Climate-smart Capital Investment Planning

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May 5, 2022

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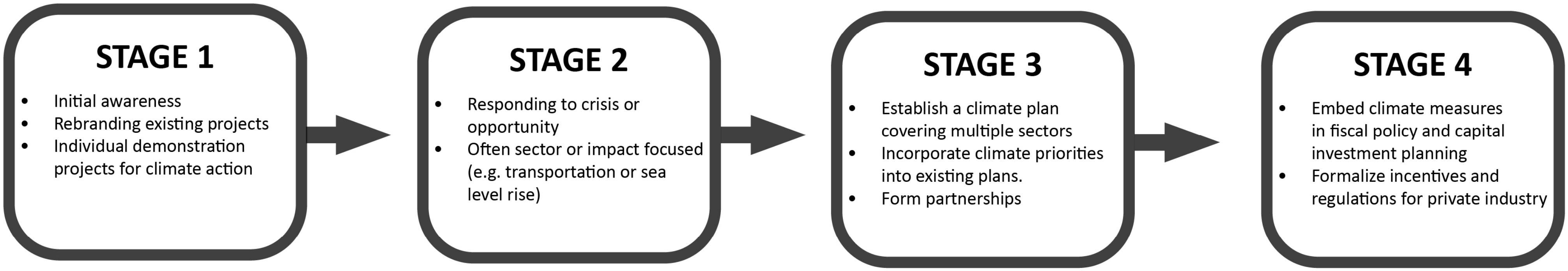
Stages of City Climate Action



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Advance to Stage 4

Embed climate action in the Capital Improvement Program

Last chance to make cost-effectively changes to investments s

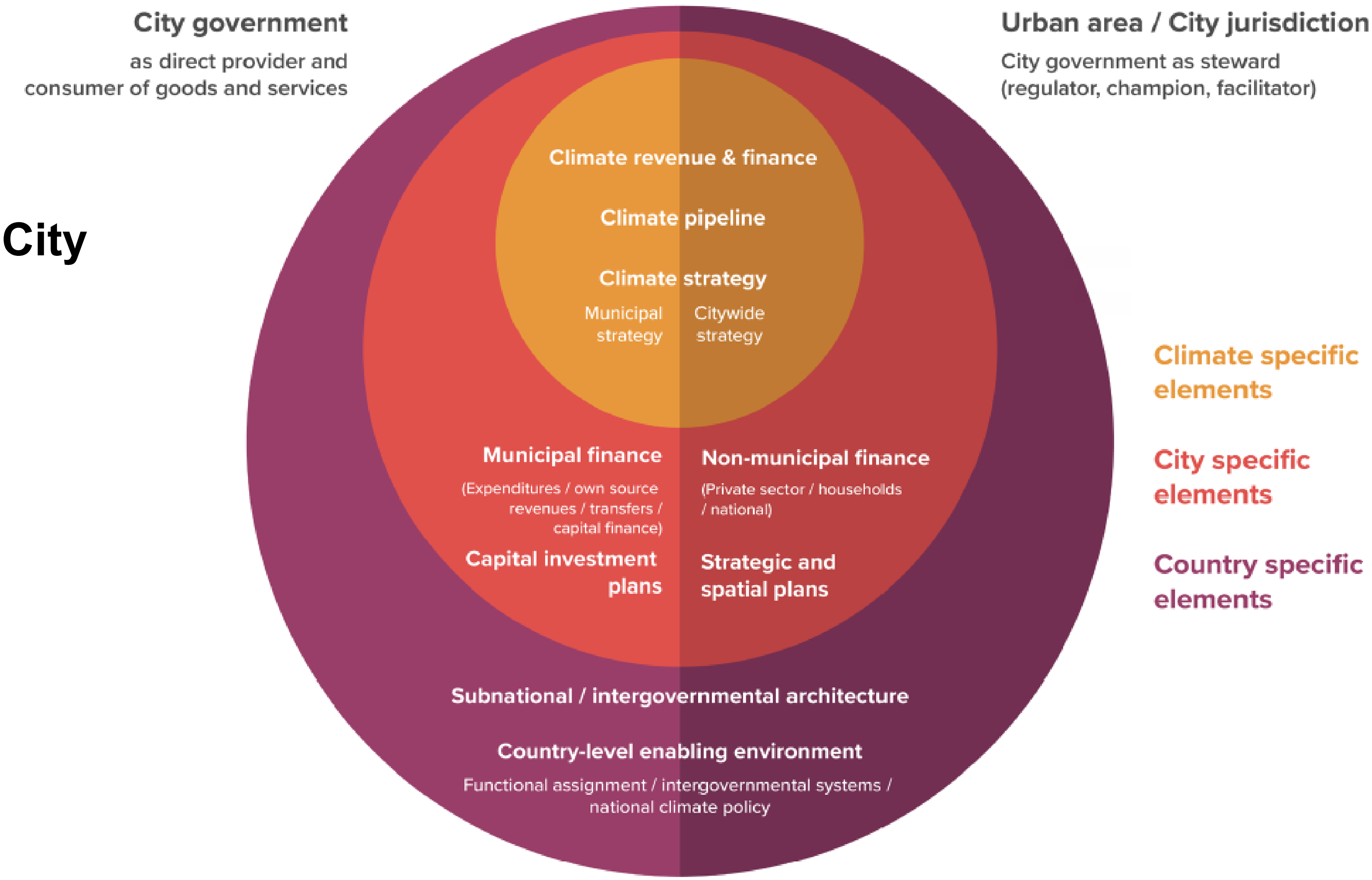
Substitute decarbonizing design and technology

Improve the resilience of the capital pipeline

Mainstream climate action in the budget cycle

Issuers using engineering & climate model measures in capital pipeline

The Enabling Environment for City Climate Finance



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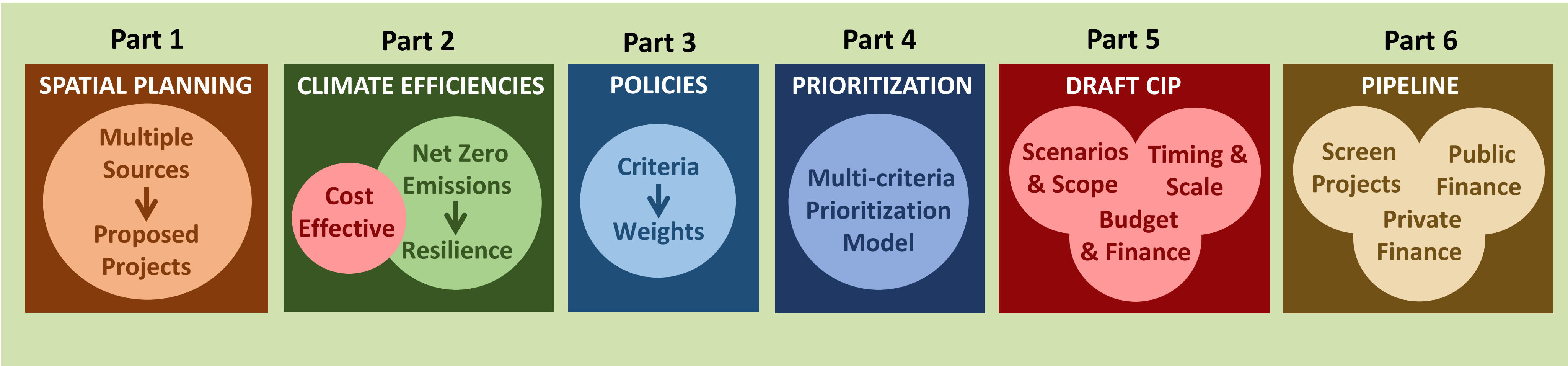
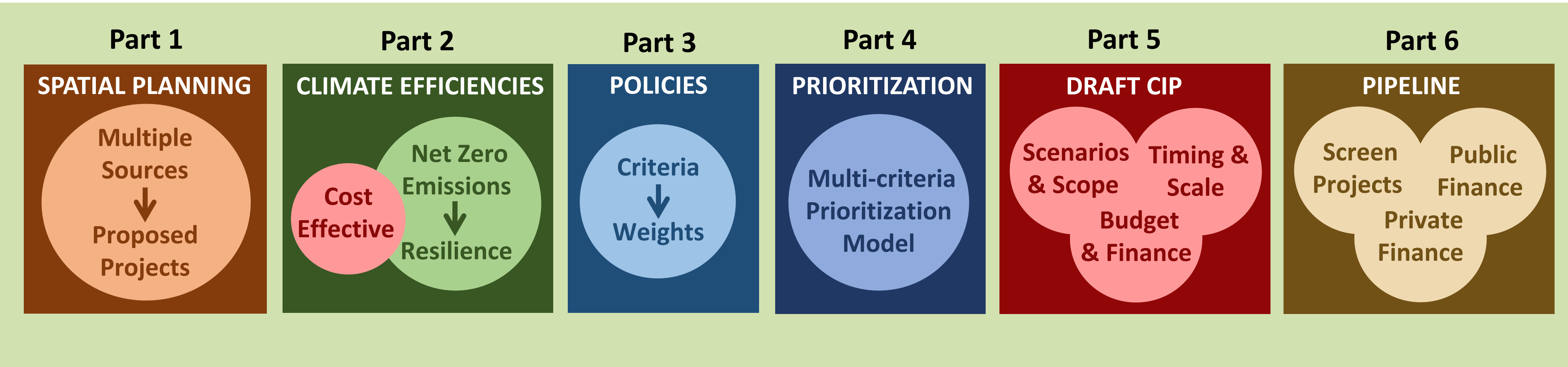
Fit Climate Measures within the Capital Planning Process



