4 A Vision for Climate-Safe Infrastructure for All

Climate Safety Through Mitigation and Adaptation: The Climate-Safe Path

Through high-level policies, executive orders and laws, California has committed to reducing its greenhouse gas emissions by 40% below 1990 levels by 2030 and by 80% below 1990 levels by mid-century. This level of commitment puts the state on a responsible path toward helping the global community achieve the targets of the Paris Accord, namely to limit global average warming to 2°C (3.6°F) or less (1.5°C or 2.7°F) by the end of this century. As discussed in Chapter 3, this is an ambitious target and will require considerable political will to achieve. Many motivations lie beneath this choice, including economic opportunity, a desire to lead politically, technologically, environmentally and morally, and enlightened self-interest. This policy orientation is also informed by the best available science that unmitigated climate change will undermine California's safety and well-being, natural resources and beauty, and crucially important economic sectors. While a 2°C (or less) warming will not prevent impacts from a warming climate (in fact, they are already being felt and more warming is inevitable), the impacts expected at that level of warming (roughly equivalent to the goals of the Paris Accord) are widely seen as considerably more manageable than those associated with greater and faster warming.

Political leaders now have an opportunity to strengthen adaptation as a political priority. They can send a directional signal that the safety of communities and the infrastructure on which they and the state's economy vitally depend is of utmost importance.

As the nearly two decades of international climate negotiations make clear, and as California's own path to increasingly stricter emissions reduction targets illustrates, stringent mitigation targets are not just a rational choice in light of potentially severe risks, but ultimately a political choice. However difficult it may be to achieve, aiming for 2°C or less is the choice that focuses the compass needle toward greater safety from some of the harmful climate impacts that would occur if emissions were allowed to further destabilize the Earth's climate system. However, the great difficulty involved in compelling the international community to make this commitment suggests that California must be prepared to contend with much greater climate impacts.

Thus, there is a parallel political choice to be made in setting adaptation targets. Over the past few years, California's political leaders and State lawmakers have laid some policy foundations for adaptation and now have an opportunity to strengthen adaptation as a political priority. They can send the same directional signal as they did with mitigation, namely, that the safety of communities and the infrastructure on which they and the state's economy vitally depend is of utmost importance. That choice is to ensure that long-lived infrastructure is planned, and may eventually need to be built, operated and maintained, to withstand future impacts from climate change associated with the "business-as-usual" emissions pathway (currently

