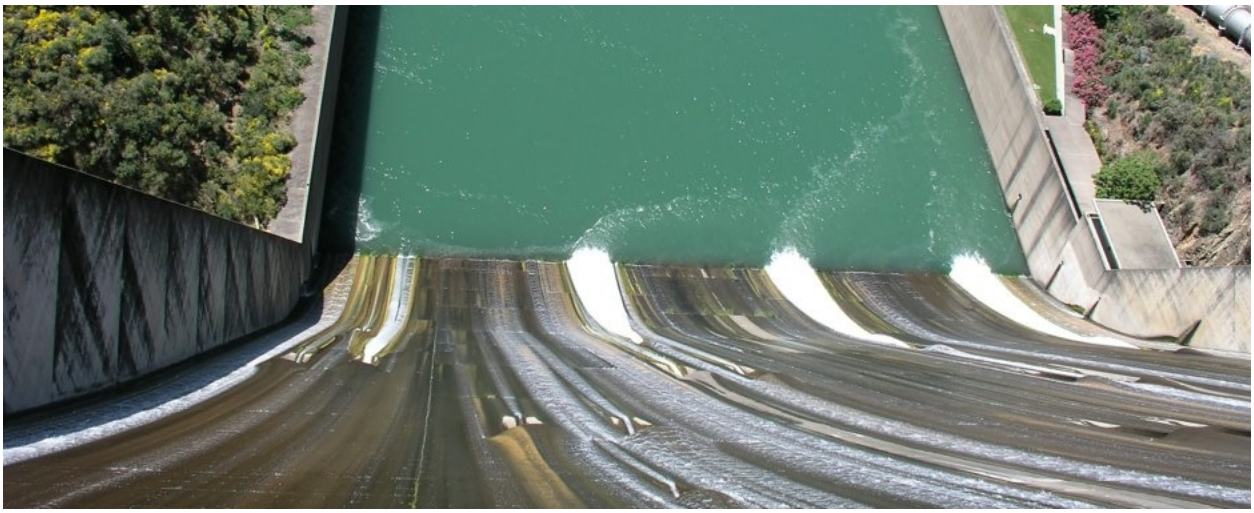

ENERGY

Energy use is tightly coupled with the climate challenge, both in terms of mitigation and adaptation. Emissions of greenhouse gasses from fossil fuels are the single largest contributor to anthropogenic climate change, and the impacts of climate change on the energy sector are anticipated to significantly affect the supply of and demand for energy at global and local scales. Options for reducing the carbon intensity of energy include increased utilization of renewables, which rely on variable resources such as sunshine, wind, or water.

The impacts of climate change on energy were not explicitly considered within the scope of the 2006 Study, but much of the climate and hydrological analysis from that study is pertinent to the assessment of impacts to Aspen's future energy supply and demand.[97] Factors such as changing normal and extreme temperatures, changing precipitation, and alterations to the timing and magnitude of stream flow carry ramifications for the resiliency of Aspen's energy supply. These factors may also influence ability to meet desired reductions in greenhouse gases as stated in the Climate Action Plan.[98]

Electricity supply implications

Renewable, low carbon energy sources rely heavily upon fluctuating natural resources such as moving water, wind, or solar radiation. As a result, renewable energy is in general more affected by change in weather or climate than fossil-based resources.[99] Aspen's energy supply is

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[97] See chapters 2 & 6, AGCI 2006.

[98] City of Aspen Canary Initiative. 2007. Climate Action Plan. City of Aspen. Available at http://www.aspenpitkin.com/Portals/0/docs/City/GreenInitiatives/Canary/CAP-final%20without%20dates.pdf

[99] Bureau of Reclamation. 2013. Literature Synthesis on Climate Change Implications for Water and Environmental Resources. Technical Memorandum 86-68210-2013-06. Denver, CO. Available at http:/www.usbr.gov/climate/docs/ClimateChangeLiteratureSynthesis3.pdf

particularly exposed to potential changes in climate and hydrology because a significant portion of the City of Aspen's electricity supply[100] comes from snowpack-dependent river flows and reservoir storage that generate power through hydroelectric facilities, such as Ruedi Reservoir (see Figure 4.4).[101] In general, climate-related issues that concern hydropower generation include water quantity and quality, temperature-related stresses, and operational impacts due to extreme weather.[102] Another interesting factor linking Aspen's energy to global trends and climate change mitigation is the emergence of electric vehicles and the potential to shift away from gasoline to electric vehicles. This may transfer a greater proportion of Aspen's energy consumption to electricity in the coming decades.