Platform of Modules drawing from Localized Databases



Energy & Emissions (design/tech/materials)

- Buildings
- Solid Waste
- Green Infrastructure
- Transport
- Water/Wastewater
- Power

Sequestration (design/tech/materials)

- Green Infrastructure
    - *Genus species*
- Wastewater
    - *Biogas*
    - *Solids*
- Direct Air Capture

Lifecycle Cost (C/OM) (design/tech/materials)

- Buildings
- Solid Waste
- Green Infrastructure
- Transport
- Water/Wastewater
- Power
- Direct Air Capture

Climate Change Impact (downscaled CC models)

- Flood
- Drought
- Fire
- Sea Level Rise
- Severe Storm
- Landslide
- Urban Heat
- Tsunami

Resilience Cost-Effects (location/design)

- Flood
- Drought
- Fire
- Sea Level Rise
- Severe Storm
- Landslide
- Urban Heat
- Tsunami

Early Support and Field Testing

2013 World Bank President's Initiative

to reach 300 cities in developing countries over 4 years to help them plan for a low-carbon future and get the needed financing flowing

- *Task force to Catalyze Climate Action*
- *Low Carbon Livable Cities & Resilient Cities Initiatives*
- *World Bank City Creditworthiness Initiative*
- *World Bank City Resilience Program*

Partnerships and funding sources

- *World Bank, PPIAF, Rockefeller Foundation, Global Environment Facility, C40 Cities Network, UN-Habitat, Korean Green Growth Fund, African Development Bank, UNIDO,…*

Workshops and technical assistance programs

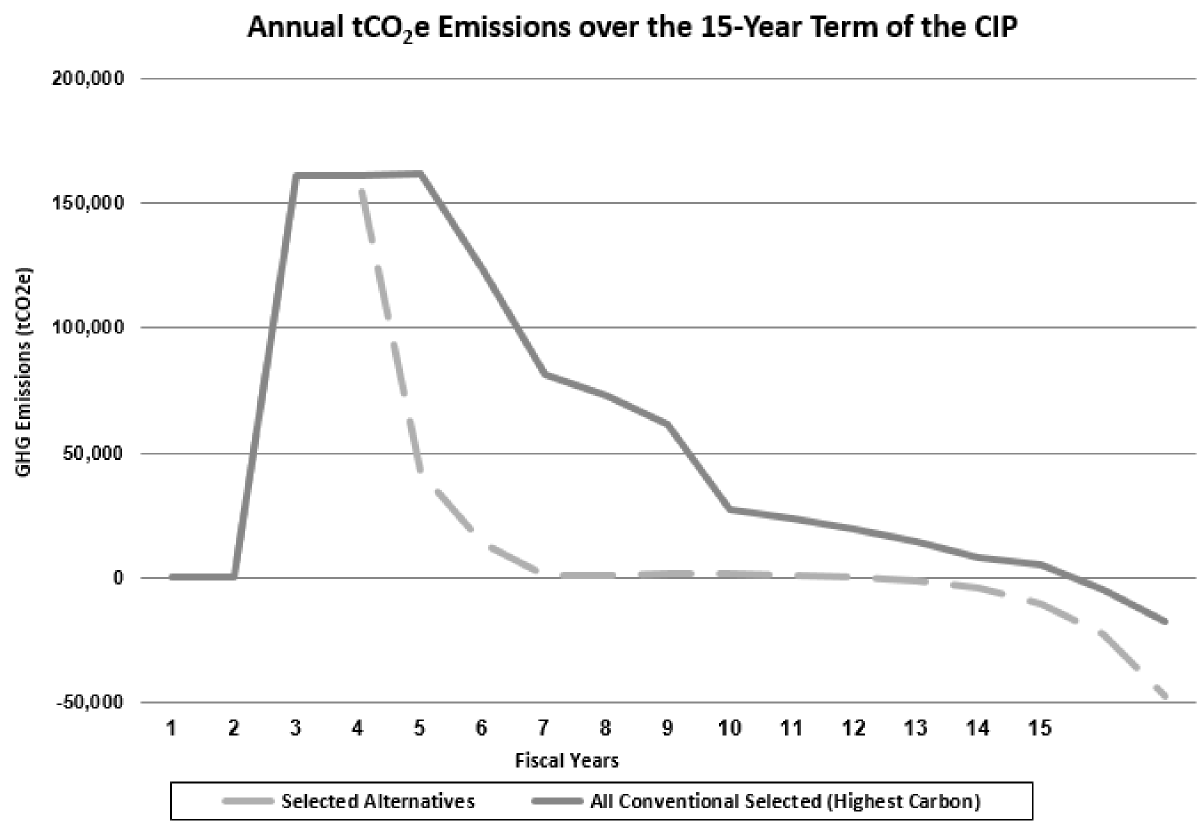
- *700+ municipal directors of finance & planning in 30+ countries, including C40 cities, Rockefeller's 100 Resilient Cities*
- *Country-wide workshops in Colombia, Jordan, Palestine, India, Uganda, Rwanda, Tanzania, Ethiopia, Kenya, Indonesia*
- *Regional workshops, East Asia (12 nations), Washington DC (18 nations)*
- *India*
- *San Francisco Public Utilities Commission*

Field Test: Modify Projects to Eliminate GHG Emissions

Review and modify project design to reduce or eliminate GHG emissions

For GHG emissions:

- Check market prices for GHG-related designs and technologies
- Modify designs for energy efficiency, elimination of fossil fuels, electrified transportation
- Alter cost estimates to reflect modifications
- Estimate capital, operation, and maintenance cost with and without modifications
- Forecast GHG emissions with and without modifications



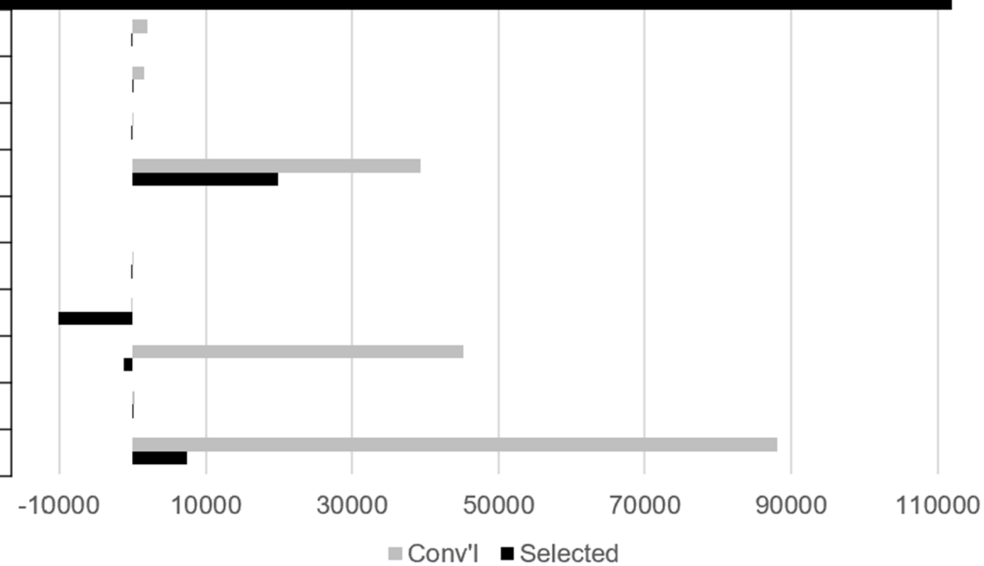
CIP Portfolio Emissions, Kampala Uganda (2016)