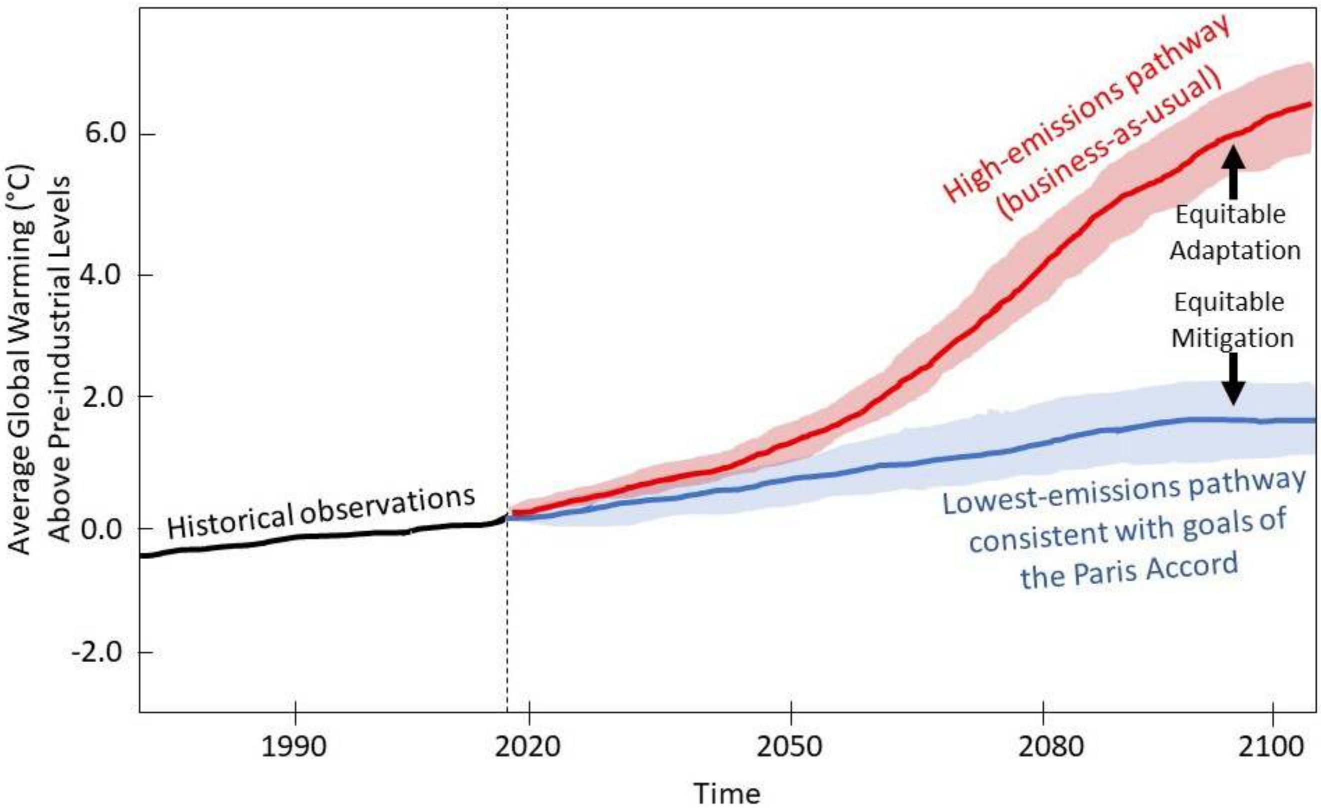

Figure 4.1 The Climate-Safe Path describes the simultaneous pursuit of stringent greenhouse gas mitigation that aims to meet the goals of the Paris Accord while charting an adaptive pathway to protect Californians against the impacts of a high-emissions scenario, both with a central focus on social equity.

the RCP 8.5 emissions scenario). Consistent with State guidance from the Office of Planning and Research (OPR), we refer to this pathway as a "high-emissions pathway" from here on.[1]

Should it become apparent over time that – globally – society has safely averted a high-emissions future, the adaptive approach promoted in this report should allow for an "off ramp" to adapt to the impacts associated with a lower-emissions pathway. However, determining the point in time when such a transition to a lower-safety threshold is indicated, is both scientifically and politically complex and requires dedicated research and public debate.

By reducing the causes of climate change through mitigation and simultaneously implementing preparedness and adaptation measures, California would pursue the safest of possible climate action pathways any state can take. We call this comprehensive strategy "the Climate-Safe Path" (Figure 4.1).

By reducing the causes of climate change through mitigation and simultaneously implementing preparedness and adaptation measures, California would pursue the safest of possible climate action pathways any state can take. We call this comprehensive strategy "the Climate-Safe Path"

[1] The emissions scenarios currently used in the Fourth Assessment, NCA4 and the Fifth IPCC assessment will be replaced with updated ones in the future. To maintain the concept without becoming obsolete when that happens, we use the more general term, which – at any one time – should be operationalized with the highest emissions scenario used by scientists to produce climate change projections.

From Guidance to Policy

Current guidance documents from State agencies on considering climate impacts recommend considering impacts associated with the high-emissions scenario within the context of specific projects. The Ocean Protection Council's (OPC) recently released updated sea-level rise guidance suggests that coastal managers consider risks from sea-level rise associated with high-emissions scenarios depending on the level of risk tolerance and potential adaptation pathways for different projects, with the highest sea levels considered for the most critical and least adaptive projects[49]. Similarly, the OPR statewide guidance for infrastructure planning *Planning and Investing for a Resilient California*, recommends that state infrastructure managers plan for impacts associated with the high-emissions scenario for all decisions with time horizons to 2050[49]. Beyond that the OPC and OPR guidance documents differ nominally from the Climate-Safe Path proposed here in that they recommend a risk assessment approach using a range of scenarios based on the criticality of the project. However, OPR's *Infrastructure Planning Guidance* does emphasize the use of the high-emissions scenario, whenever people and highly vulnerable assets may be placed at risk, if the project is more or less permanent or its failure could cause major economic impacts. Thus, the OPR guidance and the Climate-Safe Path proposed here are essentially identical. We propose a similarly adaptive and flexible approach with a stringent protective target, given the legislative intent to protect lives, the long-lived nature of most infrastructure and the continued high-emissions pathway that society appears to be on.

Guidance documents, however, are not mandatory and they will have the desired impact on decisions primarily if and when they get teeth, i.e., when they are either turned into a mandate or when effectively designed, complementary "carrot and stick" approaches ensure investment decisions protect against the impacts of a high-emissions scenario.

Realizing the Climate-Safe Path One Step at a Time

Preparing for the climate change impacts associated with the high-emissions pathway is an ambitious undertaking that has different implications for different types of infrastructure, for existing and newly built infrastructure, and for short- and long-term climate impacts. In no way does it imply that every infrastructure investment made today must build immediately to the protective level that

