coinciding with extreme heat events; infection by waterborne *Cryptosporidium* and *Giardia* following

[166] Karl et al., p 123
[167] Hisas, p. iii
[168] Gillis, p. 4
[169] Gillis, p. 4
[170] Hisas, p. 35

heavy downpours or flooding; and potential proliferation and range shifts of the vectors for West Nile virus, equine encephalitis, Lyme disease, and hantavirus.[171] Exposure to malaria will also increase dramatically as temperatures increase. Up to 80 million more people in Africa will be exposed to malaria if temperatures rise by 4 degrees Celsius.

Observed Heat Impacts

The heat itself will pose direct risks to human health. If carbon accumulation continues unabated, approximately 9 of 10 summers will be hotter than the warmest summer experienced between 1971 and 2000.[172] Resultant increases in the risk of illness and death from extreme heat and heat waves are highly likely. Heat is the leading cause of weather-related death in the U.S. Between 1999 and 2003, there were over 3,400 heat related death, and these numbers are projected to increase as temperatures rise. By the end of this century it is estimated that annual heat-related deaths in Los Angeles will increase by two to three times under a lower emissions scenario and by five to seven times under a higher emissions scenario, compared to a 1990s baseline. This projection assumed that people will become acclimated to higher temperature over time; without such acclimation, estimates are projected to be about 20 to 25 percent higher.[173]

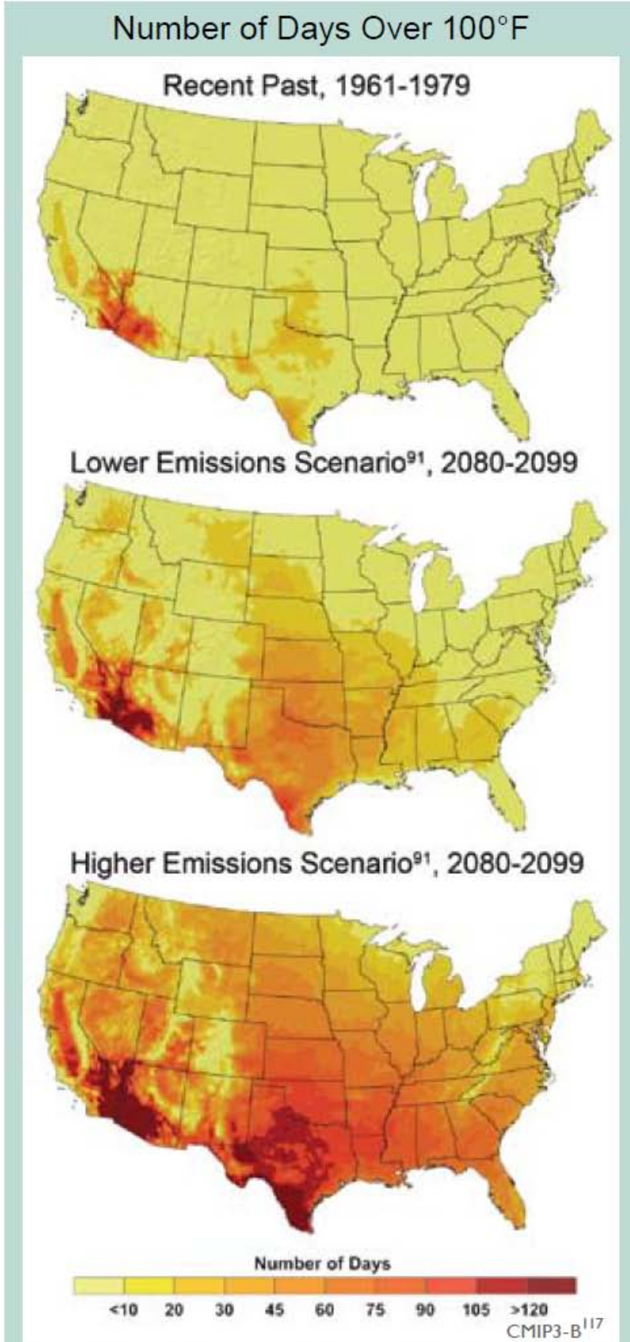
The increase in heat related deaths will be partially offset by the decrease in deaths due to extreme cold. The magnitude of this decrease is unknown, but research on deaths in 50 U.S. cities between 1989 and 2000 suggests that, on average, extreme cold spells increased death rates by 1.6 percent and extreme heat waves by 5.7 percent. Thus, the decrease in cold-weather deaths will not offset the increase in heat related deaths.[174]