Field Test: Eliminating GHG Emissions through the Climate-smart CIP

8 cities and 187 projects in Eastern Europe and East Africa

	# of projects	Annual carbon emissions for conventional (tCO_2e)	Annual carbon emissions for selected (tCO_2e)
Commercial	22	1,967.64	(170.05)
Public	32	1,542.41	30.24
Residential	5	14.00	(11.00)
Transport	78	39,287.29	19,818.94
Utility - Energy	5	0.00	0.00
Utility - Water	7	29.00	(16.00)
Vegetation + landscaping	16	(87.00)	(11,066.00)
Waste	16	45,136.00	(1,169.00)
Equip & Other	6	188.65	12.57
Total	187	88,077.99	7,429.70

Selected vs Conventional Annual Emissions (tCO_2e)

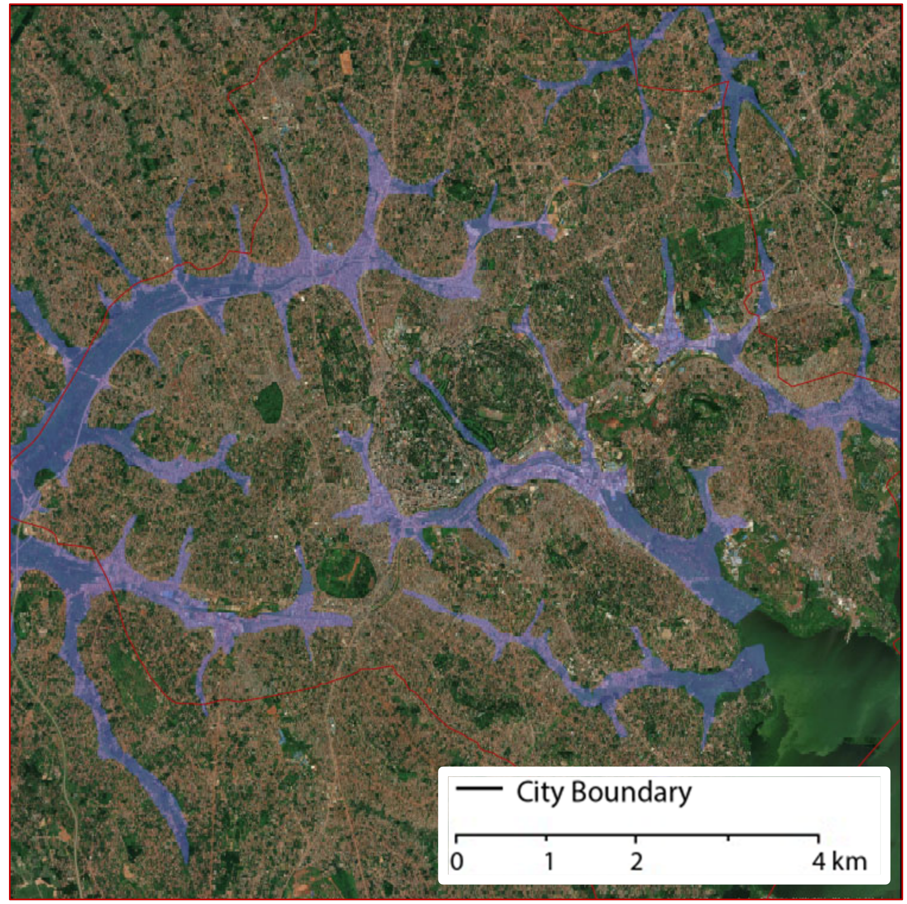


Field Test: Modify Projects to Enhance Resilience

Modify site location and design to avoid losses and enhance resilience

Process:

1. Model all hazards (extreme events into the future with climate change)
2. Compare to alternative sites as needed
3. Modify designs to withstand or adapt
4. Alter cost estimates to reflect design and site modifications
5. Estimate financial losses with and without modifications



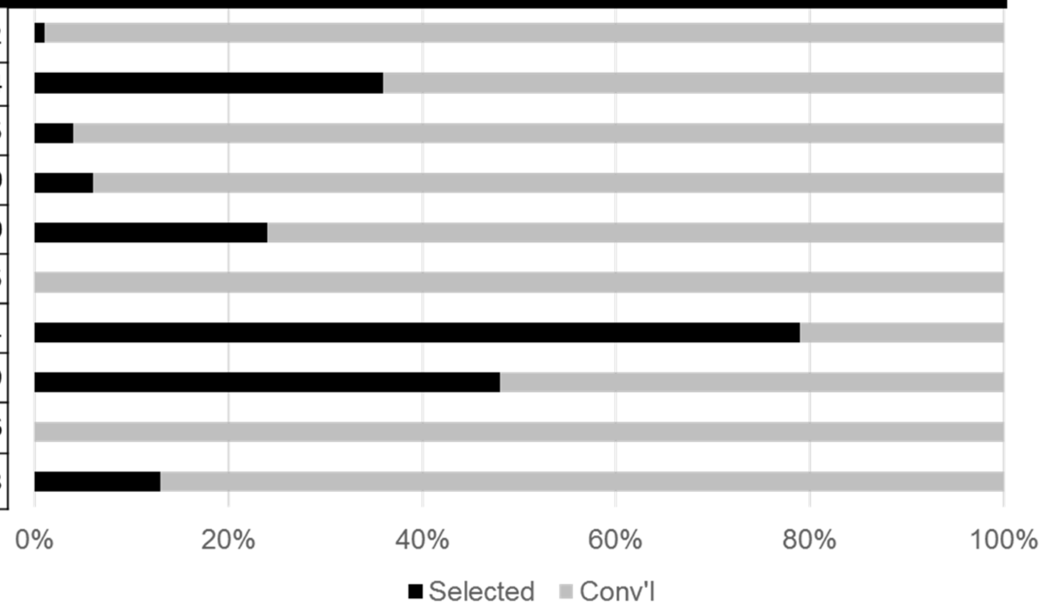
Extreme Flood Map 2100, Kampala Uganda (Q1000, 2016)