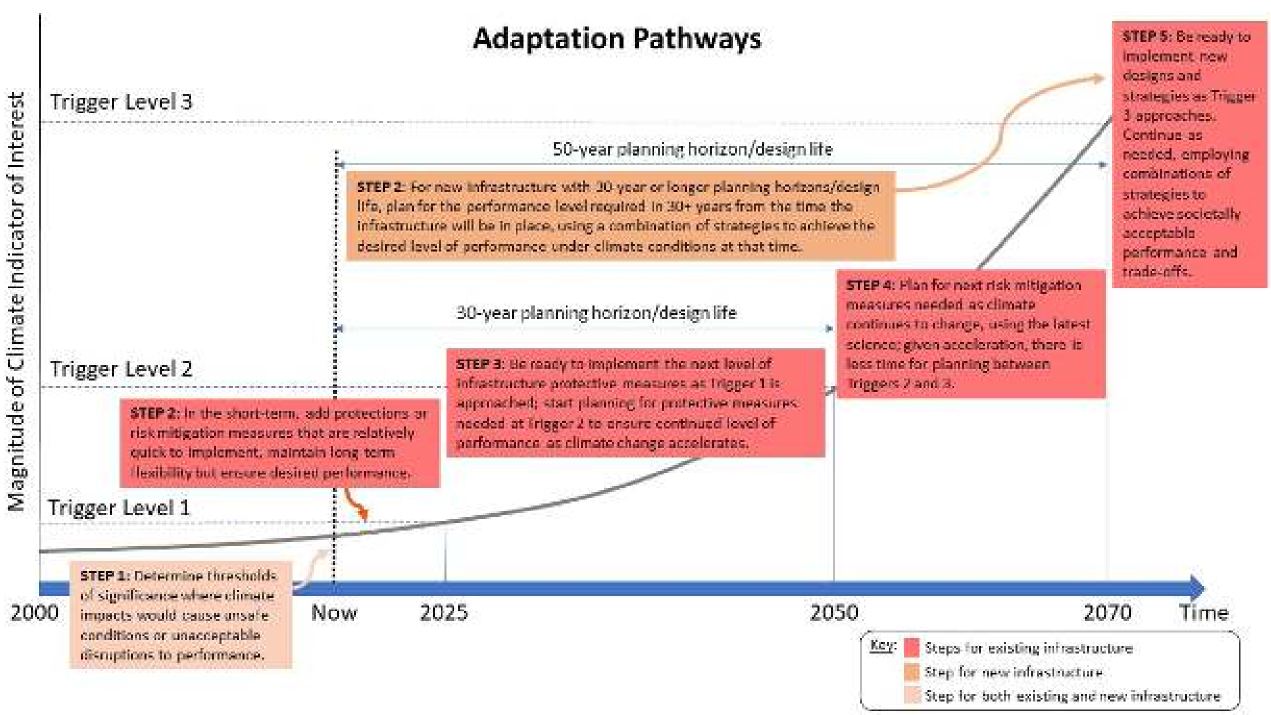

Figure 4.2 Conceptual diagram of an adaptation pathway. (Source: Adapted from Moser 2016[194], used with permission) (Explanation in text)

would be required in many decades when the impacts associated with the high-emissions pathway are beginning to unfold. In other words, realizing the Climate-Safe Path does not mean a once-and-for-all step change, but a change in many steps. This is similar to how emission reductions are achieved: not turning off all emissions at once, but successively and steadily moving toward the ultimate goal. Realizing the Climate-Safe Path means following an adaptation pathway that keeps an eye on a long-term goal but is realized through a variety of strategies in multiple stages over the course of decades (Figure 4.2).

Realizing the Climate-Safe Path does not mean a once-and-for-all step change, but a change in many steps.

Such a flexible adaptation pathway begins with an agreement among relevant stakeholders as to the desired performance/service level of infrastructure. This desired performance level also has direct implications for the degree of risk aversion decision-makers might have. As climate change continues, thresholds will be crossed where the performance of the existing infrastructure as it is currently built no longer fulfills societal expectations. Where existing infrastructure is already inadequate, steps should be taken as soon as possible to augment existing levels of protection to ensure that performance can be maintained. Planning for implementing subsequent retrofits is also begun, recognizing that lead time is needed to implement them. As climate change continues and its impacts eventually exceed the projections for which infrastructure is designed to withstand, the next level of protection – using a combination of strategies – is implemented. The more flexibility is maintained each time, the better. At subsequent steps, the best available knowledge both about climate science, societal trends and performance of different infrastructure designs must be taken into account. But planning time to the next trigger level/threshold becomes shorter as climate change accelerates. These steps are continued as long as conditions change. To realize an adaptive approach to infrastructure upgrades, it is critical that money be set aside now and over time to fund the needed future changes. Otherwise, in a different future political or economic climate, support and resources for the necessary updates could lessen and thus place greater risks on communities in the future.

While we will offer more technical and tactical detail in the subsequent chapters on what is needed to implement the Climate-Safe Path, we can already say here that building and maintaining infrastructure fit for a high-emissions world will be realized through a combination of strategies, each adding a necessary but by itself insufficient dimension to "climate safety." These strategies are based on decades of experience in hazards management and mirror the definitions for climate-safe infrastructure, resilience and related terms offered in Chapter 1[181].

For newly built infrastructure, a number of interrelated but complementary strategies must be pursued to ensure infrastructure functionality and obtain desired risk aversion levels over the changing conditions that can be expected over its lifetime:

- **Robustness:** infrastructure is built to the protective level expected to be needed to ensure acceptable functionality and reliability (assuming the high-emissions pathway) over the design life of the infrastructure (e.g., 30 or 50 years); because there is inevitable uncertainty and multiple design criteria must be met simultaneously, the infrastructure would be expected to be robust over a range of uncertain conditions;
- **Resilience:** plans are developed and practiced from now on for the possibility of a situation when an extreme event exceeds the protective level and infrastructure fails, so as to improve and speed up the response and adaptive recovery to requisite levels of protection needed at that time (sometimes referred to as safe-to-fail approaches with appropriate disaster preparedness and response management); this complementarity to robustness is shown in Figure 4.3;[1]
- **Adaptability:** plans are developed and features integrated into the design now that would allow infrastructure owners to adapt the structure to a higher level of protection should it become necessary over time;
- **Redundancy:** plans are developed now and implemented over time that help the new infrastructure maintain functionality when it or parts of it fail; and
- **Avoidance:** on the basis of vulnerability assessments already in place, underway or to be conducted in the future, infrastructure development in high-risk areas should be avoided unless the infrastructure owner is willing to pay for the necessary measures to ensure functionality over the effective lifetime of the infrastructure (often considerably longer than the design life), using the above four strategies.

