10 Summary: Barriers and Recommendations

To close this report, we return to the mandate of AB 2800, which asked to identify the informational, institutional and other barriers that stand in the way of integrating forward-looking climate science into all aspects of infrastructure planning and decision-making. We have discussed them throughout the preceding chapters and compiled them systematically in Appendix 11. We use the synthesis of this work below to set up a high-level summary of our recommendations, which address the challenges the CSIWG identified and answer the call of the enabling legislation.

Barriers: Informational, Institutional and Other Hurdles to Building Climate-Safe Infrastructure

AB 2800 stipulated, in Section 2 (c), that "[t]he Working Group shall consider and investigate, at a minimum, the following issues: (1) The current informational and institutional barriers to integrating projected climate change impacts into state infrastructure design." The topic of barriers was considered throughout the Climate-Safe Infrastructure Working Group's (CSIWG) deliberations and was also an integral part of the webinar series that supported the CSIWG's work.

Here we summarize and discuss the barriers we have identified throughout this project. Appendix 11 lists the full list of barriers that were discovered, organized by the stages in the adaptation process[312] (which are similar to the stages in an infrastructure lifecycle) and by type of barrier (for example, informational, institutional, financial and so on).

We discuss these barriers at a higher level of synthesis by type, but caution against seeing barriers in an isolated manner. For example, informational barriers such as not having a particular type of data can be reinforced by financial barriers such as lack of investment in relevant research; similarly, institutional barriers such as being tied to or lacking a particular standard or process can be reinforced by lack of capacity/skill or by particular attitudes around thinking about the future or inclusionary, meaningful stakeholder engagement. In other words, barriers are interrelated to create persistent obstacles that stymie progress on integrating forward-looking science into infrastructure planning and design.

Barriers of all types are observed across the entire life cycle of infrastructure design and operation and across every stage of the adaptation process.

Importantly, barriers of all types are observed across the entire life cycle of infrastructure design and operation and across every stage of the adaptation process. While they are fairly evenly distributed across types, overall most barriers are encountered in the Planning and in the (prior) Understanding phases of the adaptation process, with fewer currently noted in the Implementation phase. This is not so much a reflection of the severity of these barriers, but of the greater familiarity with barriers in those early stages of adaptation as most climate preparedness efforts across the state and elsewhere in the U.S. are still in the early stages[279,313]. As earlier barriers are successfully overcome, other (not-yet-recognized) barriers may emerge as adaptation progresses to implementation.

Synthesis of Barriers

We describe each type of barrier, including subcategories, prevalence and their overall significance. Appendix 11 and the discussion on sector-specific issues throughout this report provide additional detail (Figure 10.1).

Informational and knowledge barriers. Informational and knowledge barriers are significant, particularly as they are tied to the institutional ones, namely to design standards. Traditionally, engineers and architects have relied on design standards that are based on decades of empirical data of environmental conditions which were statistically constant, both regionally and seasonally. Using those standards (and data), engineers and architects designed civil infrastructure with confidence, believing that the public is protected. Because of climate change, environmental conditions now deviate significantly from the previous statistical norms and those conditions continue to change in ways that are not predictable for specific places with high confidence. As a result, the standards still used are no longer reliable. Shifting toward performance standards and the use of risk management approaches and decision-making frameworks for deep uncertainty still requires the best available science, however. The CSIWG identified a large number of specific information needs, which fell into six categories. The specific information needs and knowledge barriers (detailed in Appendix 5) vary by sector and require different interventions to overcome them.

- Lack of knowledge and understanding in certain areas, requiring more research (e.g., in methods, adaptive design, trade-offs, value/benefits of resilient design) or cross-disciplinary education on existing knowledge;
- Lack of investment in certain types of research, monitoring and evaluation (M&E) (e.g., no benchmarks, no M&E, hence no understanding of performance; lack of metrics);
- Existing knowledge and approaches are contested, i.e., experts do not agree on what is most credible or reliable; as a result, practitioners avoid new/contested approaches or rely on outdated information and methods (e.g., traditional cost-benefit analysis);
- Lack of information in usable/actionable/standardized formats (including incomplete or missing information, inconsistent information (e.g., flood risk information from FEMA vs. other sources) or information is not available at the right temporal/spatial scale (e.g., precipitation data);
- Lack of (easy) access to information either because the data is proprietary, developed by individual researchers or not in a centralized repository; and
- Lack of guidance on, and familiarity with, how to use data/information/tools/methods appropriately (e.g., lack of guidance on decision-making under uncertainty).

Figure 10.1: A wide variety of barriers make the use of forward-looking climate and other science challenging in infrastructure design. (Photo: Dismantling of a drought barrier along the West False River which served to block salt water from pushing into the central Sacramento-San Joaquin Delta from San Francisco Bay; Florence Low, DWR, used with permission).

Capacity/skill barriers. Capacity barriers can be understood in the sense of adequate numbers of staff and adequately trained and skilled employees to do the necessary work of planning for, building and operating climate-safe infrastructure. This category was among those with the greatest number of individual barriers mentioned. Together, the barriers in this category paint a consistent picture of inadequate training and skill-building to date to enable both the scientific and engineering workforce to take on the challenge of building climate-safe infrastructure for all.

