INFRASTRUCTURE & THE BUILT ENVIRONMENT

As average and extreme climate and weather trends continue to change, significant and potentially costly impacts are expected for residential, commercial, and public buildings as well as transportation, utility, and other infrastructures that connect and provide services to the community.[106] Design criteria that respond to changing climate-related risks can accrue numerous societal co-benefits, such as improved service reliability, comfort, and public health, while hardening critical assets to extreme weather events.[107] Resiliency planning with respect to infrastructure and the built involvement may include the following efforts:

- Building code review and revision
- Planning and design of new buildings or infrastructure investments
- Remodeling or replacement of existing assets

Many of the climate change related impacts to the built environment and infrastructure, such as fire, flooding, and landslide, also exist under normal climate conditions, and their importance is already reflected in regional planning documents such as the *Pitkin County Pre-Disaster*

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[106] U.S. Global Change Research Program (USGCRP). 2009. Global Climate Change Impacts in the United States. (T. Karl, J. Melillo, & T. Peterson, Eds.). Washington, DC. Http://library.globalchange.gov/products/assessments/2009-national-climate-assessment/2009-global-climate-change-impacts-in-the-united-states.

[107] Younger, M., H.R. Morrow-Almeida, S.M. Vindigni, and A.L. Dannenberg. 2008. The built environment, climate change, and health: opportunities for co-benefits. *American Journal of Preventive Medicine 35* (5): 517–26. doi:10.1016/j.amepre.2008.08.017

Mitigation Plan Update (2012).[108] However, climate change will shift the probability of some of these events and warrant further evolution of codes and best practices.

Changes to heating and cooling requirements

Climate trends in Aspen's recent past indicate relatively dramatic increases in minimum temperatures on a diurnal and monthly basis, along with an overall gradual increase in average annual temperature (see Chapter 2). Projections for Aspen and the surrounding regions indicate continuation of these trends. One result of these shifts that is relevant to the built environment will be an overall decrease in the heating load requirements of buildings and an increase in cooling requirements.[109]

"Infrastructure designed to handle past variations in climate can instill a false confidence in its ability to handle future changes."
-U.S. Global Change Research Program, 2009

Downscaled climate projections prepared by the USGS indicate a potential reduction of approximately 1500-2000 heating degree days per year and an increase of cooling degree days by approximately 300 degree days by the middle of the century under high emissions assumptions.[110] Figures 4.6a and 4.6b map out these potential changes for Aspen and the surrounding region.

For some buildings already equipped with heating and cooling systems, this shift may require only modest adjustment. However, for many Aspen buildings only equipped with heating systems, more days per year with high temperatures above tolerable comfort zones could involve significant capital investment to install cooling systems through retrofit. Although some owners may opt for behavioral changes or the "grin and bear it" approach, facilities designed to accommodate tourists or less adaptable clientele will likely be encouraged to ensure adequate cooling capacity. Smart design utilizing passive heating and cooling with appropriate efficiency attributes of building envelopes, can often achieve the comfort zone desired without additional energy requirements and even achieve energy reductions.

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[108] Pitkin County. 2012. Pre-Disaster Mitigation Plan Update. 04 January 2012. Available at http://www.dhsem.state.co.us/sites/default/files/Pitkin%20County%204.2006.pdf

[109] 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

[110] USGS. Derived Downscaled Climate Projection Portal. Last updated April 20, 2014. http://cida.usgs.gov/climate/derivative/