[2] See The L.A Metro *Resiliency Indicator Framework*[195] as an example.

For existing infrastructure, the same basic types of strategies listed above must be considered including a strategy that will become necessary when the limits of changing existing infrastructure are being approached:

- **Robustness:** as existing infrastructure undergoes maintenance, upgrades or repairs after damage, structural or material changes are made to bring the existing infrastructure to a higher protective level (if structurally possible to the level needed for impacts expected with the high-emissions scenario over the remaining lifetime of the structure) through retrofits;
- **Resilience:** because robustness and adaptability strategies may be limited with existing infrastructure, plans are developed or updated and practiced from now on for the possibility of a situation when an extreme event exceeds the protective level of the existing structure, so as to improve and speed up the response and adaptive recovery to requisite levels of protection needed at that time;
- **Adaptability:** as existing infrastructure undergoes maintenance, upgrades or repairs after damage, efforts are made to build adaptive features into the retrofit measures so as to allow further adjustments in the future (if structurally possible);
- **Redundancy:** plans are developed and implemented now that help the existing infrastructure maintain functionality when one or more parts of it fail; and
- **Retreat or Decommissioning and Removal:** assessments are undertaken to estimate the time – under the assumption of a high-emissions pathways – when the physical defense of even upgraded existing infrastructure is no longer viable and the functionality of the infrastructure can no longer be assured; based on this assessment, time-sensitive plans should be developed to either move or remove and decommission and replace the infrastructure (Figure 4.3).

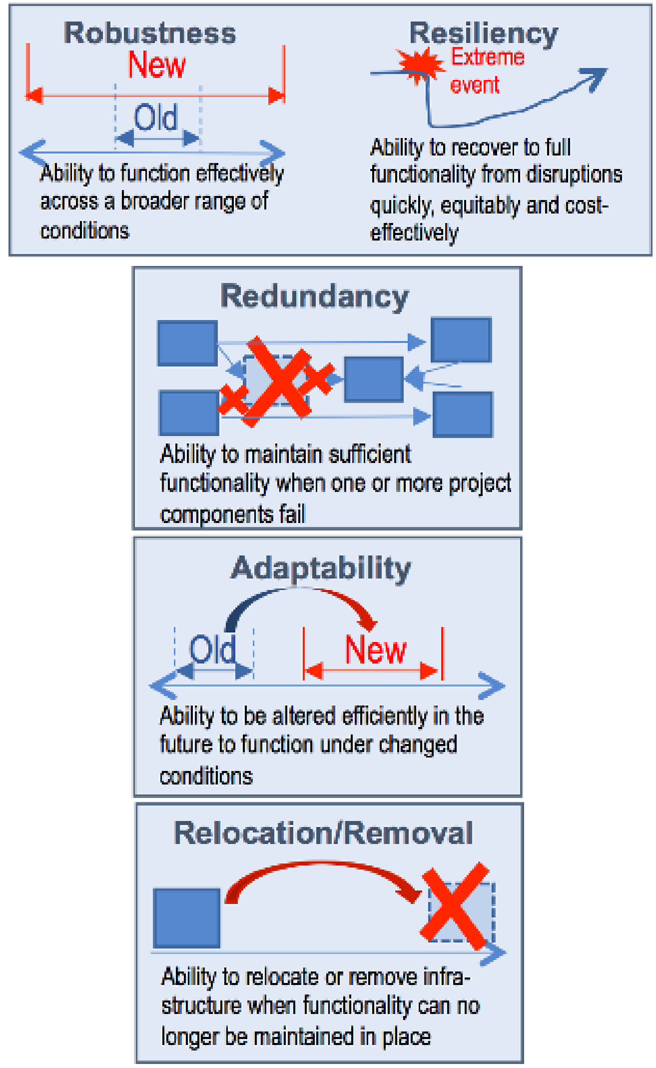

Figure 4.3 Conceptual drawings of the five basic strategies that can be flexibly combined to achieve the desired performance levels of climate-safe, sustainable infrastructure (Source: Adapted from Wallace 2017[181], original used with permission)

Over time, the dual approach of limiting greenhouse gas emissions and simultaneously investing in retrofitting, replacing and building new infrastructure that incorporates these strategies or principles will result in safer communities with more reliable infrastructure and well-practiced plans in place to recover from extreme events. This will allow infrastructure to quickly return to functionality and increased safety in the face of the trends and changing extremes experienced over time.

Importantly, designing for and working toward climate-safe infrastructure requires a shift in thinking from focusing on individual structures to thinking in interconnected and interdependent, multisectoral systems of infrastructure that can withstand not just the occasional extreme event but tightly-spaced sequences of hazardous events and complex, concatenated simultaneous events[165]. Infrastructure planners, designers, builders and operators must come to think long-term and in systems, considering both directional trends and changing patterns and characteristics of extremes.