In contrast, reducing carbon levels and emissions in a CEV scenario will limit the increase in extreme heat events. The figure below compares days in which the temperature exceeds 100 degrees Fahrenheit historically to high and low carbon scenarios at the end of the century. While the number of 100 degree days increases in both scenarios, the frequency of such days is significantly less in the lower emissions scenario.[175]

Extreme weather events caused by climate change have adverse physical and mental human health effects. Severe storms, flooding and wildlife have resulted in injury and mortality as well as destruction of property and are expected to continue under a BAU case. The 2005 hurricane season resulted in the deaths of over 2,000 Americans. This is double the average amount killed in hurricanes over the 65 years prior. Many more were left injured and homeless. Many hurricane evacuees experience stomach and intestinal illness. Beyond that, portable electric generators used after hurricanes can lead to carbon monoxide poisoning.[176]

[171] Karl et al., p. 96
[172] NRC, 2010
[173] Karl et al., p. 91
[174] Karl et al., p. 92
[175] Karl et al., p. 90
[176] Karl et al., p. 94

Figure 40: Number of Days Over 100 F



The number of days in which the temperature exceeds 100°F by late this century, compared to the 1960s and 1970s, is projected to increase strongly across the United States. For example, parts of Texas that recently experienced about 10 to 20 days per year over 100°F are expected to experience more than 100 days per year in which the temperature exceeds 100°F by the end of the century under the higher emissions scenario.[91]

The residual emotional effects of these events are also of importance. After the fact, many survivors suffer from depression and post-traumatic stress disorder.[177]

Like hurricanes, the incidence of flooding been increasing and is projected to continue doing so if climate change persists. In the past century alone, the amount of rainfall falling in the heaviest 1 percent of rain events increased by 20 percent.[178] Flooding caused by such heavy downpours leads to injuries and increased incidence of waterborne diseases. Additionally, flooding can cause sewage systems to overflow, which contaminates drinking and beach water.

These problems will be especially severe and frequent in the 770 U.S. cities and towns with "combined sewer systems". These systems carry storm and sewage water in the same pipe. As a result, they spill raw sewage into beaches, lakes, and drinking water supplies, endangering all people who come into contact with the contaminated water sources. If warming persists, the frequency of overflow in Chicago will increase by 50 to 120 percent by the end of the century.[179]

Warming has also increased the number of wildfires in the U.S. There has been roughly a 400 percent increase in the number of wildfires in the Western U.S. over recent decades. The fire season has increased in length. Continuation of this trend will lead to an increase in death and fire related injuries as well air pollution leading to eye and respiratory illnesses.[180]

As with agricultural production, the adverse effects on human health will be most severe in developing countries. These nations often lack proper emergency response systems and sanitation.

Flooding, along with droughts and rising sea levels, will also cause many previously inhabited areas to become uninhabitable. Stern predicts that by the middle of this century, 200 million people will have become permanently displaced. These individuals will be forced to migrate to areas with sufficient water supplies.

Summary of Public Health Impacts

The public health impacts of BAU versus CEV are summarized in the following tables.

Table 36: Climate Impacts of BAU vs. CEV

[177] Karl et al., p, 94
[178] Ibid.
[179] Karl et al., pp. 94-95
[180] Karl et al., p. 95