Field Test: Improving Resilience through the Climate-smart CIP

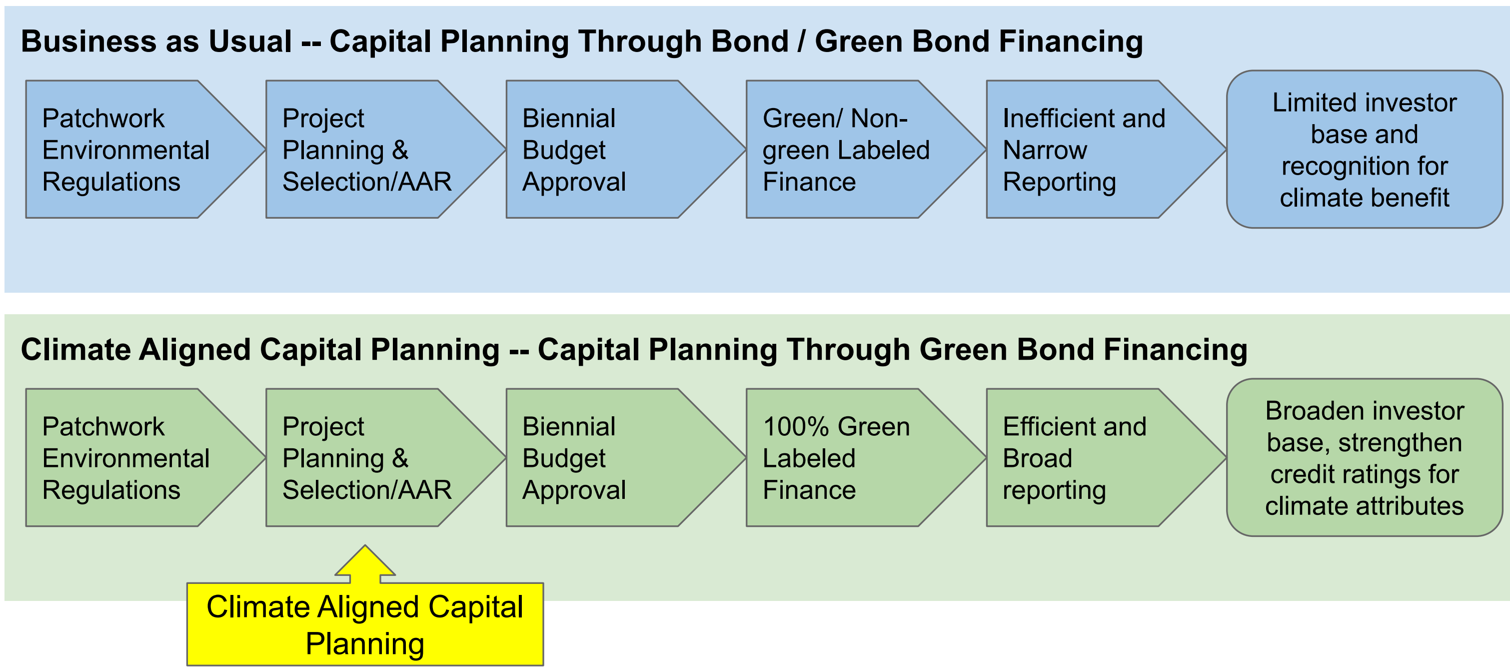
8 cities and 187 projects in Eastern Europe and East Africa

	# of projects	Total losses for conventional (million USD)	Total losses for selected (million USD)
Commercial	22	1,102.32	13.02
Public	32	1,328.93	483.14
Residential	5	82.64	3.55
Transport	78	3,683.09	213.50
Utility - Energy	5	201.34	47.90
Utility - Water	7	41.95	0.15
Vegetation + landscaping	16	62.38	49.11
Waste	16	110.20	53.29
Equip & Other	6	25.68	0.06
Total	187	6,638.53	863.73

Percent Reduction of Selected vs Conventional Losses (Conventional = 100%)



Perspective from San Francisco Public Utilities Commission (SFPUC)



Affirm the link between Climate-smart CIPs and green bond reporting & finance

Expansion of modeling to accommodate Wastewater Utilities

Pilot program calendar year 2021

SFPUC Pilot

Decarbonization
Compare project designs for:

Scale efficiencies
GHG intensity of energy source
GHG emissions
Carbon Sequestration
Capital cost
Lifecycle cost

Resilience
Compare project designs for:

Capital cost
Lifecycle cost
Vulnerability to extreme events
Over the lifecycle:

- ***Cost of extreme events***
- ***Cost of design strategies***
- ***Losses avoided***
- ***Suggested capital reserves***
- ***Resilience dividend***

Social Impact
Forecast effects on:

Local Employment (shown)
EJ Goals
Community Benefits
LOS Goals

SFPUC Pilot – Preliminary Results, Decarbonization in the CIP

			Project 1			Project 2		
			Oceanside Plant Digester Gas Utilization Upgrade			Baker Beach Green Street Project		
Criteria	Unit	Indicator	Conventional	Low Carbon	Carbon Zero	Conventional	Low Carbon	Carbon Zero
Scale	Percent	Proportion of conventional	1.00	1.00	1.00	1.00	1.00	1.00
	Percent	Percent scale of conventional	100%	100%	100%	100%	100%	100%
	M2 or Count	Square meters of conditioned space or count	20	20	20	1,553	1,553	1,553
Energy Source	tCO2e/MWh	Carbon intensity of energy sources	0.44	0.28	-	0.44	0.28	-
	Percent	Percent tCO_2e per MWh of conventional	100%	64%	0%	100%	64%	0%
Energy Savings and Sequestration	MWh/year	Energy intensity	642	230	-	366	276	241
	Percent	Percent annual tCO2e of conventional	100%	35%	0%	100%	49%	0%
	Years	Period of lifecycle	20	20	20	25	25	25
	tCO2e/lifecycle	Lifecycle emissions without sequestration	5,686	1,305	-	4,044	1,961	-
	tCO2e/lifecycle	Life-cycle carbon sequestration (at plant maturity)	512	1,726	3,454	39	32	77
	tCO2e/lifecycle	Net lifecycle carbon equivalent emissions	5,174	(421)	(3,454)	4,005	1,929	(77)
Capital Cost	Percent	Percent capital cost of conventional	100%	93%	98%	95%	96%	100%
	Million	Capital Cost	15	14	14	6	6	6
Life-cycle Cost	Percent	Percent life-cycle cost of conventional	100%	73%	90%	98%	98%	100%
	Years	Lifecycle (Years)	20	20	20	25	25	25
	Million/lifecycle	Lifecycle Operation and Maintenance Cost	17	16	16	2	2	2
	Million/lifecycle	Lifecycle Major Maintenance Cost	21	8	17	0	0	0
	Million/lifecycle	Lifecycle Cost	52	38	47	8	8	8

Indicators compare alternative project designs for:

Scale efficiencies
GHG intensity of energy source
GHG emissions
Carbon Sequestration
Capital cost
Lifecycle cost

Climate Modeling for SFPUC

SFPUC in two phases, to fit decision-making approach

- First – applying climate modifications to projects at 10% engineering
- Second – applying process to prioritize projects in the CIP

Climate modeling (Prof. Adrienne Greve, CalPoly):

- The basis for the projected impacts is typically SSP 8.5 (IPCC Shared Socio-Economic Pathways)
- For California, Cal-Adapt.org has downscaled global climate models
- Exceptions to Cal-Adapt:
  - The model that projects a drier/warmer future, HadGEM2-ES, was also chosen for most cases
  - One exception is the choice to include the model CNRM-CM5 (cooler/wetter) for flooding to assure that we were not under-forecasting future storm events.
  - For hazards not affected directly by climate change (earthquake, tsunami, and some landslides), city and state data was utilized.

SFPUC Pilot: Hazards Evaluated

The worst plausible hazard occurring during the life of project (80 to 100 years).