In short, climate-safe infrastructure would be that which is designed in a way that extreme events do not lead to catastrophic failure, neither now nor across a wide range of uncertain future conditions (Box 4.1).

Box 4.1: Flexible Combination of the Five Strategies of "Climate-Safe" Design

Climate safe infrastructure would be that which is designed such that extreme events don't lead to failure, both now and across a wide range of uncertain future conditions. To achieve this goal, it would build in robustness, redundancy, be readily modifiable to adapt to the prevailing conditions and incorporate resiliency to ensure quick recovery in case of a bigger-than-expected event.

Resiliency and redundancy in particular, are useful concepts for infrastructure design because they acknowledge that events beyond design specification will happen – and maybe more often in the future than currently expected. The common preference is to build infrastructure strong enough – robust enough – that it can withstand worsening conditions. Robustness is a concept that relates to both a particular multi-factorial way of making decisions and how resulting designs will perform regardless of how uncertain future conditions play out. A robust infrastructure design would be one that remains appropriately designed in the future even if climate conditions change in ways different from our current best prediction. Achieving robustness is often accomplished by building adaptive features into the design so that the structure can evolve in response to changing conditions, i.e., it would be readily modifiable to adapt to future prevailing conditions. The complementary notion of resilience implies that infrastructure would be designed to recover (or be restored) with low effort or costs and contingency plans would be made (including redundancy) to ensure quick return to functioning or minimal disruption of functionality at all. In other words, if or when infrastructure fails, it should do so in a non-catastrophic way, fairly compensating those who experience loss or damage (the concept of "safe-to-fail", see Chapter 6 for more details).

The flexible combination of multiple strategies to achieve climate safety will look unique in different localities and for different types of infrastructure. Here, hard and soft infrastructure are combined, and others could be added to protect a shoreline. (Photo: Ocean Beach, California; Dawn Danby, flickr, licensed under Creative Commons license 2.0).

For example, a climate-safe sea-level-rise protection scheme might include both a physical barrier designed to hold back storm surge as well as a green space that can absorb overtopping surge and thus minimize the impact of such an event. The design would also include the ability to expand the absorption capacity of the green space if future surge becomes more frequent or larger than presently anticipated. And should failure occur, plans and processes would be in place to quickly and effectively deal with the consequences should the protective features be overwhelmed by a larger-than-expected coastal storm event. Systemic infrastructure planning would also carefully assess the possibility of cascading events and the impacts of infrastructure disruption on interconnected lifelines. This multi-pronged, comprehensive approach would allow the surrounding community to efficiently regain functionality with the least possible disruption of activities and loss of life and damage to structures.

But planning for climate-safe infrastructure should also involve planning for cases – which may or may not come over the course of the functional lifetime of the infrastructure – when appropriate functioning, and thus the safety of facilities and communities, can no longer be guaranteed even after all other strategies have been applied. Where climate trends are accelerating (as, for example, in the case of sea-level rise), such a time may come faster than anticipated. But if society succeeds in reducing emissions more significantly than anticipated, that time may be far out in the future.

Thus, the full set of strategies is available – in whatever combination – to infrastructure planners and designers so that they can wisely incorporate precaution, flexibility and adaptability; ensure that infrastructure can function across the wide range of plausible future conditions; and, ultimately, be taken efficiently and seamlessly out of use if necessary.

A Climate-Safe Path for All

The vision of the Climate-Safe Path outlined here is not a path just for the privileged. Instead, it is envisioned to be a path for all. Following the Climate-Safe Path must include an integral commitment to remedying past injustice in infrastructure investment so as to ensure the safety, health, well-being and opportunities of those who have borne insecurity, public health burdens and lack of economic opportunity the most and the longest.

As we described in Chapter 3, California's infrastructure – much like that of any other US state – is in many ways inadequate for current climate conditions, much less for those expected over the next several decades or more[7]. Insufficient infrastructure investment, deferred infrastructure maintenance, and a general lack of vision and political will to make the necessary long-term investments in highly functional infrastructure has plagued the state for decades (see Chapter 8). Thus, what we call for in this report is not no- or low-cost, but it is no- or low-regret because any new and additional infrastructure investment California decides to make is remedying a current problem and constitutes an investment into its future ("paying it forward"). But it will be that only if the investment is cognizant of the changing climate in which this infrastructure must serve.

The state's most outdated and dilapidated infrastructure is not evenly distributed, neither geographically, nor socio-economically. It is not affecting Californians equally. Due to decades of underinvestment and redlining (i.e., the systematic denial of various services to residents of specific areas or segments of society), low-income communities and communities of color often confront the largest potholes, the most outdated school buildings, the leakiest pipes, the worst connectivity to modern transportation, communication and other community infrastructure. The added risks arising from climate change are not going to be equally distributed either. These same communities often have the fewest resources to deal with the risks from climate change. As such, these communities are those where the State has the greatest opportunity to make a difference.