- Inadequate/narrow/siloed disciplinary or sectoral perspectives on what are, in fact, systemic, interconnected challenges;
- Widespread lack of engagement of scientists, engineers and architects on climate change issues;
- Lack of sufficient knowledge about climate change, climate models and lack of expertise in or guidance on how to appropriately use climate data;
- Lack of training in and guidance on assessing and interpreting uncertainty and making decisions under uncertainty;
- Lack of awareness of or education about resilient, adaptive and sustainable designs (including green/nature-based infrastructure options);
- Lack of skills and staff capacity in tracking performance, assessing non-monetary benefits;
- Insufficient capability of translating policy and guidance into standards and codes;
- Lack of training in and guidance on effective stakeholder engagement and other professional skills;
- Lack of awareness, familiarity and skill in considering social equity issues in infrastructure planning and decision-making from the start (Figure 10.1).

The barriers paint a consistent picture of inadequate training and skill-building to enable both the scientific and engineering workforce to take on the challenge of building climate-safe infrastructure for all.

Attitudinal barriers. Attitudinal barriers were among the most frequently mentioned barriers overall, but they are difficult to synthesize (e.g., whose attitudes? attitudes about what?). Some pointed to attitudinal challenges among engineers and architects, such as:

- Abiding skepticism of global climate models and sometimes even the reality of climate change;
- Lack of acceptance of citizen science as valuable input to monitoring performance;
- Neglect of social equity as a central concern, integrated from the start of infrastructure planning;
- Perceived incompatibility of green/nature-based infrastructure with prevailing professional norms (Figure 10.2);
- Strict adherence to established professional norms resulting in resistance to innovation and experimentation; and
- Premature narrowing of the range of options considered due to assumptions about their public acceptance.

But engineers' and architects' attitudes were not the only barriers identified in this category. Decision-makers' and stakeholders' attitudes were also discussed:

- Lack of leadership, a pervasive lack of urgency about climate change and lack of commitment to invest in infrastructure;
- Culturally prevalent attitudes that do not favor long-term thinking;
- Lack of willingness to pay for resilience (resulting from the above-mentioned attitudes);
- Lack of trust among stakeholders partly due to divergent values and priorities, partly due to past experience; and
- Varying levels of risk aversion/risk tolerance.

Finally, scientists often are less interested in applied problem solving and there are disciplinary prejudices that can prevent active and frequent multi- and transdisciplinary interaction and collaboration.

Political barriers. While fewer in numbers, political barriers were often seen as being of ultimate importance for progress to be made toward climate-safe infrastructure. Some of those barriers do not originate from within California but reflected the current lack of leadership at the federal level. Others referred to politics with a "small p" – the politics in the room or at the local/state level.

- Lack of federal political leadership on climate change in general, resulting in de-prioritization at best and unhelpful controversy at worst, as well as inadequate progress on federal infrastructure investment;
- Against a background of politicized debate and near-term priorities absorbing limited funds, lack of political will to prioritize climate change and commit to climate preparedness and adaptation;
- Lack of support for novel infrastructure designs (e.g., green/nature-based infrastructure);
- Lack of political will to address past legacies of institutional racism, neglect of certain communities and to redress those infrastructure inequities now;
- Inability to generate public support for infrastructure investment, including lack of skill and willingness to effectively communicate costs and benefits; and
- Lack of commitment to aspects of infrastructure operation and maintenance (e.g., monitoring) if they don't generate political benefits.

Figure 10.2: Attitudinal barriers – such as the perceived incompatibility of green or nature-based infrastructure with prevailing professional norms in engineering – can pose significant hurdles to moving toward climate-safe infrastructure designs. (Photo: Tree-planting in urban area; USDA)

Financial barriers. Another category of barriers that weighed heavily not by the number of unique barriers identified but by the overriding importance to actually getting infrastructure built. Many of the types of funding challenges are not unique to infrastructure[279] but are often magnified due to the large price tag on infrastructure. Financial barriers are the substance of a nationwide debate over the past several years, and the need for infrastructure investment was a leading priority in California's June 2018 primary election cycle. But, again, the more specific categories of barriers identified point to different foci and intervention points.

- Lack of funding for every stage in the infrastructure lifecycle, including inadequate resources for infrastructure-related research, lack of funding for strategic planning; lack of funding for infrastructure in general and for green/nature-based infrastructure in particular; difficulty of keeping infrastructure in state of good repair (high maintenance costs); and lack of funding for monitoring systems and for long-term, ongoing data collection;
- Higher upfront cost, particularly of climate-resilient infrastructure;
- Long-term funding uncertainty;
- Limited funding options available or considered;
- Lack of coordination among funding agencies; inability to coordinate or combine funding sources and types due to disconnected timing or other factors; and lack of funding for coordination;
- Unfunded mandates;
- Lack of monetary incentives to plan for climate change;
- Restrictions on use of funds (e.g., disaster recovery funding) or constraining eligibility criteria;
- High discount rates that devalue the future; and
- Difficulties related to valuing risks and benefits and thus with making the economic case for infrastructure investment.

Financial barriers weigh heavily due to their over-riding importance to actually getting climate-safe infrastructure built.