<table>
<tr><th>BAU</th><th>CEV</th></tr>
<tr><td colspan="2" align="center">Climate</td></tr>
<tr><td colspan="2" align="center">Food Production Productivity</td></tr>
<tr><td>• Additional CO_2 will increase yields of some crops because it is the primary fuel for plant growth.
o Increases soy bean yields by approximately 15 percent[181]
o Some yield increases are expected in the Great Plains[182]
▪ Negative impacts of CO_2 will likely outweigh benefits
▪ temperatures above a certain threshold (84 degrees for corn and 86 degrees for soybeans) cause yields to fall dramatically[183]
▪ Predicted climate in the US by the end of the century, crop yields will decrease by at least 30 percent[184]
• Share of hunger could increase for one in five people[185]</td><td>▪ No CO_2 fertilization effect
▪ Net yields will not decrease</td></tr>
<tr><td colspan="2" align="center">Observed Disease Impacts</td></tr>
<tr><td>▪ Climate change will alter replication, survival persistence, habitat range and transmission of many pathogens. Examples include:
o Food poisoning outbreaks from salmonella coinciding with extreme heat events
o Infection by waterborne Cryptosporidium and Giardia following heavy downpours or flooding[186]</td><td>▪ Avoid changes in replication, survival persistence, habitat range and transmission of food, water or animal borne pathogens</td></tr>
<tr><td colspan="2" align="center">Observed Heat Impacts</td></tr>
<tr><td>▪ 9 of 10 summers will be warmer than the warmers summer experienced between 1971 - 2000[187]
▪ Increases in risk of illness and death from extreme heat
▪ Annual heat related deaths in Los Angeles in a higher emissions scenario will increase by 5 to 7 times compared to a 1990 baseline[188]</td><td>▪ Annual heat related deaths in Los Angeles in a lower emissions scenario will increase by 2 to 3 times compared to a 1990 baseline[189]</td></tr>
</table>

[181] Gillis, p. 4
[182] Hilias, p. iv
[183] Gillis, p. 4
[184] Ibid.
[185] Hilias, p. 35
[186] Karl et al., p. 96
[187] NRC, 2010
[188] Karl et al., p. 91
[189] Ibid.

BAU	CEV
Severe Weather Impacts[190]	
▪ Flooding, drought, hurricanes, etc. ▪ Adverse mental and human health effects of extreme storms o Mortality, injury, carbon monoxide poisoning o PTSD and depression ▪ Adverse human health effects of floods o Increased incidence of waterborne diseases o Sewage overflows that contaminate drinking water and beaches ▪ Increased incidence and size of wildfires o Burns and death o Pollution causing respiratory and eye illness	
Potential Migration Impacts	
▪ Flooding, droughts and rising sea levels will cause 200 million people to be permanently displaced by 2050[191]	

[190] Karl et al. pp. 94-96
[191] Stern, 2007

Table 37: Fossil Emissions Impacts of BAU vs. CEV

BAU	CEV
Fossil Emissions Impacts on Air and Water	
Mercury and Birth Defects[192]	
• Coal fired generation is responsible for 65 percent of all mercury emissions • Exposure to mercury can cause speech and hearing problems, lack of coordination, asthma attacks, heart disease and increased risk of cancer • Mercury exposure especially harmful to pregnant women and young children. o Retards cognitive development and stunts lung growth in children o Reduces IQ of fetuses o 300k-600k kids at risk for neurological and developmental disorders annually	• Avoid health problems associated with mercury emissions from coal fired generation
PM and Asthma	
• 92 million live in areas with unhealthy levels of PM in the U.S. Health problems associated with this are as follows:[193] • Premature deaths/reduced life expectancy o 24,000 premature deaths in 2004[194] • Heart attacks • Asthma attacks Lung tissue damage • Stroke	• Avoid health problems associated with PM emissions from coal fired generation • Environmental regulation between 2004 and 2010 reduced PM from coal plants and decreased premature deaths to 13,200[195]
Ozone Depletion	
• Increase ground-level ozone, a component of smog o Decrease short term lung function and damage lung lining ➔asthma and premature death[196]	• Projected overall reduction in ground-level ozone at the end of the century compared to 1996-2000 levels[197]

[192] NCS, p. 38
[193] NCS, p. 40
[194] Ibid.
[195] CATF, p. 5
[196] Karl et al., p. 92
[197] Ibid.