Figure 4.6a Projected change in heating degree days

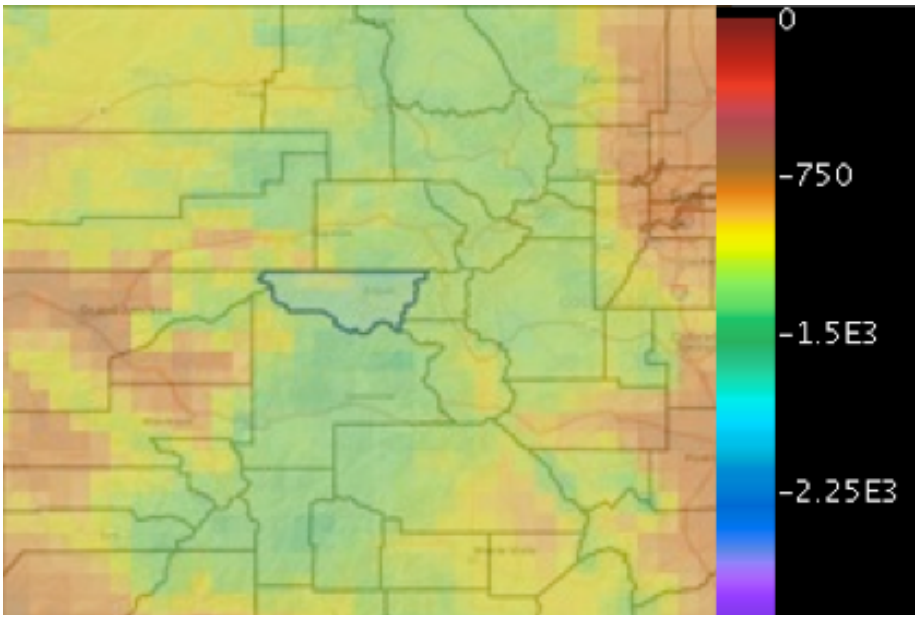

Figure 4.6b. Projected change in cooling degree days

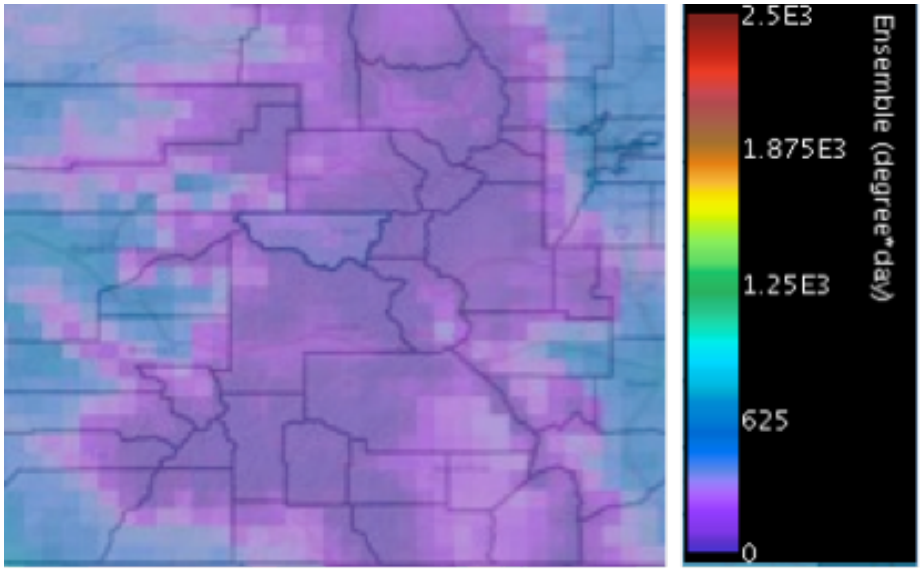

Figure 4.6a shows change in heating degree days per year for the projection period 2041-2070 using an ensemble of models running on the IPCC SRES A1FI (high) emissions scenario. Pitkin County is outlined in blue. Heating degree days for the area surrounding Aspen are expected to decrease (see color legend for approximate values) relative to 1960-1999 modeled values. The Degree Day Threshold is at 65.0ºF (18.3ºC). **Figure 4.6b** shows change in cooling degree days per year for the projection period 2041-2070 using an ensemble of climate models running on the IPCC SRES A1FI emissions scenario. Pitkin County is outlined in blue. Cooling degree days for the surrounding area are expected to increase (see color legend for approximate values) relative to 1960-1999 values. Threshold considered is 65ºF (18.3ºC). Source: USGS Derived Downscaled Climate Projection Portal.