Legal/regulatory barriers. We distinguish legal and regulatory barriers from other institutional barriers (discussed next) due to the weight that regulatory issues have in how and where infrastructure is built. As with the political barriers, legal and regulatory issues did not only arise from within State jurisdictions, but sometimes were related to different regulatory requirements at different levels of governance. In general, however, the large number of barriers in this group arose predominantly from the lack of relevant and needed or useful regulation and – in a smaller number of cases - from the existence of a law or regulation that constrained consideration of climate change and alternative designs.

- Lack of policy guidance on what to plan for and difficulty of translating existing (high-level) guidance into action;
- Lack of rules and regulations that would foster/require consideration of climate change (e.g., no requirement to assess exposure to climate change; no requirement to use certain data, no requirement to do a full life cycle assessment);
- Lack of design criteria, standards, performance goals/targets and guidelines for inclusion of climate change in infrastructure design, implementation, monitoring and evaluation;
- Lack of clarity on liability (via a standard of care) with regard to considering climate change in infrastructure design;
- Lack of professional standards related to climate change;
- Lack of regulatory incentives (e.g., accelerated permitting);
- Rating systems are not adopted as code leaving them without regulatory power;
- Lack of code enforcement, including exemptions after disaster or in other special circumstances, and lack of accountability for inadequate designs or maintenance;
- Existing laws, regulations and standards/codes that could be or have already been experienced as limiting the consideration of climate change, even if infrastructure owners have been willing to do so (e.g., Americans with Disabilities Act (ADA) access requirements; regulations pertaining to the preservation of historical buildings and cultural resources; codes that prevent rebuilding after disaster taking climate change into account);
- Unclear jurisdiction where infrastructure crosses jurisdictional lines (including the possibility that different jurisdictions have different priorities, capacities and needs); and
- Different or even contradictory standards and risk assessment approaches (e.g., FEMA's recognition of certified levees only; the National Flood Insurance Program's (NFIP) exemption of historical buildings from flood protection requirements even in high-hazard zones).

Figure 10.3: Institutional barriers, such as differences in planning horizons, lack of long-term planning and lengthy permitting processes can delay the transition to climate-safe infrastructure being built. (Photo: Port of Oakland waterfront; 1FlatWorld, flickr, licensed under Creative Commons license 2.0)

Institutional barriers. Institutional barriers identified by the CSIWG frequently affected or interacted with other barriers, but most commonly these types of barriers related to siloed governance of infrastructure, even though there are many cross-sectoral, cross-lifeline, cross-jurisdictional interdependencies (Figure 10.3). These barriers result in delays, miscommunication, lack of coordination, inefficiencies, missed opportunities and disjointed planning. Common subcategories included the following:

- Differences in planning time horizons across levels of government or types of infrastructure;
- General lack of longer-term planning;
- Lengthy time from initiation to complete implementation of infrastructure projects (up to 20 years), (e.g., due to lengthy reviews and permitting);
- Lack of cross-sectoral and cross-jurisdictional communication, coordination and partnerships (e.g., due to siloed management, zoning inflexibility, lack of awareness of other sectors' concerns and resources; lack of a State "infrastructure czar" overseeing integration of systems; loss of coordination through and power of Community Redevelopment Authorities);
- Lack of processes for comprehensive valuation, evaluation, assessing the quality of risk assessment, risk management or evaluation approaches;
- Competing rating systems (mandatory, voluntary) and competing standards (backward-looking/static standards, forward-looking standards); and
- Externalization of certain consequences from systemic assessment;

Other barriers. The final (smaller) category of barriers contains a variety of barriers that did not fit the other seven categories but were mentioned as having played or as potentially playing a significant role. For example:

- Repeated extreme events and disasters across California in recent years, particularly in 2017 and 2018 (extended drought, multiple record-breaking wildfires, landslides and flooding) are now garnering significant media, public and political attention. Prior to these events, California lacked the catastrophic weather-related events of the magnitude of Hurricanes Katrina (2005), Sandy (2012) or Maria (2017). Without swift yet thoughtful policy initiatives that use such windows of public and policy-makers' attention, the State will miss the opportunity to advance policies to move toward greater climate-safety;
- Physical limitations related to existing infrastructure, i.e., the greater difficulty of integrating climate change considerations in retrofits than in new infrastructure;
- Industry lag time in adopting new practices in design and construction; and
- A general lack of demonstration projects, including monitoring of their effectiveness.

Summary of Recommendations

From Vision to Implementation

In this report, we have charted a path – the Climate-Safe Path for All – that starts out from the challenges and pre-existing conditions to a vision of climate-safe infrastructure via a framework to action. We have described our current infrastructure and the challenges faced from climate change today and in the future We have discussed the best-available climate science, highlighting where our existing science can be bolstered to best suit the needs of state architects and engineers. We have outlined the current paradigm for planning, designing and building infrastructure and have demonstrated how that old path is not robust enough for a future under changing climate conditions. Through the development of the Climate-Safe Path for All, we have provided a vision for how state engineers and architects can take the knowledge that exists today and use it to build the climate-safe infrastructure of tomorrow – infrastructure that is accessible and available to everyone. We have identified the institutional and information gaps and barriers, and we have developed a suite of recommendations to address each (Table 10.1).