Natural Hazards

Climate Change Impacts

Climate-Exacerbated Impacts

Flooding

Sea Level Rise

Earthquake

Urban Heat Island Effect

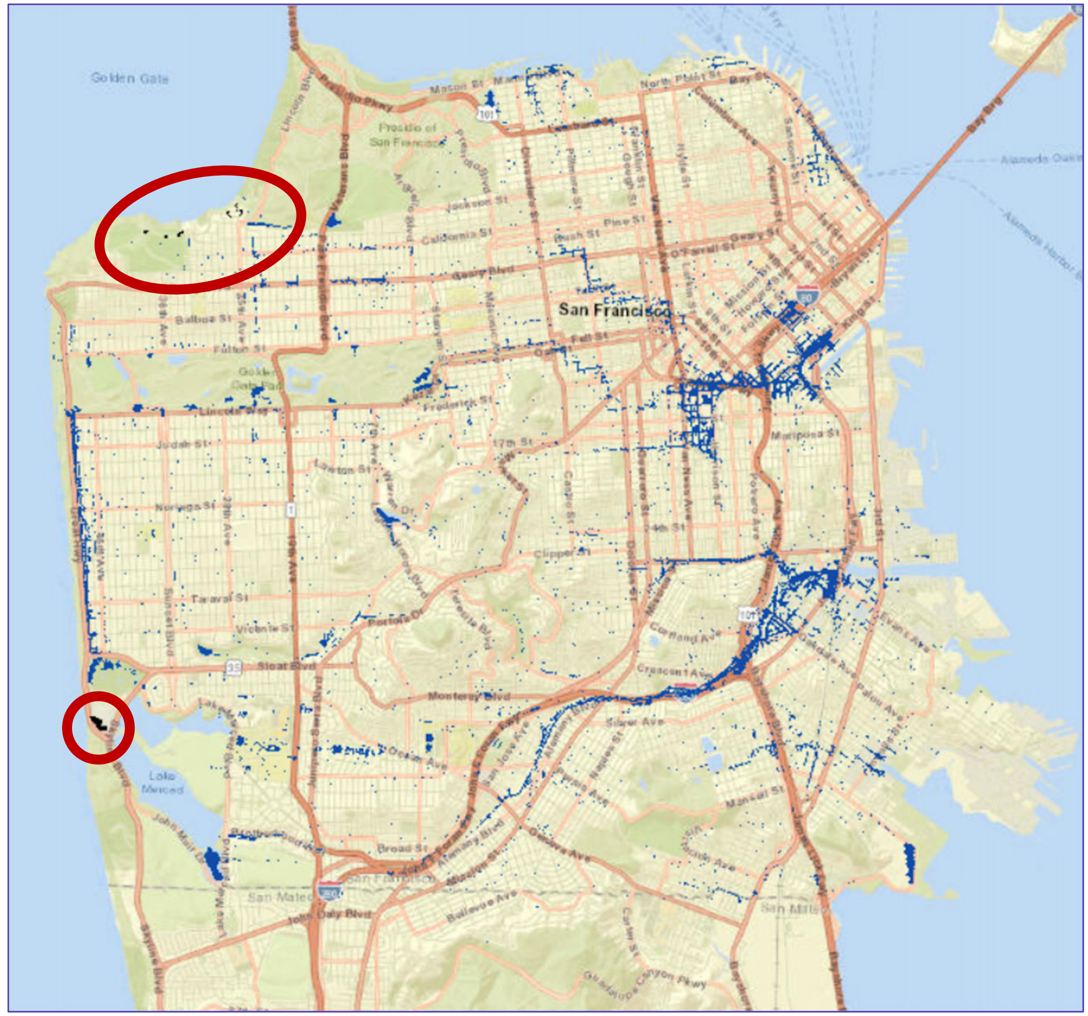
Tsunami

Fire

Landslide/Liquefaction

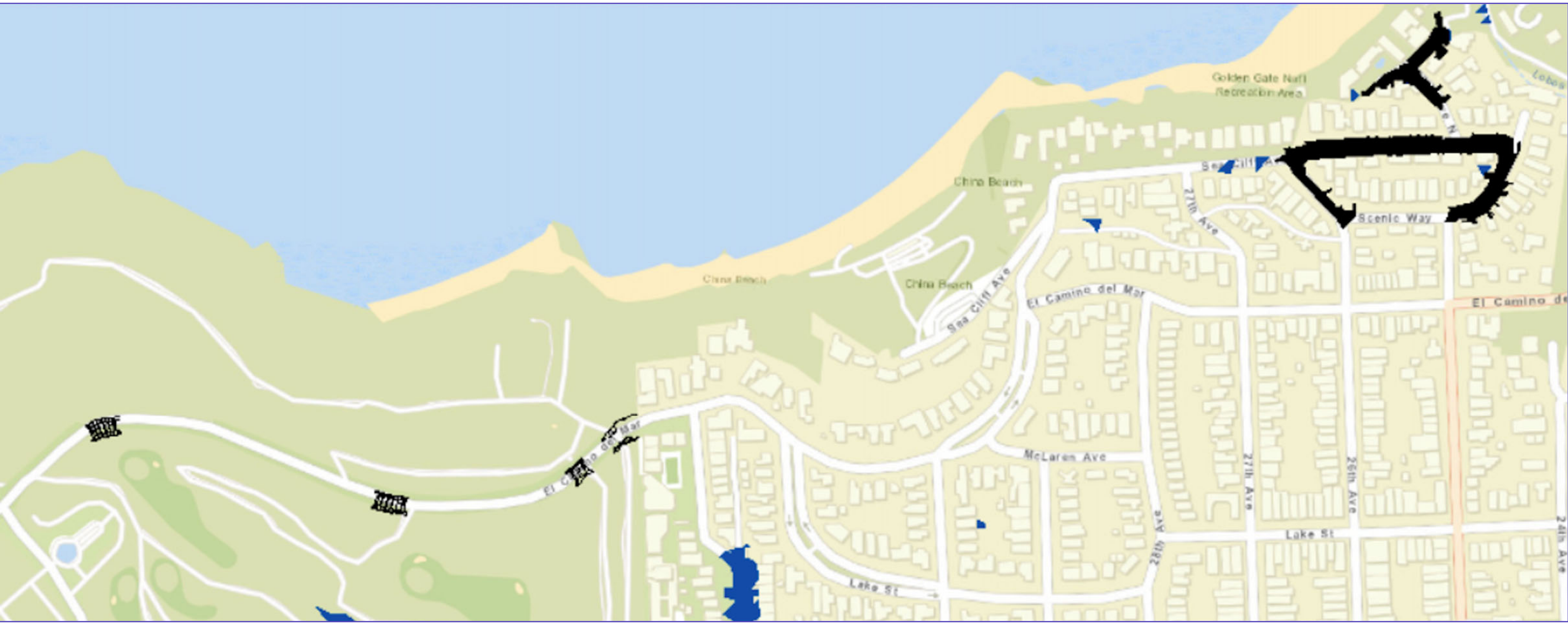
Flooding

- Based on downscaled climate models (Cal-Adapt) and NOAA storm frequency tables
- Future flooding resulting from intense rain was forecast by SFPUC staff
- Location on a peninsula limits the surficial flood risk



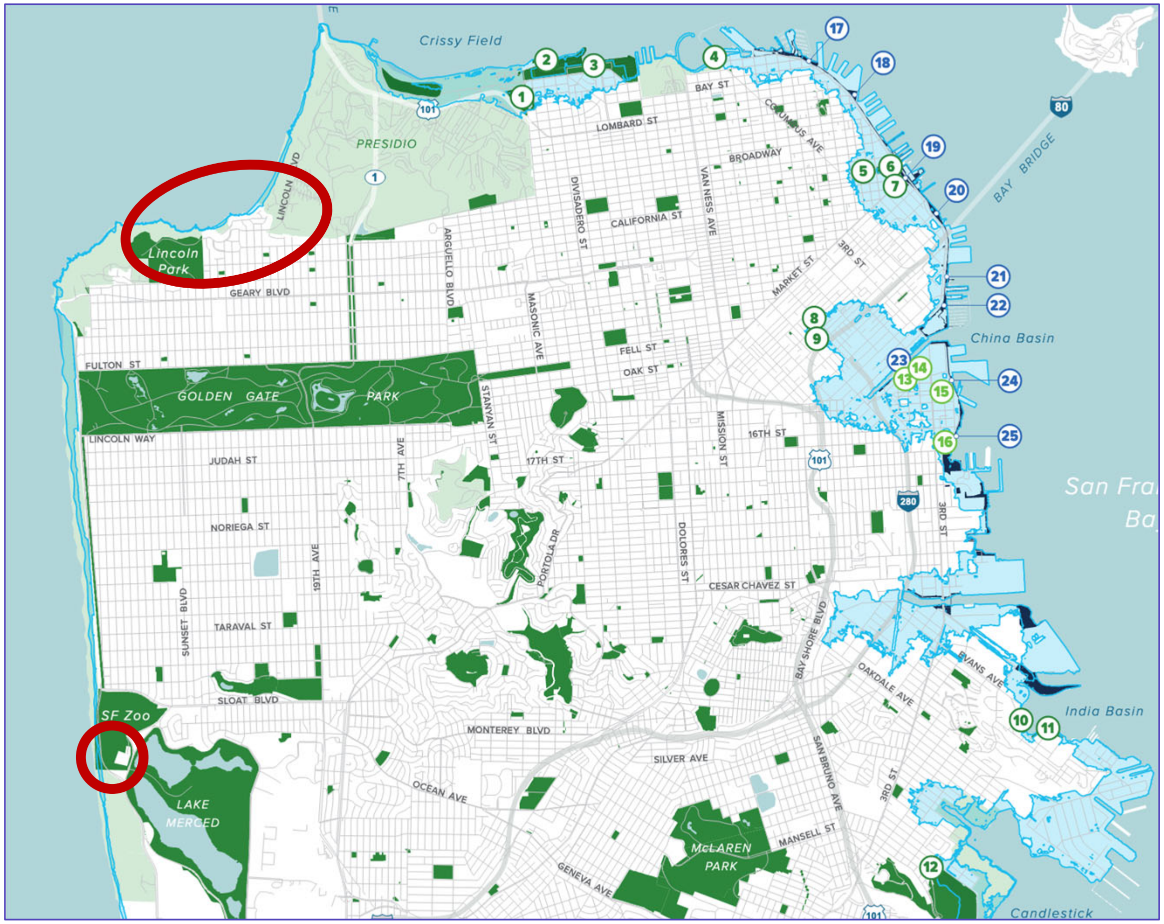
Flooding – Oceanside Biogas

Flooding – Baker Beach



Sea Level Rise

- Cal-adapt (CEC 2021)
- 2.74 m scenario
- Increased levels of sea level rise primarily affect the eastern edge of the city.