Table 38: Water Supply Impacts of BAU vs. CEV

BAU	CEV
Water Supply	
Hg	
• Continued mercury poisoning of lakes due in large part to coal fired generation[198] • Fish and humans who consume them will subsequently be contaminated by mercury	• No mercury emissions from coal fired generation → reduce mercury contamination in lakes
Water Supply Availability	
▪ Historically[199] o Downward trend in snowpack and shifts towards earlier spring runoff ▪ Projected[200] o Increased duration and intensity of droughts o Decreased snowpack (especially in places with freezing climate) o Gradual decline in runoff o Less water available in summer	▪ Safeguard the West's water supplies ▪ Increase the use of renewable energy technologies which use significantly less water, if any at all.[201]
Water Quality	
▪ Surface water ecosystems may experience decreases in their ability to remove pollutants and improve water quality.[202] ▪ Rising water temperatures[203] o Increased algae leading to eutrophic conditions in lakes o increases in lake water temperatures consistent with a doubling of CO2 would cut the habitat available for cold water fish in half	
Water Supply and Electricity Production	
• Conventional fossil fuels are water intensive • Water consumed for conventional oil and gas production in the Rocky Mountain Oil and Gas Supply region will increase by 200 million MGD by 2030 o Enough to meet the annual needs of 5 million people[204] • Oil shale development will lead to further increases in water consumed for oil and gas production o Water would be transferred from agriculture to industrial uses[205]	• Incentivize production and use of renewable technologies • Wind, solar PV, and dry-cooled solar CSP use little to no water • Replacing one 500-MW pulverized coal plant with wind turbines would save 1.9 billion gallons a year of water withdrawals and 1.6 billion gallons a year of water consumption.[206] o enough to meet the annual needs of 50,000 people.

198 NCS, p.38
199 WRA and EDF, p.5
200 Karl et al., p 123
201 SNWA and EDF, p. iii
202 Karl et al., p. 123
203 SNWA and EDF p. 6
204 SNWA and EDF, p. ii
205 Ibid.
206 SNWA and EDF, p. 11

12. Conclusion

The Western Electricity System is at a Cross Roads

The western United States is at a crossroads. Wise electricity sector investment choices will lay the foundation for a robust, competitive and healthy West for generations to come. Unwise choices will leave western businesses at a competitive disadvantage in the global marketplace, western consumers with higher electricity bills and westerners of all walks of life with an unhealthy environment.

This analysis has demonstrated that the Western electricity sector investing more than $200 billion by 2030 regardless of the development path taken, the choices made will significantly affect quality of life in the West out to 2050 and beyond. Significant investment will be required because coal, gas and nuclear facilities will need to be retired or replaced, population, economic growth, and electrification will drive gross electricity demand up, demand reduction efforts like energy efficiency programs will continue, new electric generation will be built and new transmission will be added. The question is not whether hundreds of billions will be invested but rather how they will be invested.

The analysis has also shown that existing renewable energy and energy saving statutory mandates will determine some investment choices, but utilities, other electricity providers and policy makers have the opportunity to determine where additional investment flows. The direction and pace of grid evolution will depend upon these choices.

Thus, the analysis concludes that the policy and investment choices made could take the West in two very different directions. Western utilities and electricity providers may choose to operate the grid much as it is today and invest in refurbishing and expanding fossil generation, as well as building additional infrastructure to deliver fossil generated electricity. In other words, grid operation and expansion could follow a BAU trajectory.

Alternatively, policy makers and electricity providers may choose to modernize the grid and grid operations and focus their discretionary investment on information, communications and system control technologies that enable more energy saving, more low carbon energy production and more sophisticated grid operations. In other words, grid operations and expansion could follow a CEV trajectory.

If no choice is made, investment will be driven by inertia rather than intention and the grid of 2030 and 2050 will look very much like the grid of 2010. This report asserts that making an intentional choice between the BAU and CEV trajectories now is the responsible course of action.

Failure to make a wise, intentional choice now could saddle future electricity consumers with stranded costs, damage the natural environment, deprive job seekers of employment opportunities and leave western businesses with a grid that causes a competitive disadvantage in global markets. The choices made now will also affect the capacity of the West to reduce carbon emissions for decades to come.