Inadequate engagement during the infrastructure planning and decision-making processes, systemic disadvantaging through decision criteria and cost-benefit requirements, long-standing institutionalized racism and narrow thinking about the role of infrastructure across multiple sectors and within a region or community are at the root of this inequitable investment in infrastructure[3,196,197].

As the Movement Strategy Center argues in its *Pathways to Resilience* report[198], "climate resilience is not about 'bouncing back.' Instead it is about bouncing forward to eradicate the inequities and unsustainable resource use at the heart of the climate crisis... [Thus,] climate resilience requires a holistic view of the challenges we face, and it calls for solutions at the intersections of people, the environment and the economy." This is consistent with the paradigm of "sustainable infrastructure" promoted since the early 2000's by the American Society of Civil Engineers[3] (ASCE) although still requiring widespread adoption.

Again, the State already promotes social equity and inclusion as one of its guiding principles for adaptation in its statewide adaptation strategy (*Safeguarding California*[199]) and through EO B-30-15. Making social equity explicitly central to infrastructure investment as a matter of State policy is not a leap, but an extension, a matter of consistency across State policies.

The Climate-Safe Path must include an integral commitment to remedying past injustice in infrastructure investment so as to ensure the safety, health, well-being and opportunities of those who have borne insecurity, public health burdens and lack of economic opportunity the most and the longest.

PolicyLink, an Oakland-based racial and economic equity advocacy group which includes a focus on infrastructure, suggests the following principles to guide equitable infrastructure planning, policy and investment[200]:

- Include residents in decision-making;
- Serve underinvested communities without pushing out existing residents;
- Improve the environmental health and quality of life for residents of disinvested communities;
- Be equitably owned, financed and funded;
- Create good jobs and business opportunities for local residents; and
- Invest in workforce training.

[3] For the full range of sustainability policies, strategic roadmaps, certificate programs and resources, see: http://www.asce.org/sustainability/.

The Working Group endorses these principles. In fact, effects of increasing impacts from climate change is a human rights issue[201]. Holding paramount the safety, health and welfare of the public is central to the code of ethics of the engineering profession. The Working Group's strong conviction is that social equity in infrastructure development should not be a last-minute adjustment of an already-decided plan, nor merely one among many criteria to guide infrastructure decisions. If the protection of lives is the goal, social equity must be considered in the beginning, middle and end of infrastructure planning and decision-making. It is the outcome that is planned for from the start, and that means a different process must prevail. As Dr. Beverly Scott put it in one of the CSIWG meetings, "Are we planning *for* communities, or *with* them?" Figure 4.4).

Social equity thus rises to an overarching priority, guiding climate-safe infrastructure planning, design and implementation. In light of the greatest need for infrastructure investment in low-income communities and communities of color, and the legislative intent of AB 2800 to ensure the safety of Californians as climate change threats to the state's infrastructure increase, equity should be included every step of the way from infrastructure planning and decision-making to implementation and performance evaluation, with clear indicators and guiding questions to show the way (Box 4.2).

Figure 4.5 illustrates how to rate infrastructure investments. The three criteria are the degree to which they would (a) reduce the state's risks from climate change, (b) remedy past lack of investment in infrastructure and (c) explicitly reduce/remedy social inequity through comprehensive approaches. This would lead to clear priority setting in favor of those regions and communities of the state that have long been neglected and are therefore in greatest need now.

Figure 4.4 To ensure the safety of all Californians as climate change threats to the state's infrastructure increase, equity should be included every step of the way from infrastructure planning and decision-making to implementation and performance evaluation. (Photo: US Army)

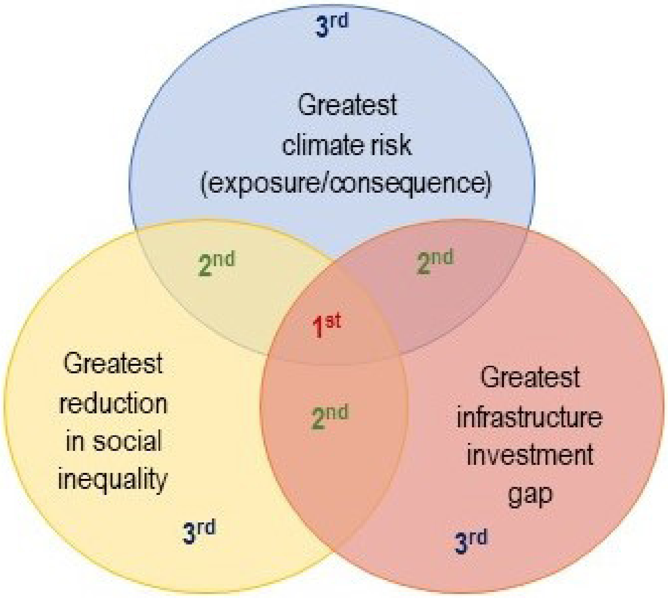

Figure 4.5 Prioritizing infrastructure investments in line with the Climate-Safe Path for All proposed here should be guided by three criteria: (1) where is the risk the greatest?; (2) where is the greatest infrastructure investment gap?; and (3) where can the investment most reduce inequality and increase opportunity? This will result in tangible improvements for long-neglected communities and regions of California.