Below, we pull together the 10 major recommendations, which, when taken in concert, provide a clear pathway from vision to implementation. They answer the mandate of AB 2800 and more, and we view them as essential to realizing the vision. We also highlight the initial first steps the State can take to start its journey along the Climate-Safe Path for All.

Recommendation 1

The State Legislature should establish as official State policy "The Climate-Safe Path for All", which is a flexible adaptation pathway realized through a variety of strategies, in multiple stages over the course of decades. The Climate-Safe Path for All accounts for the full life-cycle costs of infrastructure and uses a multi-sectoral, systems approach. It prioritizes infrastructure investments based upon the greatest risks and investment gaps, as well as where investment can most reduce inequality and increase opportunity. For highly vulnerable, long-lived infrastructure, State agencies should consider climate change im-pacts associated with a high-emissions scenario while continuing to implement all applicable State laws related to stringent greenhouse gas emissions reductions.

Adopt the Vision

As with the State's bold greenhouse gas emissions reductions goals, the Climate-Safe Path sets out an equally bold path to plan, design and build new and retrofit existing infrastructure to be safe for all. With the Climate-Safe Path, the State recognizes that to do this, future infrastructure projects must assume a high-emissions scenario future (currently RCP8.5), where infrastructure will be exposed to severe levels of climate impacts. Initial first steps include:

- All state infrastructure agencies should establish as a matter of agency-wide policy an adaptation and resilience requirement, namely that all investments in new and existing State-owned, -funded and -regulated infrastructure employ the five sets of strategies of robustness, resiliency, redundancy, adaptability and avoidance/retreat/removal to work toward increasing climate-safety.
- State agencies should furthermore establish formal and readily implementable guidelines at the agency/programmatic level and at the project level as to what it means to "incorporate climate change" into infrastructure planning, design, construction, operation and maintenance.
- Development of guidance will often require workload and expertise beyond what is available in current budgets. To achieve this recommendation, agencies should have adequate funding and efficient ways to leverage similar activities from other agencies and solicit outside scientific and technical expertise.
- State legislation, propositions and State agency policy directives related to infrastructure should direct infrastructure investment where it is needed most as determined by a rating of climate risks, the infrastructure investment gap and the potential to reduce social inequities.

Take a Systems Approach

Following the "It Takes a System" approach, the remaining recommendations discuss how best to advance the state's collection of existing and needed data and analytics (Recommendations 2 and 3), their imminent projects and project pipeline (Recommendation 4 and 5), existing and needed governance structures and mechanisms (Recommendation 6), financing tools (Recommendation 7) and implementation aides (Recommendations 8, 9 and 10) necessary for building climate-safe infrastructure for all.

Recommendation 2

In the past, the State's financial support for its various climate science efforts and decision-support tools has been uneven and insufficient. At a minimum, the State Legislature should provide a permanent source of funding for the State's mandated Climate Change Assessment process, the State's ongoing Climate Change Research Program, and decision-support tools and other assistance that disseminate their findings, so as to meet the needs for improved understanding and forward-looking science information.

Through the pioneering work of several State agencies such as the California Energy Commission (CEC) and the Department of Water Resources (DWR), the State already has an impressive compendium of publicly-funded, state-of-the-art climate science that can be used to support state engineering and architectural projects. The CSIWG identified these valuable resources and identified critical gaps in the available information. Once a sustained source of funding is developed, an important next step is to convene a follow-up panel or process to prioritize information gaps identified by the CSIWG into high, medium and low priority. Some of the highlighted research and science needs identified by the current CSIWG include:

- Produce statewide IDF curves with associated uncertainty for future climate conditions;
- Continue to invest in high-resolution climate modeling to better define spatial and temporal structure of extreme events;
- Prioritize funding for inclusion of traditional knowledges and paleoclimatology;
- Building on the State's previous investment in USGS's CoSMoS model[1] for sea-level rise and storm surge, determine where exactly in the state even more fine-scaled hydrodynamic modeling is needed and focus additional resources there;
- Invest in research that merges case studies, ensemble modeling and forecast experiments to investigate the likelihood, mechanisms, joint probabilities and predictability of climatic extremes that pose significant threats to California's infrastructure;
- Develop fine-spatial scale historical demographic information as well as information on infrastructure use and foster a detailed understanding of the factors that drive those use patterns so as to inform projections of future changes in these trends; and
- Produce projections of changes in technology and infrastructure use.

A monitoring program is an essential companion to future research in support of climate-safe infrastructure.

With the help of the Strategic Growth Council (SGC), the California Natural Resources Agency (CNRA) and the CEC, future renditions of the Strategic Climate Change Research Plan should incorporate the identified research priorities, including the most appropriate agencies and outside partners capable of addressing them. Moreover, DWR, working with other State agencies as well as a diverse group of stakeholders, has recommended formally establishing and funding a California Climate Science and Monitoring Program. Monitoring of how both the climate and existing infrastructure is responding to the climate is critical for ensuring adaptive approaches to maintaining safe infrastructure; a monitoring program is thus an essential companion to any future research. Finally, the State should provide modest and stable additional funding to expand the State Climatologist Office to enable the State Climatologist to engage the climate science community and in turn advise State government on climate change issues.