Contrasting Futures

Portfolio Differences

The paper uses recent results from the Western Electricity Coordinating Council (WECC) Transmission Expansion Planning and Policy Committee (TEPPC), the State and Provincial Steering Committee (SPSC) and the Western Renewable Energy Zone (WREZ) project as a starting point in characterizing the Business as Usual (BAU) and Clean Electricity Vision (CEV) generation portfolios. The BAU development trajectory builds upon the TEPPC 2010 Base Case portfolio to characterize the 2020 BAU Base Case. Beyond 2020, the BAU case assumes that coal, nuclear and hydroelectric generation persist at 2020 levels, renewable generation increases to meet RPS goals and gas generation grows to meet incremental demand.

The CEV development trajectory uses the two TEPPC/SPSC cases (the 2010 Reference Case and the 2010 High Demand Side Management case) as well as the 2010 Western Grid Group (WGG) Case to characterize the 2020 CEV generation portfolios. The CEV cases assume continuing nuclear generation at 2010 levels, slightly declining hydroelectric generation, aggressive energy saving, aggressive distributed generation (DG), and aggressive conventional coal retirement. Energy saving and DG reduce demand substantially in the CEV cases relative to the BAU cases. However, to the extent that there is incremental demand caused by coal retirements and residual demand growth, the CEV assumes that these incremental needs are met by growing renewable energy generation beyond western State RPS requirements.

The BAU and CEV analyses complement the TEPPC/SPSC cases by putting the 10 year cases into the context of 40 year investment trajectories. The WREZ resource characterization results are used to select renewable energy generation resources for any needs beyond 2020 RPS requirements.

The CEV cases also build off of Western Climate Initiative (WCI) Integrated Analysis Model (IAM) results. WCI results indicate that cost effective attainment of the WCI climate goal requires the electricity sector to reduce carbon emissions in proportion to its share of western emissions. The CEV uses these WCI results in assuming that the electric sector reduces its proportional share of the CEV carbon reduction goal. The CEV carbon reduction goal is steady progress toward an 80 percent reduction below 1990 levels by 2050.

Grid Operations and Planning Differences

BAU and CEV futures also imply dramatic differences in how the grid will be operated and planned for decades to come. Today's western electricity system uses large central station fossil, hydro and nuclear generation to meet more than 90 percent of the electricity needs of the West. Renewable energy, conservation, energy efficiency and distributed generation resources meet less than 10 percent of the need. Furthermore, most electric generation infrastructure in the West is 30 to 50 years old. In short, the western electricity system was built on the assumption that base load generation would meet most electricity need. The system was not built to be flexible and as a result it is slow to assimilate new technologies and has difficulty taking advantage of the West's renewable resource wealth.[207]

BAU development of the grid perpetuates the large, base load fossil basis of the western grid and thus does not require significant changes in how the grid is operated or planned. The BAU future does include achieving compliance with existing renewable energy statutory requirements so BAU grid operations will have to become somewhat more flexible, but the BAU grid would operate largely as it does today.

[207] The last fifty years have brought dramatic improvements in computer information systems, electricity system control technologies, battery and storage technologies, renewable energy generation technologies, energy efficiency and building science technologies, and electricity distribution and transmission system technologies. Technological change over the last 50 years constitutes a trend rather than an anomaly and the rate of technological change attributable to information systems, electronics and materials science discoveries is rapidly increasing.

A CEV future is a commitment to high levels of demand reduction, high levels of distributed generation and high levels of renewable resource development. Therefore, development of the CEV grid requires installation of advanced information and control system electronics and evolution of grid operation to practices that emphasize flexibility on the demand and supply side.

Recent research demonstrates that new information, communications, system control and generation technologies allow significant change in how electricity will be generated, delivered and used in the coming decades.[208] Cost effective implementation of a CEV trajectory requires easy integration of customer side of the meter resources, large increases in renewable energy generation and ready coordination of regional resources.

Differences in Grid Coordination Among Balancing Areas

For the last 50 years, generation facilities tended to be large, remotely located and primarily intended to serve an individual utility company's own need. The self-provision basis of the grid led to division of the western electricity system into 38 "Balancing Areas" (BAs) where each BA is responsible for ensuring reliability within its borders. While BAs share resources to some extent, regional exchange of resources accounts for a relatively small proportion of the resources used to meet electricity requirements and regional resources are not typically used to follow the ups and downs of electricity supply and demand. The BAU trajectory would likely continue the self-provision preference.