Figure 4.4 City of Aspen utility electricity sources (2013)

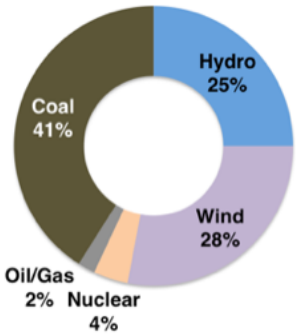

Figure 4.4 provides a snapshot of electricity sources for the City of Aspen Electric system in 2013. The composition of energy sources vary from year to year based on climate conditions and purchasing agreements. For instance, the portion of City of Aspen electric supply from hydro for 2014 is expected to be 37%, as compared to the 25% shown above. Source: City of Aspen.

At Ruedi Reservoir, the reservoir level, which is significantly affected by winter snowpack, is a key factor in energy production, along with other management concerns such as water rights, upstream diversions on the Frying Pan, recreational needs for the reservoir, water temperature for the Frying Pan fish ecology below the dam, and flood management. Figure 4.5 characterizes the relationship between winter snowpack measured at the Kiln SNOTEL station on April 1st and the annual electricity production generated by Ruedi. Although numerous variables play a role in water management and electricity production at Ruedi, there is a clear relationship between local snowpack and electricity production. This vulnerability is addressed to some extent by the existing diversity—both in location and type—of Aspen's electric supply mix and the ability to acquire sources outside the Roaring Fork Valley, but the correlation between snowpack and energy production highlights the potential for extreme conditions such as drought to alter renewable energy production on a year-to-year basis.

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[100] This considers only electricity supply provided by the City of Aspen operated electric utility and not the portion of electricity supplied to Aspen by Holy Cross Energy.

[101] City of Aspen-100% Renewable Power by 2015. Go 100% Renewable Energy Web Page. Renewables Policy 100 Institute. Available at http://www.go100percent.org.

[102] Bull, S.R., D.E. Bilello, J., Ekmann, M.J. Sale, and D.K. Schmalzer. 2007. Effects of climate change on energy production and distribution in the U.S. *Effects of Climate Change on Energy Production and Use in the U.S.: A report by the U.S. Climate Change Science Program and the subcommittee on Global Change Research.* Washington, D.C.

Over the long term, climate change may have a major effect on electric production for the Upper Colorado River Basin, affecting reservoirs such as Ruedi. While interannual precipitation amounts vary greatly year to year, trends in maximum SWE and total annual precipitation since 1981 above Ruedi Reservoir are relatively flat based upon the Kiln SNOTEL site data. If precipitation remains about the same as recent decades, rising temperatures will still alter runoff. Model estimates show that for a 1.8ºF (1.0ºC) increase in temperature there is about a 3% to 10% decrease in runoff.[103] Other model analyses indicate the importance of precipitation as well: for a 10% reduction in precipitation there is a corresponding 20% reduction in runoff. In this work, estimates for the Upper Basin in the case of a 2ºC increase in temperature by 2050 indicate a decrease in runoff on the order of 4-18%. These long-term effects, coupled with annual and inter-annual variability, will offer new challenges to hydroelectric managers.[104]