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.

To operationalize Recommendation 1, the CSIWG suggested the following concrete next steps:

1. 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 consider and then employ an appropriate combination of the five strategies described above to work toward increasing climate safety.
2. 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. This guidance should rely on the concepts and suggestions made in this report.
3. At the program level, guidelines should address the full range of decisions related to infrastructure, including policy, planning, procurement, funding, cross-agency/cross-sector coordination to foster systemic approaches and program evaluation; and
4. At the project level, guidelines should clarify and specify agency-relevant risk and vulnerability assessment approaches, event tree analysis, full life cycle cost assessments, assessment of costs, benefits, tradeoffs as well as potential risk mitigation measures.
5. 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.

To operationalize the social equity dimension of Recommendation 1 specifically, the CSIWG suggested the following critical next step:

1. State legislation, propositions and state agency policy directives related to infrastructure should direct infrastructure investment where it is needed most as determined by a screening of climate risks (see Climate-Screening Tool in Chapter 6), the infrastructure investment gap and the potential to reduce social inequities. This would prioritize infrastructure upgrades, repairs and new investment in long-neglected communities and regions of the state.

Box 4.2: An Equity Indicators Framework

Demographics:
Who lives in the region and how is this changing?
- Racial/ethnic diversity
- Demographic change
- Population growth
- Racial generation gap

Economic vitality:
How is the region doing on measures of economic growth and well being?
- Is the region producing good jobs?
- Can all residents access good jobs?
- Is growth widely shared?
- Do all residents have enough income to sustain their families?
- Is race/ethnicity/nativity a barrier to economic success?
- What are the strongest industries and occupations?

Readiness:
How prepared are the region's residents for the 21st century economy?
- Does the workforce have the skills for the jobs of the future?
- Are all youth ready to enter the workforce?
- Are residents healthy?
- Are racial gaps in education and health decreasing?

Neighborhoods:
Are the residents of [the region] prepared for and connected to the region's opportunities?
- How are demographics changing?
- How are residents doing on measures of economic opportunity and readiness?
- Are residents connected to opportunities?

Connectedness:
Are the region's residents and neighborhoods connected to one another and to the region's assets and opportunities?
- Do residents have transportation choices?
- Can residents access jobs and opportunities located throughout the region?
- Can all residents access affordable, quality, convenient housing?
- Do neighborhoods reflect the region's diversity? Is segregation decreasing?
- Can all residents access healthy food?

The National Equity Atlas has developed an equity indicators framework, along with several regional profiles to illustrate how it would be applied (examples for the San Francisco Bay, Sacramento and Los Angeles regions and Fresno County are available, see PolicyLink and PERE[200,202-205]. The guiding questions and associated quantitative indicators, especially disaggregated data on each of the indicators, offer a tangible way toward improving, tracking and evaluating social equity over time. (Source: Adapted from PolicyLink and PERE (2017)[202], p.13, used with permission)

From Vision to Action: A Framework for Action

In order for this vision of climate-safe infrastructure to be realized, integrating the best available forward-looking science (of climate change as well as demographic, socio-economic, technological and ecological changes relevant to infrastructure investment decisions) is necessary, but insufficient. Publicly accessible data and information inputs, as well as high-quality analytics such as risk and vulnerability assessments, are essential both to set standards and guidelines and for ongoing operation and maintenance. But they are only one part of an action-oriented framework that will result in the ultimate intent of AB 2800, namely that infrastructure investments get made and that climate-safe infrastructure is actually built so that lives are protected and the foundation for a prosperous future is built and maintained.

We therefore propose the following framework that places the integration of forward-looking science into infrastructure planning and design in the context of additional necessary steps and areas for improvement in order for climate-safe infrastructure to be implemented on the ground (Figure 4.6).

The five core components of this framework mirror key needs of any infrastructure planning and design process, and we dedicate a chapter to each in the remainder of this report.

- **Data and Analytics (e.g., risk and vulnerability assessments, along with the necessary tools)** Infrastructure planning and design requires many types of data, model simulations and forward-looking science – appropriately used and interpreted. This is a central focus of AB 2800, and we will discuss in greater detail what information is needed, what information is currently available or should be produced in the future in Chapter 5.