[1] For more information, see: https://walrus.wr.usgs.gov/coastal_processes/cosmos/

Recommendation 3

Because of the diversity of State agencies, types of infrastructure and their vulnerabilities, and the specific needs for climate science, there cannot be a one-size-fits-all recipe for State agencies to engage with the climate change science community. That said, the State budget should provide full funding to State infrastructure agencies so they can dedicate time and support to their engineers and architects to substantively and collaboratively interact with climate scientists and other relevant experts in the creation of useful advice, guidance and tools on a regular and ongoing basis, in a way and at a level appropriate to their needs.

Whether it is through a national scale connection to the Sustained Climate Assessment, or through augmentation of the state's Adaptation Clearinghouse (Figure 10.4), including its Technical Advisory Group, or the better use of gatherings such as the California Adaptation Forum (CAF), formalized processes should be developed in which state engineers and architects have deliberate and sustained interaction with physical and social climate change scientists from diverse research institutions, as well as professional organizations and other experts and stakeholders. Some of the immediate first steps discussed earlier include:

- Expand timely options for state engineers and architects to travel outside of California to participate in professional conferences in order to continue learning about and gaining comfort with climate science, as well as continuing to build their network of peers and colleagues;
- Through a user-needs driven and broadly inclusive process, Cal-Adapt should be bolstered and updated to incorporate California-specific, engineering-scale information to have an authoritative site of publicly available information. Concurrently, a concerted outreach effort is needed to raise awareness of this information among state engineers and architects; and
- Equally important to the quality of the data provided via Cal-Adapt, once the tool is established, tool developers (within academia, consultancies, or State agencies) should provide training to end users to help them become familiar with and supportive of innovation and best practices related to sustainability and resilience, including support for collaborative processes.

Formal processes should be developed in which state engineers and architects have deliberate and sustained interaction with physical and social climate change scientists, professional societies and stakeholders.

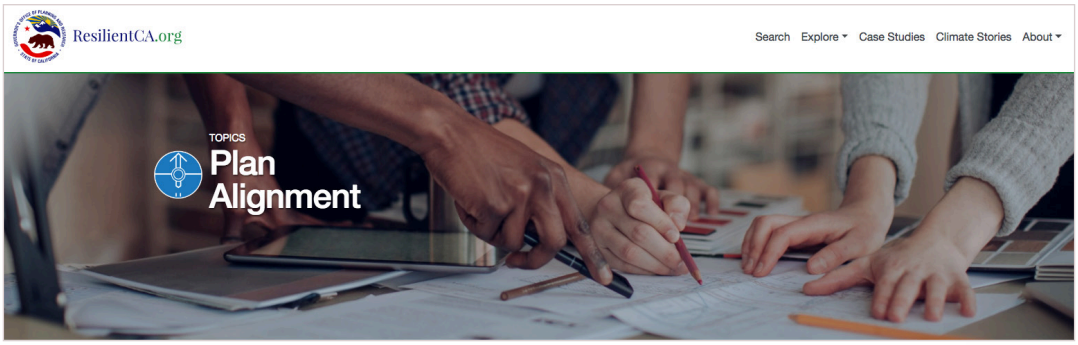

Figure 10.4: The state's recently launched Adaptation Clearinghouse could become an important resource for centralized delivery of scientific information needed by engineers and architects, but concerted outreach to practicing engineers is needed to raise awareness of this treasure trove of resources. (Photo: Screenshot of CA.resilience.org)

Recommendation 4

During the all-important pre-development phase, projects are conceptualized, planned and designed. The State budget should improve this process by building staff capacity and greatly increasing project funding to better account for a changing and uncertain climate, by addressing social inequity, and by assessing and accounting for the true costs and benefits of integrated projects across their full life-cycle.

During pre-development, infrastructure projects go from being just an idea to being plans and designs ready to be built. Pre-development determines the goals of the project, assesses their economic and technical feasibility, explores and decides among different design options, and involves all necessary components of project planning to make projects investor-ready. The most effective pre-development is more than a technical planning and design exercise (Figure 10.5). In keeping with the CSIWG's definition of climate-safe infrastructure, it should consider the broader concepts of statewide, sectoral or cross-sectoral and systems-oriented infrastructure investment. Examples of this type of work is being piloted in the San Francisco Bay Area Resilient by Design competition.

The most effective pre-development considers systems-oriented infrastructure investment

Figure 10.5: Training of engineers, architects and infrastructure planners is needed in the principles and approaches of effective pre-development of climate-safe infrastructure. (Photo: Training of scientists and practitioners; Susanne Moser, used with permission)

There are critical elements of successful pre-development planning and a range of tools to assist it. These include:

- Effective and inclusive stakeholder engagement from the start (see also Recommendation 5 below);
- Developing a climate-screening process to help identify the level of analysis needed and - together with stakeholders - to prioritize which projects to include in the "project pipeline";
- Comprehensively calculating the cost effectiveness of climate-safe infrastructure;
- As appropriate and where information is available, employing a probabilistic risk management approach, using techniques such as robust decision making, scenario planning, adaptation (or adaptive) pathways and flexible engineering design analysis;
- Effective communication to link the small initial steps and successes with the goals of the larger adaptation pathway; and
- Training on the above principles and approaches to ensure that practitioners are employing these strategies appropriately.