Figure 4.7a Projected continuous dry days for Pitkin County

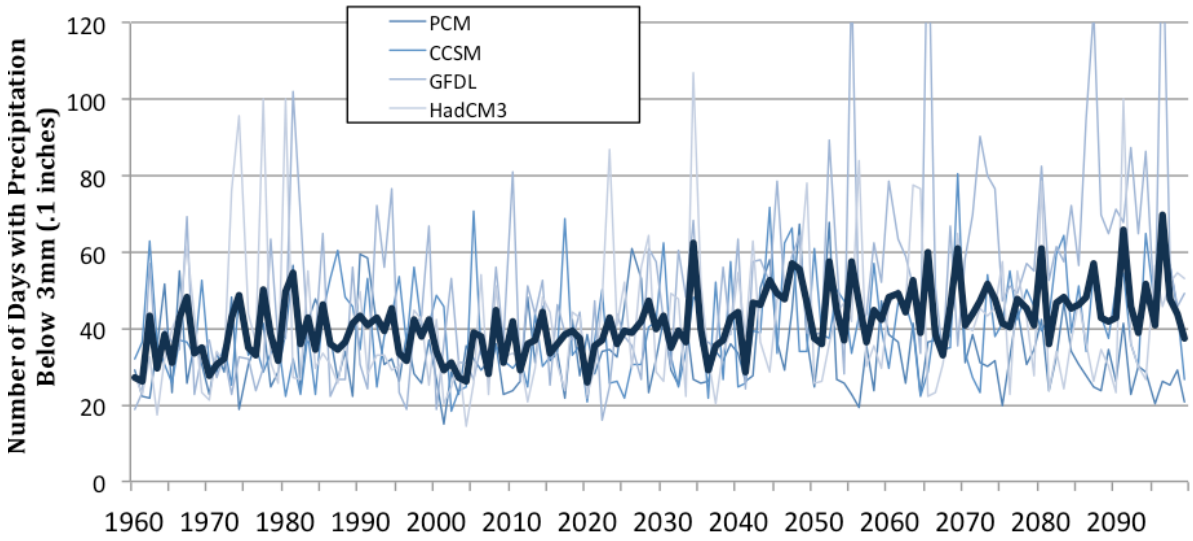

Figure 4.7b Modeled heavy rain in Pitkin County

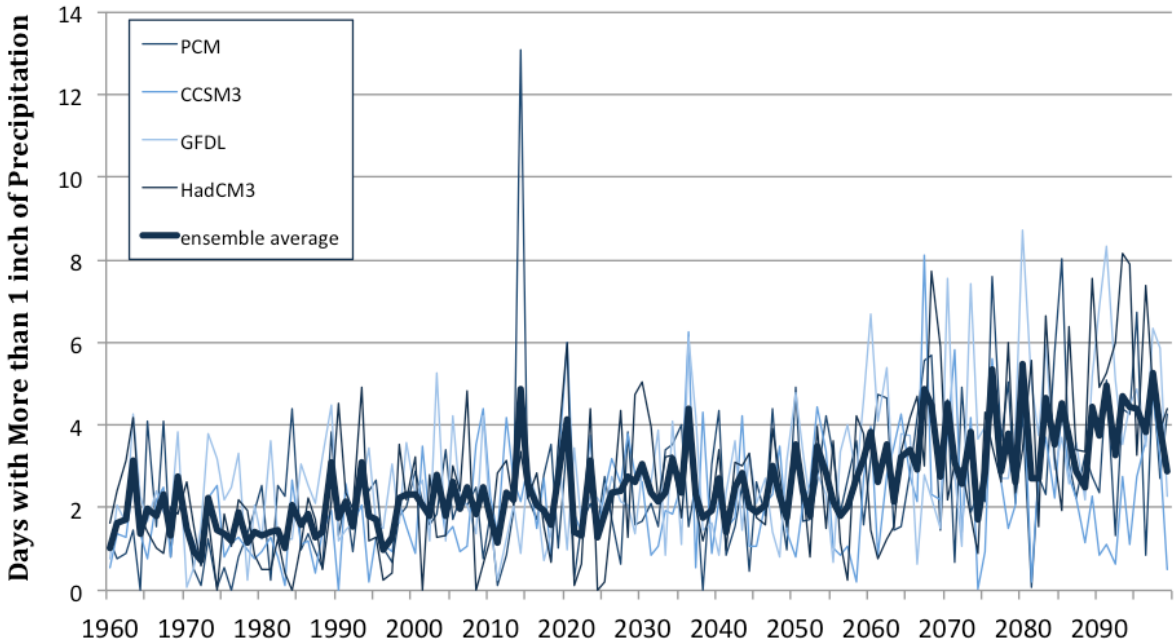

Figure 4.7a shows an increase in the length of the longest period each year receiving less that 3mm (0.1 inch) of precipitation under a high emissions scenario (A1FI). The average number of modeled dry days per year between 1960-1969 was 38.5. By the middle of the century (2040-2069), projections show this number increasing to 45.7 and by the end of the century (2080-2099) 47.9. Figure 4.7b shows an increase in the number of days receiving greater than one inch of precipitation projected for Pitkin County. Model results present downscaled multi-model CMIP3 data that assess the number of days receiving more than 1 inch of precipitation under a high emissions scenario (A1FI). The average heavy rain days for the modeled period 1960-1969 was 1.7. By the middle of the century (2040-2069), the projected number of days with heavy rain increases to 2.7, and by the end of the century (2080-2099) 3.9. Source: USGS Derived Downscaled Climate Projection Portal.

Impacts from extreme events

Aspen's location alongside the Roaring Fork River, large tracts of forest, and steep hillsides poses significant risk of flood, fire, landslide, and mudflow. Existing pre-disaster planning acknowledges these risks but does not take into account the effects of a future changing climate.[111] Assessing the likelihood of future flood and fire risk is confounded by uncertainty in the projection of the magnitude and timing of future hazards, particularly projections of changing extremes in precipitation—or lack thereof—that are most relevant for identifying flood, fire, and landslide risk, in addition to the more prolonged impacts of drought.