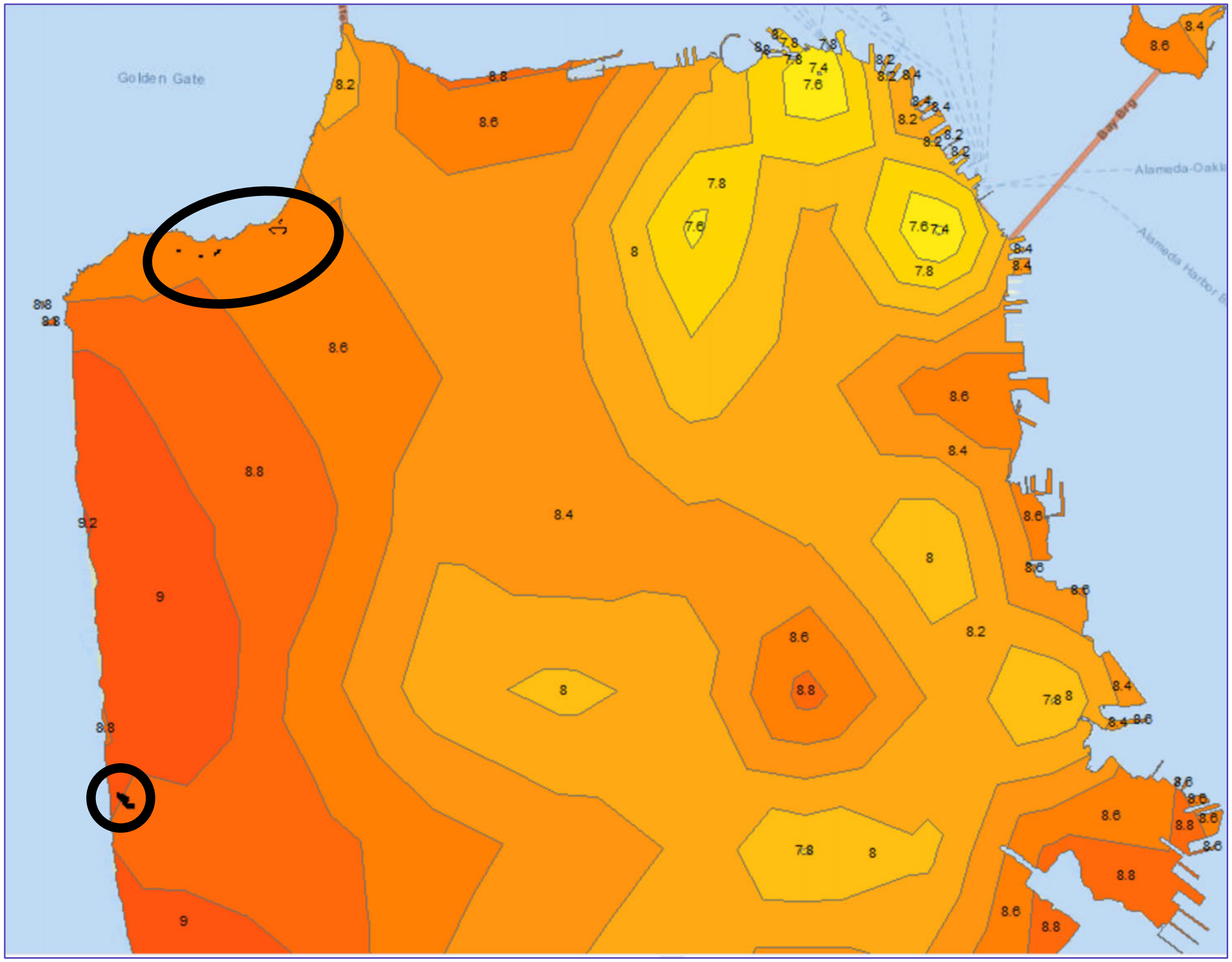


City of San Francisco, 2020

Earthquake

"The Modified Mercalli Intensity (MMI) estimates the shaking intensity from an earthquake at a specific location by considering its effects on people, objects, and buildings."

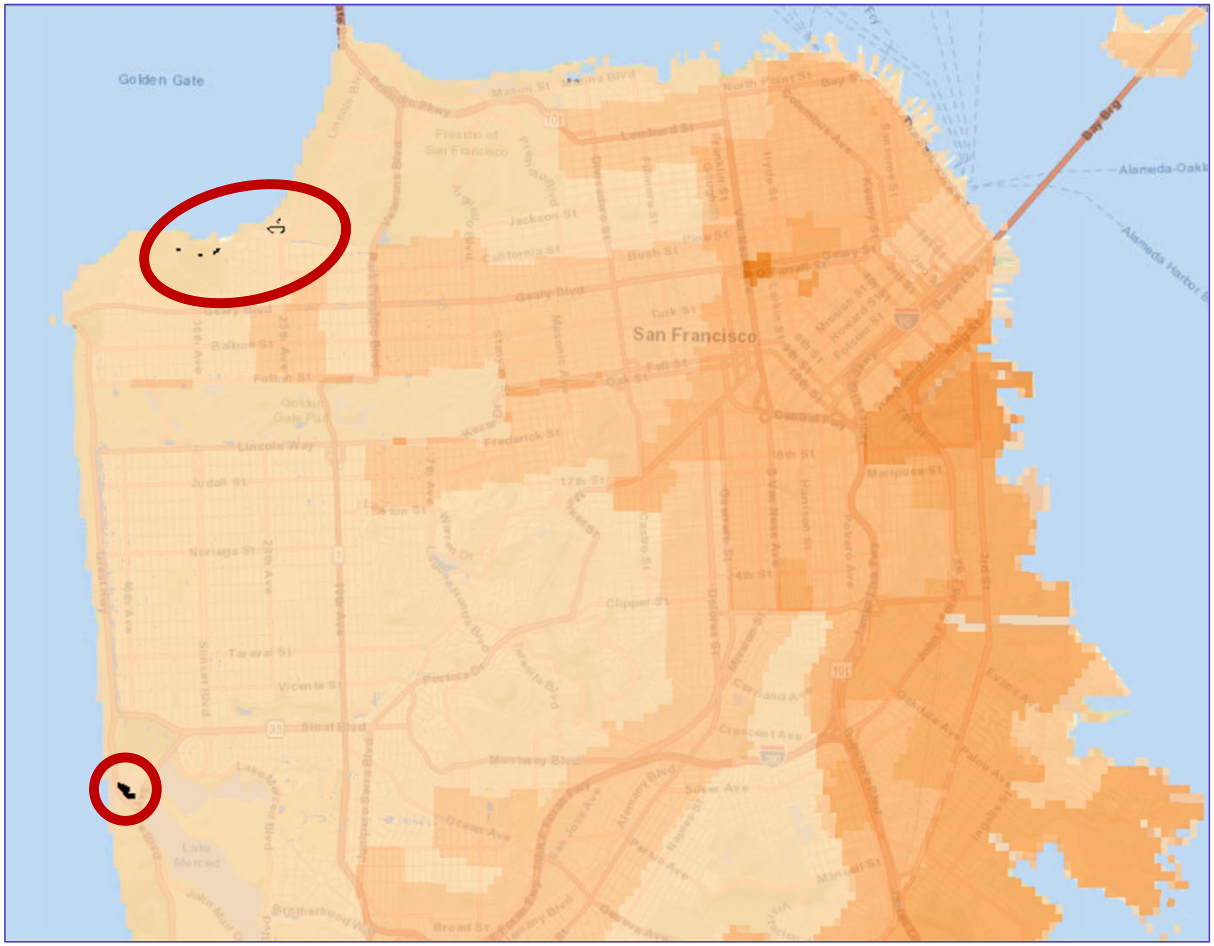
(ABAG Resilience Program, 2021, https://abag.ca.gov/sites/default/files/making_sense_of_the_modified_mercalli_intensity_scale.pdf)