Recommendation 5

Difficult decisions will have to be made and the impacts of potential policies or decisions on different stakeholder groups are complex and challenging to assess. It is critical therefore to engage all affected stakeholders in a meaningful way, from early on and throughout any decision-making process, using the seven principles of equitable planning and decision-making.1 The Strategic Growth Council is well positioned to take a range of steps to encourage, improve and provide guidance on effective stakeholder engagement in the context of infrastructure development.

Stakeholder engagement is essential at every step of the process of crafting climate-safe infrastructure, from initial stages of discussion, to implementation, to maintenance and decommissioning. An important check against decision-making at any stage should always consider whether decisions are being made *with* communities, rather than *for* communities. Intentional stakeholder engagement is instrumental for developing a just, fair and socially inclusive process that gives voice to all members of society (Figure 10.6). To operationalize this recommendation, State agencies, policy-makers and project owners should:

- Create opportunities for timely and meaningful engagement by a wide range of stakeholders to help develop and evaluate potential policies and programs;
- Develop guidelines (or even requirements) for effective stakeholder engagement in infrastructure projects;
- Encourage agency staff to attend relevant conferences and meetings to make their constituents aware of proposed guidelines and to solicit comments;
- Hold trainings for stakeholder engagement facilitators; and
- Track progress on social equity.

Intentional stakeholder engagement is instrumental for developing a just, fair and socially inclusive process that gives voice to all members of society.

Figure 10.6: Many infrastructure decisions involve difficult trade-offs and engineers and architects need to have the skills to effectively convene, facilitate and navigate stakeholder conversations. (Photo: Carlsbad, California, desalination plant; vanderhe1, flickr, licensed under Creative Commons license 2.0)

Recommendation 6

Consistent with Executive Order B-30-15 and AB 1482, State agencies should update all relevant (i.e., climate-sensitive) infrastructure standards and guidelines that they can directly affect. Alternatively, or in addition, they should develop new state-specific guidelines where there are gaps to address climate resiliency by incorporating forward-looking climate information in those standards and codes. Where State agencies rely on standards developed by standard-setting organizations, state engineers and architects should work through the relevant professional organizations to advance development of climate-cognizant standards. Until new standards and codes are in place, State agencies should develop guidelines that go above and beyond minimum standards and codes to meet the goals of the Climate-Safe Path for All. Where agencies don't have resources to fulfill this workload, they should be fully funded in the State budget.

In the course of its deliberations, the CSIWG identified many institutional barriers to integrating forward-looking climate science into existing standards, codes and guidelines. State agencies differ in their technical capacity to make needed updates to existing standards and codes (and/or developing new ones where needed) vs. those who must await standard-setting organizations to provide those updated standards, which the State would then adopt. While policy guidance should be unambiguous, the way to implement it at the level of standards and codes will need to be flexible to reflect this range of in-house capacities.

Thus, Recommendation 6 encourages State agencies, when possible, to update their respective standards and codes to address climate resilience; when not possible, they should provide subject matter expertise to standard-setting bodies to ensure that climate resiliency is addressed in updates or new codes. Moreover, as new codes are being developed, or old ones are being updated, State agencies should use voluntary standards that are relevant to their respective infrastructure and that go above and beyond minimum standards and ensure climate resilience.

Among the most important barriers are questions around liability, which constitute a large and complicated enough challenge that a separate panel should be convened to address all the nuances and complexities and to provide guidance and recommendations to infrastructure agencies.

New types of standards and procedural mechanisms provide opportunities for increased climate resiliency. These include:

- Performance-based standards;
- Standards for professional practice;
- Standards of care;
- Different procurement approaches for various types of climate-safe infrastructure projects; and
- ASCE's Manual of Practice (MOP) that recommends an adaptive design approach.

Building on the ASCE's forthcoming MOP, the CSIWG proposes the development of a California-specific MOP that: addresses all critical infrastructure in the state; references the climate science information that is most relevant to California and produced in and for the state; and adequately supports the work of this Working Group with in-house staff and external experts and commensurate funding.

Finally, State agencies require supporting information, tools and innovative design approaches to implement climate-safe infrastructure (Figure 10.7). The CSIWG sees an important opportunity for the State to improve the benefit-cost assessment (BCA) approaches it uses. Instead of conventional BCA, the State should use more sophisticated methods that account for:

- The full infrastructure life-cycle, not just initial capital outlays;
- The cost of inaction;
- The deep uncertainty in both climatic and non-climatic aspects of the future;
- Adaptation pathways and the adaptive implementation of design choices;
- Benefits and costs to systems, not just projects; and
- The social costs and benefits to ensure that equity is explicitly accounted for.

In addition, the State should support applied research and testing of adaptive design for different types of critical infrastructure as well as developing rigorous economic methodologies for determining the true cost and benefits of implementing adaptive design; and design policies that allow and encourage infrastructure which is either sufficiently "modular" or built with sufficient "safety buffer" to accommodate changing climate change risks over time.