Figure 4.5 Electricity production and snowpack above Ruedi Reservoir

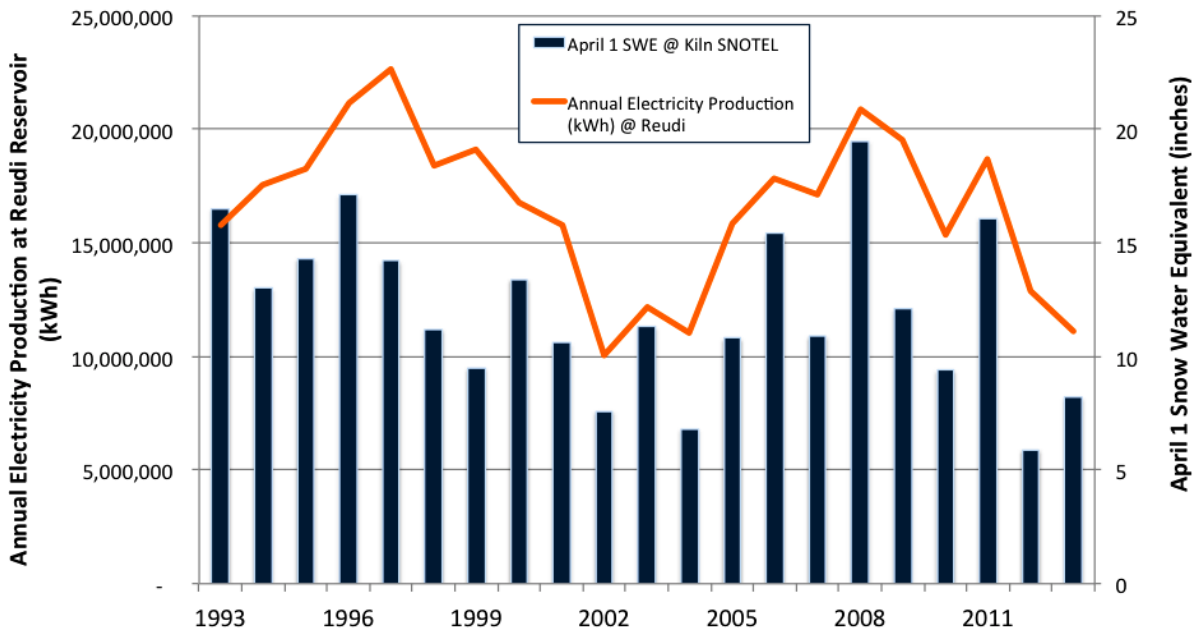


Figure 4.5 shows annual electricity production at Ruedi Reservoir alongside snow water equivalent measurements taken on April 1 each year at the Kiln SNOTEL monitoring site. Although the April 1st measurement is only a proxy for Ruedi reservoir water supply, the correlation between annual production and April snowpack highlights the connection between climate variability and renewable energy production in the Roaring Fork Valley. Source: NRCS SNOTEL and City of Aspen.

[103] Vano et al. 2014

[104] Hoerling, M., D. Lettenmaier, D. Cayan and B. Udall. 2009. Reconciling Projections of Colorado River Streamflow. *Southwest Hydrology* 31.

Energy demand implications

Aspen's changing climate will affect the nature and timing of energy demand, particularly the heating and cooling demand in area buildings. The following subchapter on infrastructure and the built environment presents projections for heating and cooling degree days by mid-21st century. Since energy for cooling is predominantly provided by electricity, whereas energy for heating is mainly provided by natural gas, both the timing and overall annual electricity demand will change. Rising temperatures lead to more cooling days, which in turn means a rise in summer electricity demand. This shift in the nature of energy demand, along with anticipated increases in population, places an even greater burden on regional and municipal efforts to reduce energy demand through efficiency improvements and to lower the carbon intensity of energy use.

Climate risks to national and international energy supply

Aspen's tourism-based economy relies on a national and international energy infrastructure to provide reliable and affordable energy, particularly for the sources utilized to transport visitors by air or ground. In addition to alterations to hydropower production beyond the Roaring Fork Valley, a number of other climate related outcomes may impact global energy supply including:[105]

- Energy production curtailed regionally and nationally due to water, temperature, and supply constraints
- Direct impact on production due to extreme events
- Sea level rise damage to existing energy infrastructure and impairment of new energy infrastructure

Aspen's exposure to this impact may be limited due to the affluent profile of visitors coming to Aspen. Many visitors may be able to absorb even significant changes in the price of energy—either at home or for travel—and may also be able to manage short-term drops in energy reliability.