Earthquake Shaking Scenario: San Andreas Fault, CISN 2018

Urban Heat Island

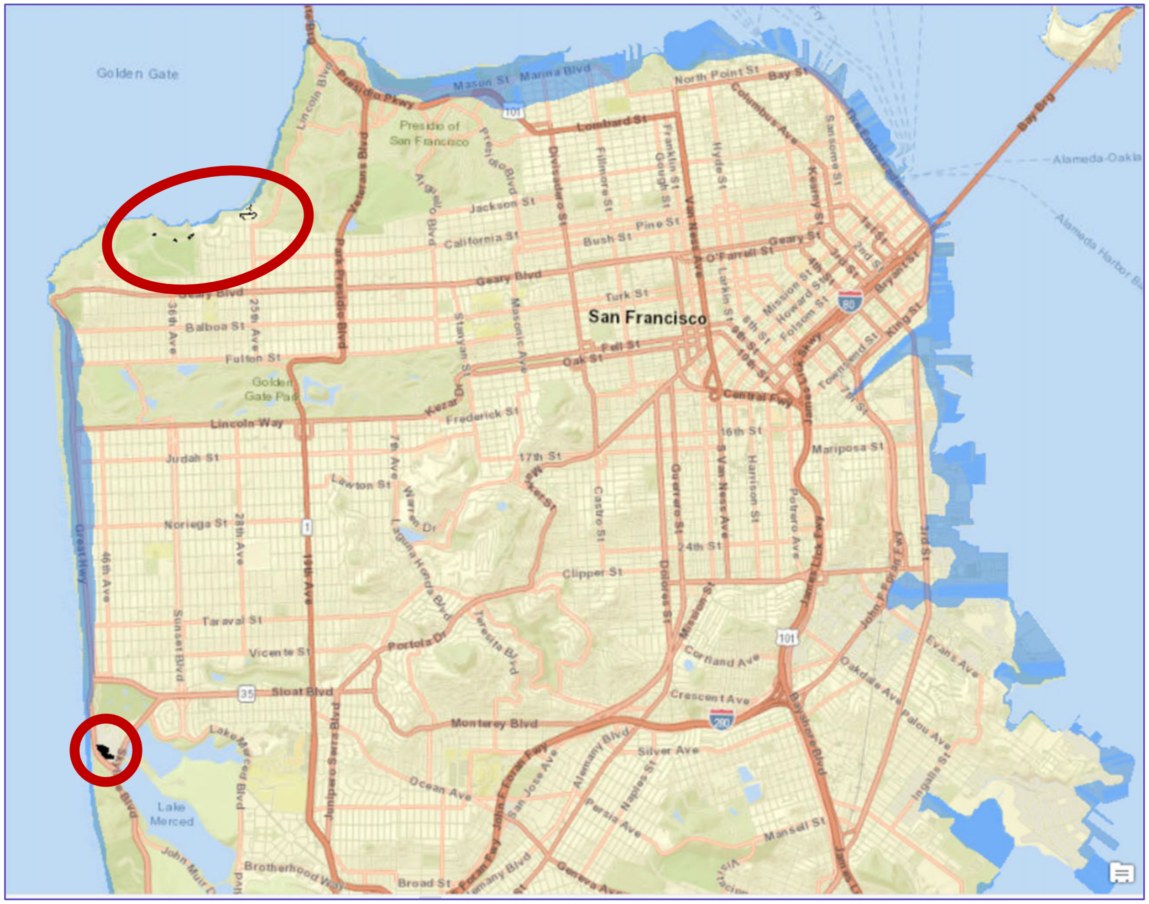
- Combines urban heat and climate change temperature change (NOT heat waves)
- Accounts for greenspace, water, and trees
- Accommodates future development plans
- Projects future population growth



4-4.5°C
4.5-4.8°C
4.8-5.2°C
5.2-5.8°C
5.8-6.5°C
6.5-7°C

Tsunami

Location of both pilot projects along the bluffs on the west side of the city means risk is low in the event of a tsunami.

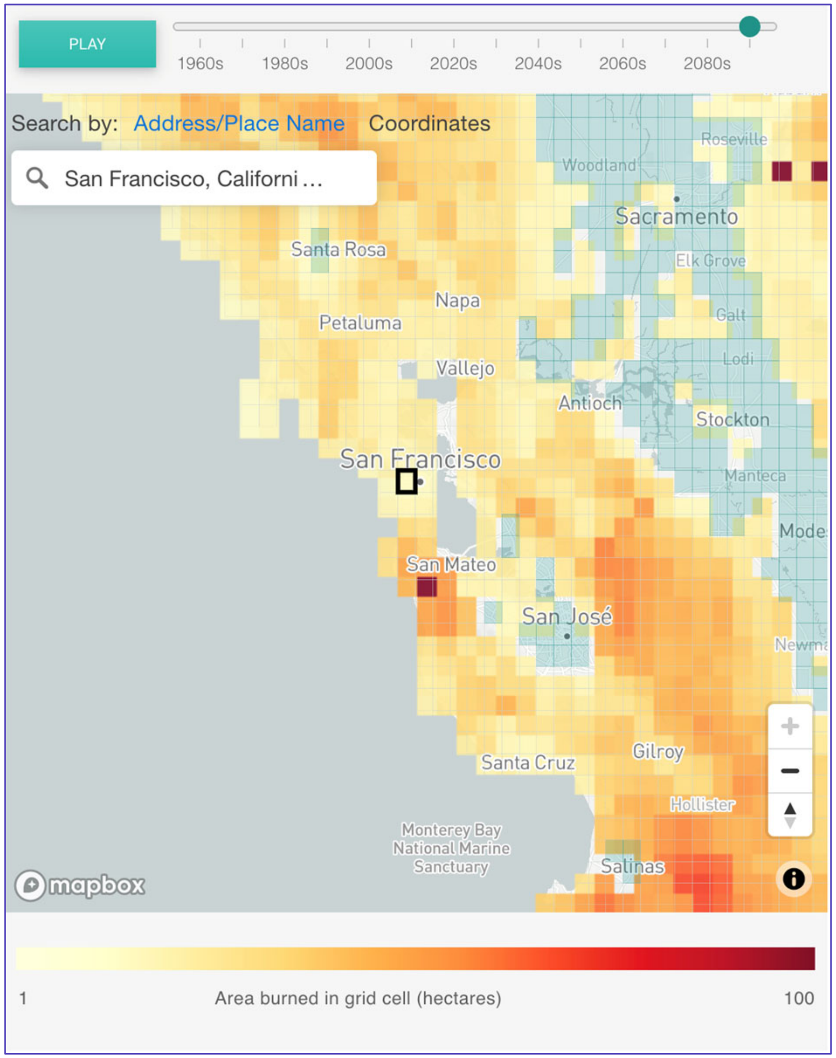


ABAG, 2021; California Geological Survey, 2021

Fire

Cal-adapt (2021)

- In 2090, it is still projected to be at the bottom of the fire risk scale in CA.