Figure 10.7: Different agencies require different types of information to support climate-safe infrastructure during planning, operation and maintenance. Close interaction between scientists, engineers and architects helps to identify those context-specific information needs. (Photo: Folsom hydropower dam; DWR, used with permission)

Recommendation 7

Because improving resilience is not a zero-sum activity, adding resilience in one area cannot be balanced by relaxing resilience requirements somewhere else. Adding requirements for resilience will come at a cost, so unfunded mandates are not feasible. The true costs over the full life-cycle of infrastructure projects should be assessed broadly, and the State should make efforts to help policy-makers and the public better understand the necessity of bearing these costs. Educational, promotional and other outreach should be conducted to generate support for the expenditures.

A follow-on activity to the work of the Working Group should explore the complex questions that arise about how to take climate change into account from a fiscal perspective. Moreover, the State has no comprehensive or reliable estimates of what climate change impacts and adaptation would cost at the State or local level. A range of factors make such estimates difficult to determine, but significant opportunities for filling knowledge gaps and improving on existing partial assessments is possible. The CSIWG identified a number of practical steps forward to implement the overarching recommendation on developing the funding and public support for investment in a climate-safe future:

- The State should include economic analyses of the costs and benefits of climate-safe infrastructure as an explicit focus in the next update of the Strategic Climate Change Research Plan to develop better estimates of the fiscal challenges and opportunities;
- With available and improved methodologies in hand, State agencies should carefully evaluate expected costs and benefits of current and proposed policy approaches to infrastructure planning and design, including via interdependencies with other agencies and policies, and to publicly disclose those costs, benefits and interdependencies;
- The State should find ways to compile and critically assess economic valuation methodologies, particularly of difficult-to-assess costs and benefits, that are available in the literature and update outdated State economic valuation practices, so that the environmental and social benefits can be more effectively integrated into feasibility studies;
- Agencies should build greater in-house technical know-how on innovative financing mechanisms;
- Working closely with financial advisers from the private and public sectors, including philanthropy, the State should explore and implement innovative funding mechanisms; and
- The Technical Advisory Council (TAC) of the State's Integrated Climate Adaptation and Resiliency Program's (ICARP) has begun investigating indicators and metrics of adaptation success. The TAC or a subset of the TAC, in cooperation with relevant State agency staff, external researchers, stakeholders representing social equity interests and financial experts should develop a suite of metrics that are meaningful to all parties – funding seekers and funding providers.

Equally important is for the Strategic Growth Council and other State agencies to launch serious outreach efforts to help Californians more fully understand why investment in climate-safe infrastructure is necessary.

Equally important to the above is for the Strategic Growth Council and other State agencies to launch serious outreach efforts to help Californians more fully understand why investment in climate-safe infrastructure is necessary, why the Climate-Safe Path for All is the safest and – in light of observed climate trends and already-experienced catastrophic impacts – likely a highly cost-effective way forward, and to make the case for continued financial reforms that remove some of the structural obstacles to a more reliable and affordable approach to infrastructure financing.

Recommendation 8

The Strategic Growth Council should coordinate with the Government Operations Agency, the Labor and Workforce Development Agency, and other relevant agencies to develop a work plan on how to address the training and professional development gaps of its infrastructure-related workforce as identified in this report, and begin to implement that work plan as soon as feasible. Because the Strategic Growth Council does not currently have the staff capacity and funding to implement this task, it would require adequate funding to do so.

Over the course of the CSIWG's work, a recurring theme was the need to have the skilled workforce to get climate-safe infrastructure appropriately designed, built, operated and maintained (Figure 10.8). The CSIWG identified a subset of actions that can be taken immediately to help advance this recommendation:

- Engage with professional societies, state-based engineering schools and universities, the American Society of Adaptation Professionals, private sector engineering and architecture firms and others deemed relevant in the development of the recommended workplan;
- Incentivize a rapid and substantial expansion of end-to-end, multidisciplinary climate change research, education and application programs;
- Set expectations through professional standards, qualification and continuing education requirements of state engineers and architects and those receiving State funding; and
- Expand and institutionalize the State's internal decision support capabilities, including a professional development pipeline of well-trained professionals by requiring staff to engage in ongoing professional development in the areas found to be most in need of advancement.

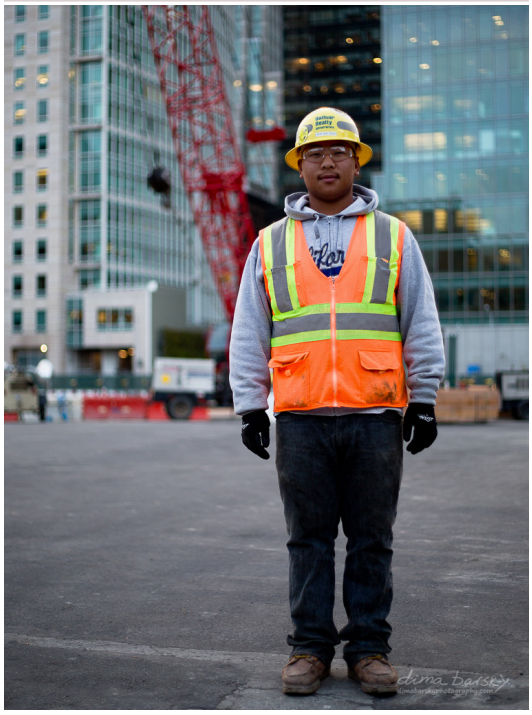

Figure 10.8: A recurring theme during the deliberations of the Climate-Safe Infrastructure Working Group was the need for a skilled workforce to appropriately use, interpret and act on scientific information. (Photo: Construction worker; Dima Barsky, flickr, licensed under Creative Commons License 2.0)

California is not alone with this struggle, thus the recommendations in this report for how to implement sustained and effective training and professional development can have implications beyond just the State of California.