In contrast, a CEV trajectory requires cooperation and coordination among utilities and evolution of grid planning so that distributed and large scale renewable technologies can be cost effectively accessed and utilized west wide to ensure reliability. As such the CEV trajectory requires a transition toward a western grid where 38 BAs coordinate to a much greater extent.

Differences in Regulation and Policy

BAU and CEV futures also require different regulatory and policy mechanisms. The utility regulatory structure in place today was chosen more than 50 years ago to induce utilities to invest in large, base load utility-owned generation. The cost based, rate of return regulation paradigm created incentives that are well-suited to the 5 to 10 percent annual growth in electric demand seen in the 1950s and 1960s. A BAU future is intertwined with the perpetuation of the 1950s regulatory paradigm, and thus no significant changes in institutions, regulations or policy are needed in the BAU future.

A CEV future depends on aggressive amounts of electricity demand reduction, customer demand response and customer sited distributed generation. The cost of service, rate of return paradigm does not induce investor owned utilities to invest in customer side of the meter resources thus the regulatory paradigm must change in a CEV future. Furthermore, a CEV trajectory requires much greater regional coordination and cooperation to build the infrastructure that access and efficiently utilize the best renewable resources in the West. Conventional regulation does not adequately induce investor owned utility participation in regional projects, and so once again the regulatory paradigm must change. While Publicly Owned Utilities (POUs) do not profit from generation and grid investment in the same way that investor owned utilities do, POUs have also focused on developing resources within their own boundaries to serve their own need and efficient implementation of a CEV trajectory will require these POU policy choices to change.

[208] See for example, Peter fox-Penner, "Smart Power: Climate Change, the Smart Grid and the future of Electric Utilities." 2010.

Contrasting Fortunes

The assumed differences between BAU and CEV portfolios, operations, coordination and policy imply different BAU and CEV investment choices and the different investment choices produce contrasting performance results.

Many recent studies assert that benefits are created from transitioning to a more technologically advanced, lower carbon electric system. These studies indicate that such a grid can produce significant jobs, competitiveness, health, environmental and security benefits relative to perpetuating a business as usual approach to the grid.[209] Other studies assert significant economic and reliability benefits of continuing the BAU resource mix, grid operation and regulatory policies.[210]

This paper builds portfolios of resources that comport with BAU and CEV trajectory assumptions and evaluates the economic, environmental, energy security and public health performance differences.

Economic Performance Differences

The CEV Addresses BAU Market Failures. Accurate price signals and fair markets lead to highest value investment. CEV addresses externalities, public goods and market barriers and BAU does not. As a result, BAU over-invests in high emitting resources and under-invests in electricity saving resources, customer sited resources and regional resources.

The BAU and CEV Trajectories Face Different Cost Drivers. While most CEV cases require more investment, the BAU portfolios have higher fuel and carbon costs. CEV portfolios cost consumers less unless natural gas prices and carbon prices stay low out to 2030 and beyond. For the cost differences quantified, cost differences in 2030 between the BAU Base Case and the CEV Low and Base Cases vary from BAU being $12 billion less expensive to $46 billion more expensive. The cost differences include a cost of carbon but do not include other externality costs.

BAU and CEV Job Creation Differences. Job creation differences between trajectories arise due to differences in investment portfolios, differences in import replacement, differences in electric service quality and cost, and differences in rates of innovation. The direct and indirect job creation difference for the 20 year period ending in 2030 between the BAU Base Case and the CEV Low Case or Base Case portfolios is a CEV net addition of 100,000 to 130,000 full time equivalent person-years of employment. This difference does not reflect employment differences arising from changes in electric service quality and cost, nor does it reflect employment differences arising from differences in innovation.

BAU and CEV Risk Protection Differences. CEV represents a credible commitment by the West to carbon reduction and therefore represents an insurance policy that partially mitigates risks associated with climate change. The social cost of carbon ranges from $20 per ton to hundreds of dollars per ton, depending on the severity of climate change outcomes. The CEV reduces the probability of higher social cost outcome.