Modeling products derived from downscaled climate projections under high emissions scenarios project an increased number of days of heavy precipitation as well as longer dry spells with little or no precipitation. These regional model results suggest a shift in the type of extreme climate events Aspen may experience — a shift from what was considered normal during the 20th century. Figures 4.7a and 4.7b project both an increase in the number of heavy rain days and an increase in the duration of consecutive days receiving little (under 3mm) to no precipitation. This finding is consistent with general expectations of climate change where precipitation, regardless of overall quantity, will come less frequently but in heavier amounts. In other words, when it rains, it pours.[112]

Impacts associated with increased extremes in both dry periods and heavy rain events merits consideration in planning, design, and construction of buildings and infrastructure. In addition to floods, landslides and mudflows, other potentially destructive events associated with extreme precipitation have been identified as a key risk to settlement and society by the IPCC.[113] The Aspen area community is situated nearby numerous unstable geologic features such as alluvial fans, rock fall areas, and otherwise unstable slopes.[114]

Response strategies

Response strategies to climate-related risks posed to infrastructure and the built environment, as in other sectors, may involve a combination of efforts that assess site-specific risks for the purpose of (re)designing assets to reduce exposure or enhance resiliency. Review and reconsideration of existing building, energy, stormwater, and zoning regulations in the context of future climate risks could be one component of this iterative process.

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[111] Pitkin County 2012.

[112] Madsen, T. and E. Figdor. 2007. When It Rains It Pours - Global Warming and the Rising Frequency of Extreme Precipitation in the U.S. Environment America Research and Policy Center. http://www.environmentamerica.org/uploads/oy/ws/oywshWAwZy-

[113] IPCC WGII 2007.

[114] WRC Engineering Inc. 2001. Storm Drainage Master Plan for the City of Aspen, CO. http://www.aspenpitkin.com/Portals/0/docs/City/engineering/stormwater/ Development/1963-20.pdf

Box 4.6 Infrastructure & Built Environment Summary

Climate-related Changes
- Shift in the magnitude of temperature and precipitation extremes
- Reduction in wintertime minimum temperatures; increase in maximum temperatures
- Alterations in timing of runoff and quantity of run-off

Future Potential Impacts
- Increase in hazards to structures and infrastructure from flood, fire, and drought
- Increase of buildings' demand in cooling load and reduction in heating load

Potential Responses
- Evaluation and possible revision of building codes and infrastructure standards that address changing hazard risk
- Further evaluation of preparedness and response to low probability, high consequence events (e.g. more catastrophic wildfires)
- Integration of resilience and GHG reduction efforts into planning of codes and energy-intensive infrastructure such as transportation

Opportunities
- Rationale for improved building design requirements; integrating development codes with long term climate mitigation goals
- Integrating additional stormwater and mudflow mitigation techniques into urban design projects and parks
- New infrastructure engineered for the range of likely future scenarios will be able to be in service longer, have greater resiliency to change, and require lower resource utilization

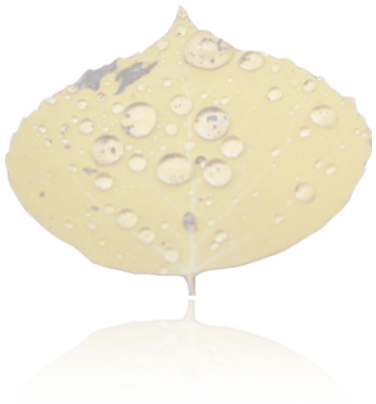
Lingering Uncertainties
- How to determine climate change related infrastructure investments compared to best practices based upon historical climate data

Collective action with private property owners to assess risk and devise strategies as well as consultation with regional, statewide, and federal agencies and resources may be beneficial in identifying pathways that involve collective action and shared risks. Insight from green infrastructure, architecture, and land planning that account for both environmental hazards to human development and potential impacts on the environment from infrastructure development may lead to more transformational strategies that enhance resiliency, preserve capital investments, and improve well-being and public health.

In terms of coming up with adaptive strategies for first-order single stressors such as a prolonged drought, there are often second and third order impacts to consider. With drought

there are riparian habitat impacts and increased risk of fire. With fire, there is increased risk to human health and the built environment. Economic effects would include impacts to fishing and rafting recreation, available water for irrigation, etc. These multi-stress situations can have far deeper overall affects on the community and its resiliency when considered in total.

Another important factor in adaptation planning is that when climate related impacts fall within a manageable range their impacts are taken in stride with existing systems and responses; however, some impacts do not scale in a linear fashion, but rather reach thresholds which, when exceeded, break down a community's ability to cope.[115]



[115] Wilbanks, T.J., P. Kirshen, D. Quattrochi, P. Romero-Lankao, et al.. 2008. Effects of Global Change on Human Settlements. In: Analyses of the effects of global change on human health and welfare and human systems. A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research. [Gamble, J.L. (ed.),K.L. Ebi, F.G. Sussman, T.J. Wilbanks, (Authors)]. U.S. Environmental Protection Agency, Washington, DC, USA: 89–109.