Response strategies

Responding to the potential impact of climate change on Aspen's energy resources will require more site-specific study of local energy sources. In addition to potential impacts of climate change on energy supply, changes in timing and in overall quantity of energy demand and non-climate drivers such as population growth may also be worth consideration. Strategies that

[105] USGCRP 2009.

Box 4.5 Energy summary

Climate-related Changes:
- Increasing summertime high temperatures
- Warming wintertime minimum temperatures
- Alterations to snowpack and timing and quantity of runoff

Future Potential Impacts
- Uncertainty of future dependability of energy sources, such as hydroelectric
- Increase in cooling load and reduction in heating load demand in buildings
- Climate-related risks to national and international energy supply

Potential Responses
- Development of site-specific evaluation of energy resource among future climate scenarios
- Diversification of location and type of renewables
- Integration of demand side management and GHG reduction strategies in energy resiliency planning

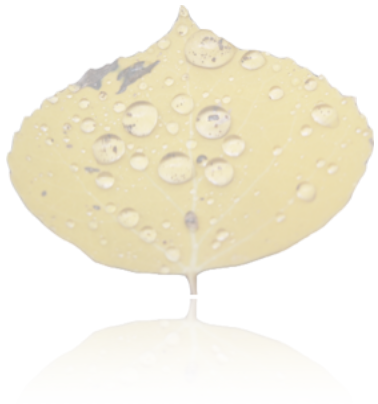
Opportunities
- Code requirements for greater building efficiency, reduced carbon emissions
- Reduction in heating degree days and increase in cooling degree days may smooth out annual energy demand curve for Aspen's utility, currently a "winter-peaking" utility
- City of Aspen electric and Holy Cross Energy can incorporate future climate projections in their supply and demand planning, particularly in relation to the anticipated increase in renewable sources
- Aging infrastructure replacement can incorporate future climate projections in design standards (road, runway, bridge abutments, power system capacity, etc.)

Lingering Uncertainties
- System effects of electricity becoming a greater share of total energy supply
- Extent of additional annual and seasonal alteration of solar and wind resources
- Effect of future trends in precipitation, streamflow, and water storage on hydroelectric potential

enhance resiliency may include reducing vulnerability to sudden local changes in climate and hydrological conditions by acquiring a more diverse source of energy production capacity within and beyond the Roaring Fork Valley.

The City of Aspen Electric utility has a progressive approach of acquiring a high percentage of its electricity from renewables with the goal of achieving 100 percent. The portion of the upper valley supplied by Holy Cross Energy is operating under the Colorado Renewable Portfolio goals. Both utilities have active programs on the demand side to increase efficiency. In addition,

the Community Office of Resource Efficiency provides incentives for renewables combined with audits and efficiency upgrade incentives. Evaluating these programs anew in light of how climate change can affect supply and demand in the coming years will further these programs while building greater resiliency.

Under the guidance of the City's Canary Initiative, a carbon inventory was initiated and subsequently updated. This set of studies points to transportation as the major contributor to Aspen's total greenhouse gas emissions. On this front, a mass transit bus system (RFTA) has been successful in reducing individual vehicle use and in abating congestion valley-wide; however, in general the fuels component of energy use has been more problematic in achieving overall reductions compared to electricity. Fuels are a global commodity, so the question of reliable fuel supply is tied to how climate change affects global supply. Continued dialog that explores overall valley, community, and neighborhood design, combined with understanding of present and desired social frameworks for lifestyle and work, can alter transportation requirements and potentially reduce present and future dependence on fossil fuels for mobility while reducing vulnerability to external factors in fuel markets.

Less research has focused on how climate change will affect the transportation sector than how it will affect electricity supply, but there is ample research on the relationship between climate change and the built environment, particularly in relation to heating and cooling loads — Aspen's largest source of greenhouse gas emissions after transportation and electricity.