[209] See Union of Concerned Scientists (2009), Synapse Economics and the Civil Society Institute (2010), Ackerman, et al (2009), Center for Economic Progress (2009), the Center for Naval Analysis (2010), Jacobsen and Delucchi (2011) and Stern (2006).
[210] See The American Coal Council (2011), Chupka, et al (2008), Green (2011) and The INGAA Foundation (2011).

Energy Security Differences

BAU and CEV Coal and Natural Gas Differences. CEV portfolios do not depend on increasing supplies of natural gas nor do they depend on continuing supplies of coal, thus CEV portfolios are insulated from potential supply disruptions or price spikes in natural gas or coal supplies. Natural gas supply and price has historically been volatile and the price of coal includes significant environmental, public health and carbon costs that are not yet reflected. BAU portfolios face the energy security risks of rising prices and the potential of fuel supply disruptions.

BAU and CEV Oil and Gas Differences. CEV invests in advanced information, communication and control system technologies and introduces policy changes that vastly increase the flexibility of the grid. Therefore, CEV facilitates transportation electrification and thus provides the energy security benefit of transitioning the West away from imported oil.

Environmental and Public Health Performance

Direct Impacts

Criteria Pollutant Impacts. BAU portfolios have more coal and natural gas fired resources and therefore the BAU portfolios have higher levels of criteria pollutants.

Water Use Impacts. BAU Base Case water use is more than twice the water used in the CEV Low and Base Cases.

Land Use Impacts. CEV large scale renewable energy build outs directly use between 600,000 and 1,500,000 acres of land. BAU requires less land for generation and transmission footprints but uses far more land for fuel exploration and production.

Climate Change Induced Impacts

The CEV cases represent a credible commitment by the West to do its part to reduce carbon emissions to the IPCC 2050 target. If the West and other regions and sectors fail to make these commitments then the sources cited in the body of the report declare that there will be impacts on:

Temperature and precipitation. Failing to limit carbon accumulation will lead to changes between 2 and 11.5 degrees by 2100. Jointly making commitments could limit carbon accumulation below 450 ppm could limit temperature increases to 2 additional degrees Celsius by 2100. For every degree Celsius change, southwest runoff will decrease 3.3 to 6.1 percent and northwest runoff will increase 1.2 percent.

Ecosystem Processes & Biodiversity. Physical changes in the environment such as increased temperatures and changes in precipitation will result in increases in sea level, drought, wildfires and flooding will affect ecosystems and human activities. These changes directly affect many species through affecting their habitats.

Water Supply. The arid southwestern U.S. is projected to experience longer and more severe droughts from the combination of increased evaporation and reductions in precipitation.

A $200 Billion Decision

The West will invest hundreds of billions of dollars in the electricity system by 2030. Aging infrastructure and growing demand will drive large investment regardless of the development trajectory chosen. Differences in investment cost and differences in fuel and carbon cost will drive costs higher in different measure between a BAU and CEV trajectory, but costs and prices will increase in either case.

The magnitude of the cost and price differences are highly uncertain because many factors such as the cost of fuel, the cost of carbon, the rate of technological change and the cost of raw materials are highly uncertain. One's opinion about which future will cost more depends on one's opinion about how these uncertainties will turn out.

If one accepts the notion that unabated carbon emissions are a serious global problem, and if one accepts that the western electricity sector can increase the likelihood that carbon emissions reduction will accelerate if the West does its part to address carbon emission reduction, then the choice to follow a CEV path is clear. If one does not accept this notion then the preference between BAU and CEV trajectories depend on one's opinions about how cost uncertainties will turn out and on one's opinions about the environmental, energy security and public health performance advantages held by a CEV future as highlighted in this report.

As discussed above, BAU and CEV trajectories are so different with respect to infrastructure required, grid operation and planning, and electricity regulation and policy, that making a deliberate choice between a BAU and CEV is important. Since the BAU trajectory perpetuates the practices and institutions we have today, and practices and institutions are by their very nature rigid, failure to make an intentional choice to commit to a CEV trajectory today is tantamount to choosing a BAU future by default.

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