The State should set expectations of a quality workforce through professional standards, qualifications and continuing education requirements of state engineers and architects and those receiving State funding.

Recommendation 9

The State should establish a Standing CSIWG to devise and implement a process for coordinating and prioritizing Climate-Safe Path related resilience policies and actions at the highest level. This panel would provide a needed forum for agencies to coordinate their policies, take advantage of synergies, address potential conflicts and learn from one another. As AB 2800 is slated to sunset in 2020, the work of a standing CSIWG would require an extension of AB 2800 and adequate financial support to conduct its business.

The CSIWG proposes the development of a standing CSIWG, which would have the following roles:

- Coordination;
- Central point of contact for infrastructure across the state;
- Forum to advance climate-safe infrastructure questions; and
- Leadership in incorporating forward-looking information in engineering standards.

The standing CSIWG panel would improve cross-sector coordination and integration by:

- Identifying ways to minimize obstacles to collaboration;
- Experimenting with new forms of coordination (e.g., coordinated integrative budgeting for projects);
- Fostering standing cross-agency working groups for infrastructure (such as for the development of the California-specific Manual of Practice (MOP), to explore legal issues around liability, or to prioritize infrastructure-related research needs;
- Ensuring wider and more effective stakeholder participation; and
- Fostering regular communication across silos.

Figure 10.9: A standing Climate-Safe Infrastructure Working Group would coordinate the State's infrastructure-related activities, serve as a central point of contact and as a forum to advance climate-safe infrastructure questions, and provide critical leadership to ensure forward-looking science is incorporated into infrastructure planning, design and construction. (Photo: Bridge work at night; Caltrans, flickr, licensed under Creative Commons license 2.0)

Recommendation 10

The State budget should provide full funding to State agencies to make deliberate efforts in reducing or eliminating the barriers that hinder or slow down adoption of State-level climate-safe infrastructure policy into practice. Key focus areas include the translation of Climate-Safe Path policy into practice manuals and contracting language, providing incentives to account for climate change in infrastructure projects, identifying metrics of success for monitoring and evaluation and developing a best-practices compendium.

Ultimately, for all of these recommendations to be used by on-the-ground contractors – those who implement the plans developed by state architects and engineers – they must be translated and made accessible to all working on infrastructure. The California-specific MOP provides one mechanism for this by providing step-by-step guidance for how to incorporate some of the more novel and non-traditional approaches to engineering described in Chapter 6.

The CSIWG recommends several important additional steps to help with the translation of State-level policy into climate-safe infrastructure project implementation on the ground:

- Once procurement approaches have been thoroughly assessed by a future working group for their advantages and disadvantages, guidance should be developed for infrastructure owners for writing different types of bids;
- Effectively assessing and managing bids, design proposals and construction requires adequate training of staff in infrastructure agencies, which is not always a given at this time;
- The standing CSIWG or a designated working group should engage with legal and financial experts as well as engineering and climate change experts to develop model contract language and other support to assist with linking policy to project-level contracts; and
- The standing CSIWG should also systematically examine the hurdles and opportunities for improved inclusive procurement practices as it transitions to building more climate-safe infrastructure and develop an inclusive procurement practices toolbox.

Furthermore, incentives – financial and otherwise – provide the inducements to break from traditional and well-trodden paths and try the innovative approaches and paradigm shifts necessary to move infrastructure design into the new Climate-Safe Path paradigm. Metrics of success and performance also provide tools that achieve multiple goals such as: enabling deliberate planning and decision-making; providing a mechanism for accountability and governance; providing justification of adaptation expenditures; providing the information needed for adaptive design; and supporting communication, public engagement and public support. And, finally, peer-to-peer learning supported by the development of a best practices compendium provides references, tools, ideas and inspiration for engineers and architects as they work towards a safer future for all.

Figure 10.10: For State policy to be translated into projects on the ground, planners need help in developing appropriate contract language. A California-specific Manual of Practice, model contracts, incentives and a set of performance metrics are all ways to support implementation. (Photo: Trinidad Head, Humboldt County; R. Bertolf, Wikimedia Commons, licensed under Creative Commons license 2.0)

In Closing

Through all of its climate-focused activities, the State of California has been laying the foundation for the work of the CSIWG. AB 2800 allowed the Working Group to tackle the tensions and challenges with changing ways of thinking and doing and creating new paths for infrastructure planning in the state. In using the systemic approach to move from vision to implementation, and in following the recommendations that provide the bricks for the Climate-Safe Path, California has the opportunity to Pay it Forward. It must make these investments today to ensure the safety, well-being and prosperity of all Californians tomorrow.

California has the opportunity to Pay it Forward. It must make these investments today to ensure the safety, well-being and prosperity of all Californians tomorrow.

Figure 10.11: Investing in California's climate-safe infrastructure today is "paying it forward" – for the sake of the safety, well-being and prosperity of all. (Photo: Ian D. Keating, flickr, licensed under Creative Commons license 2.0)