- **Project Pipeline (e.g., project planning and pre-development, standards for prioritization, project management flow)** Infrastructure projects are often years to even decades in the making. Where and what to prioritize, to what standards of performance climate-safe infrastructure should be built, and planning and deciding about them in a transparent and inclusive fashion requires effective project management and coordination. A well-developed project pipeline is a necessary pre-condition to attract infrastructure finance and involves successful stakeholder engagement, efficient progress through the permitting process, multi-sectoral alignment and other processes, which we describe in chapter 6.
- **Governance Structures (e.g., at various scales)** Many types of infrastructure involve engagement of multiple levels and different kinds of jurisdictions and can include multiple State agencies or sectors, for funding and financing, review and permitting, oversight, operation and maintenance. Appropriate and effective governance structures and processes are required for complex partnerships and financing but may be lacking or need clarification and streamlining for efficient functioning. Governance also involves the rules, codes, standards and guidelines that govern where and how infrastructure is built. We discuss these needs in Chapter 7.
- **Financing Tools (e.g., funding/revenue, financing/loans, innovative instruments incl. insurance)** Federal and State funding sources alone are widely seen as insufficient to catch up on past inadequate infrastructure investment, resulting in a call for private sector involvement and innovative partnerships and financial tools to generate the necessary funds. In addition to familiar tools such as bonds, taxes and fees, a number of innovative tools are currently being piloted. We review these trends, needs, related obstacles and opportunities in Chapter 8.
- **Implementation Aids (e.g., training, professional development, M&E, public engagement)** None of the above will be realized at the rate and quality needed without engineers, architects, planners, procurement officers and on-the-ground operations personnel having the necessary professional training and know-how to appropriately use available scientific data and tools. They must also be able to understand different planning or financing options and be capable of navigating complex governance challenges. Thus, to enable climate-safe infrastructure to be built, relevant staff require professional development opportunities, accountability mechanisms, and a cyclical, iterative approach – informed by ongoing monitoring and evaluation of the performance of infrastructure – to periodically reassess climate risks and adjust infrastructure planning and design approaches accordingly over time. We will discuss critical needs in this category in Chapter 9.

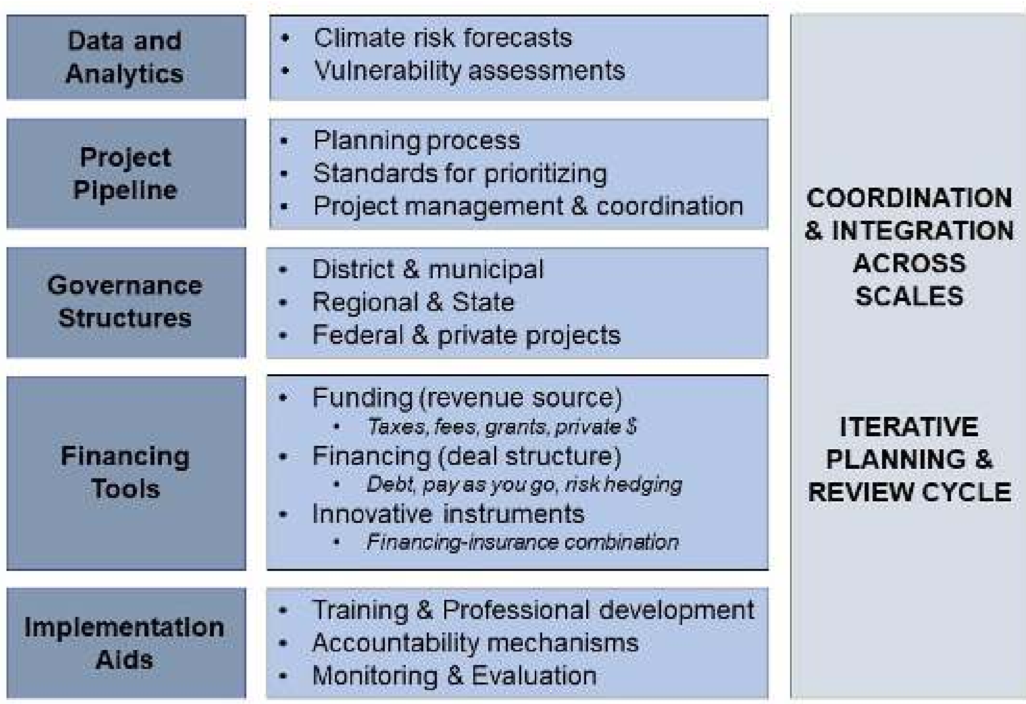

Figure 4.6 A strategic, integrated framework for action is needed to ensure that the vision of Climate-Safe Infrastructure for All gets realized. It includes data and analytics which inform infrastructure planning and design to generate a prioritized list of projects that can be implemented with the help of appropriate governance structures, financing tools and implementation aids. (Source: Adapted from Cleveland 2018 webinar; original used with permission)

It is clear from the discussion so far, and from what will be explained in much greater detail in the following chapters of this report, that the integration of forward-looking climate science alone will not "solve" the problem of the state's infrastructure being ill-prepared for the current and coming climatic conditions. A systemic, iterative approach must be developed that links climate and other forward-looking science to planning, governance, financing and the appropriate conditions for project implementation.

To ensure strategic advancement toward realizing the Climate-Safe Path for All, and to make implementation more likely, future State legislation and programs developed by the Strategic Growth Council and individual State agencies (as well as other entities interested in or charged with climate-safe infrastructure planning and design) should adopt an "it takes a system" approach as a foundation for building climate-safe infrastructure.

To ensure strategic advancement toward realizing the Climate-Safe Path for All, and to make implementation more likely, future legislation and programs should adopt an "it takes a system" approach

The following five chapters take on each of the framework-to-action elements in greater detail, beginning with the data and analytics in Chapter 5.

Figure 4.7 At "The Longest Table" event in Howard County, Maryland, 320 residents sat a a 320-foot long table and shared their respective vision for their community. This type of socially inclusive engagement ensures equitable respresentation; everyone had a seat at "the table." (Photo: Howard County (Md.) Library System, flickr, licensed under Creative Commons license 2.0)