Landslide & Liquefaction

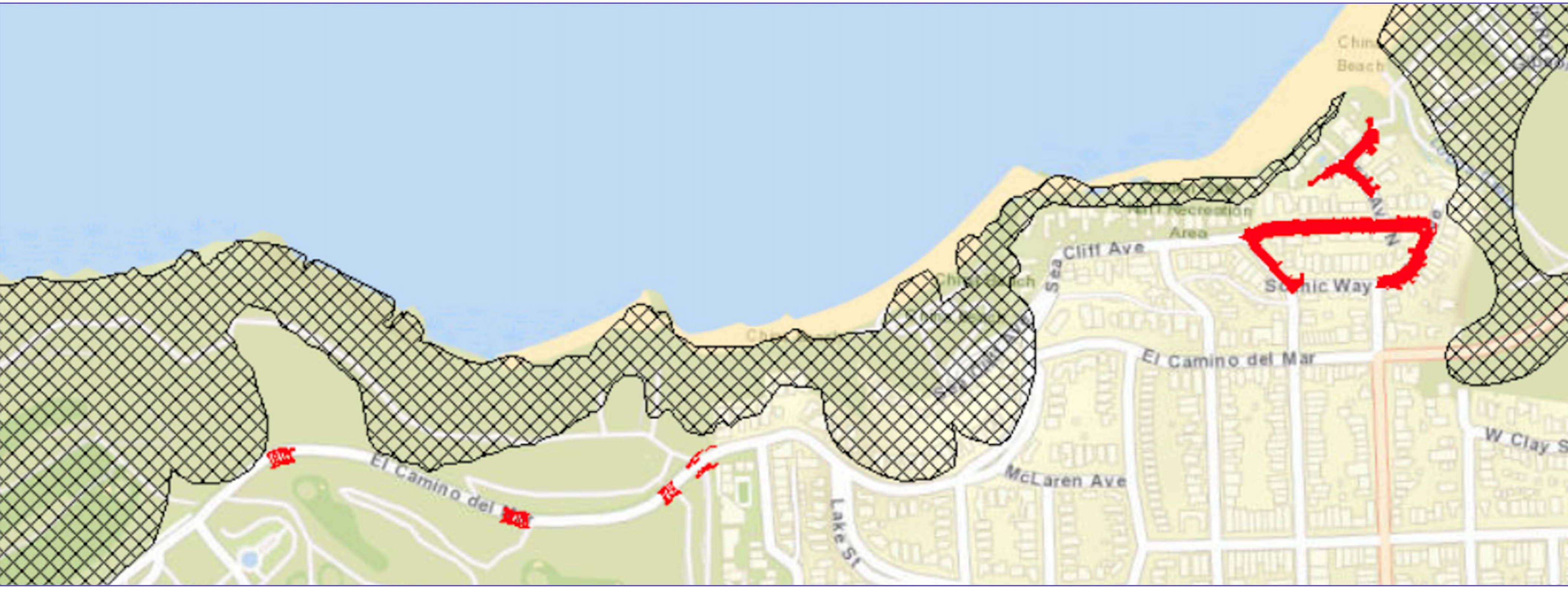
“Seismic Hazard Zone Map presenting areas where liquefaction and landslides may occur during a strong earthquake. Three types of geological hazards, referred to as seismic hazard zones, may be featured on the map: 1) liquefaction, 2) earthquake-induced landslides, and 3) overlapping liquefaction and earthquake-induced landslides.”

(SF Gov, 2019)

Landslide & Liquefaction
Oceanside Biogas

SF Gov, 201

Landslide & Liquefaction



SF Gov, 2019

SFPUC Pilot – Preliminary Results, Resilience in the CIP

Category	Unit	Proportion of conventional	1 Oceanside Plant Digester Gas Utilization Upgrade (Low Carbon / Carbon Zero)			2 Baker Beach Green Street Project (Low Carbon / Carbon Zero)		
			Resilient Convtl	Resilient Moderate	Resilient Robust	Resilient Convtl	Resilient Moderate	Resilient Robust
Capital Cost	millions	Capital cost including expenses for resilience	14	14	14	6	6	6
	Proportion	Percent capital cost compared to conventional (cost of facility)	98%	98%	98%	100%	100%	100%
Life-cycle Cost	millions	Percent lifecycle cost compared to conventional (lifecycle cost of facility)	90%	90%	90%	100%	100%	100%
	Years	Lifecycle (Years)	20	20	20	25	25	25
	Million/year	Annual Operation and Maintenance Cost (including expenses for resilience)	1	1	1	0	0	0
	Million/lifecycle	Lifecycle cost (with low carbon and resilience modifications)	47	47	47	8	8	8
Vulnerability to Extreme Events	As shown	All Plausible Extreme Events	5	5	5	6	6	6
	Ratio	Rosenhead Robustness Factor	5	5	3	6	6	2
			5	5	5	6	6	6
	millions	Avoided cost from resilience (one occurrence of each extreme event)	-	-	15	-	-	1
	Proportion	Percent cost from hazards compared to conventional (one occurrence)	100%	100%	11%	100%	100%	85%
	millions	Total operation loss from hazards (one occurrence)	0	0	0	0	0	0
	millions	Total capital loss from hazards (one occurrence)	17	17	2	4	4	3
	millions	Capital reserves for CIP for resilience (one occurrence of each extreme event)	17	17	2	4	4	3
Climate Informed Cost	Years	Frequency of occurrence in life-cycle **(an illustration, not an estimate)**	1	1	1	1	1	1
	millions	Cost of hazards to conventional in life-cycle	17	17	17	4	4	4
	millions	Cost of hazards to resilient alternative in life-cycle	17	17	2	4	4	3
	millions	Avoided cost from resilience in life-cycle (all extreme events)	-	-	15	-	-	1
	Proportion	Percent of life-cycle cost of hazards (all extreme events)	100%	100%	11%	100%	100%	85%
	millions	Capital reserve to repair and continue operations (all extreme events)	17	17	2	4	4	3
	millions	Lifecycle capital expenditure for resilience (all extreme events)	64	64	49	12	12	12

Indicators compare alternative project designs for:

Capital cost
Lifecycle cost
Vulnerability to extreme events
Over the lifecycle:

- ***Cost of extreme events***
- ***Cost of design strategies***
- ***Losses avoided***
- ***Suggested capital reserves***
- ***Resilience dividend***

SFPUC Pilot – Preliminary Results, Job Creation Forecasts in the Climate-smart CIP

	Oceanside Plant Digester Gas Utilization Upgrade				Baker Beach Green Street Project			
Type of Project	Wastewater				Stormwater			
Estimated contract value (million USD)	$11.75				$4.50			
Contract value (million USD)								
	Assumption		User Override		Assumption		User Override	
	Percentage	Value	Percentage	Value	Percentage	Value	Percentage	Value
Indireect costs	40%	$4.70	40%	$4.70	40%	$1.80	40%	$1.80
Direct costs	60%	$7.05	60%	$7.05	60%	$2.70	60%	$2.70
TOTAL	**100%**	**$11.75**	**100%**	**$11.75**	**100%**	**$4.50**	**100%**	**$4.50**
Direct cost (million USD)								
	Assumption		User Override		Assumption		User Override	
	Percentage	Value	Percentage	Value	Percentage	Value	Percentage	Value
Material costs	50%	$3.53	68%	$4.78	50%	$1.35	34%	$0.93
Labor costs	50%	$3.53	32%	$2.27	50%	$1.35	66%	$1.77
TOTAL	**100%**	**$7.05**	**100%**	**$7.05**	**100%**	**$2.70**	**100%**	**$2.70**
Labor costs (million USD)								
	Assumption		User Override		Assumption		User Override	
	Percentage	Value	Percentage	Value	Percentage	Value	Percentage	Value
Laborer	36%	$1.26	36%	$0.82	38%	$0.51	38%	$0.67
Operating engineer	21%	$0.72	21%	$0.48	17%	$0.23	17%	$0.30
Electritian	13%	$0.47	13%	$0.30	10%	$0.14	10%	$0.18
Carpenter	9%	$0.31	9%	$0.20	11%	$0.15	11%	$0.19
Painter	4%	$0.15	4%	$0.09	6%	$0.08	6%	$0.11
Plumber	5%	$0.18	5%	$0.11	5%	$0.07	5%	$0.09
All others	12%	$0.44	12%	$0.27	13%	$0.18	13%	$0.23
TOTAL	**100%**	**$3.53**	**100%**	$2.27	**100%**	**$1.35**	**100%**	$1.77

For each project,
a forecast of the effects
on:

Local Employment (shown)
EJ Goals
Community Benefits
LOS Goals

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