

**Mandated on-site wastewater reuse in San Francisco: The role of distributive fairness  
for policy acceptance**

Josianne Kollmann<sup>1</sup>, Sasha Harris-Lovett<sup>2,3</sup>, Kara L. Nelson<sup>4</sup>, Nadja Contzen<sup>1,5</sup>

<sup>1</sup> Eawag: Swiss Federal Institute of Aquatic Science and Technology, Dübendorf,

Switzerland

<sup>2</sup> Berkeley Water Center, University of California, Berkeley, USA

<sup>3</sup> San Francisco Estuary Partnership, San Francisco, USA (present affiliation)

<sup>4</sup> Department of Civil and Environmental Engineering, University of California,

Berkeley, USA

<sup>5</sup> University of Groningen, Groningen, Netherlands

## Supplementary information

### Supplementary Note 1

#### Information text on on-site systems and multiple-choice questions

##### On-site water reuse and how it is regulated for residential buildings in San Francisco

###### What is on-site water reuse in general?

Water that is generated within a building, such as wastewater or condensate from air conditioners, can be **collected, treated, and reused on-site** (i.e., within or in the surrounding of a building) **for non-potable\*** purposes. For such on-site water reuse, specific technologies, called on-site water reuse systems, need to be installed and operated. This also includes the necessary infrastructure (e.g., dual piping for fresh, potable water and treated, non-potable water). **The use of such systems can help to save fresh water resources.** For example, using treated, non-potable water instead of fresh water for toilet flushing and clothes washing can reduce the consumption of fresh water by up to 40%. As San Francisco is facing increasing water scarcity, the local utility promotes on-site water reuse as a way to supplement the city's fresh water resources.

###### How is on-site water reuse regulated in San Francisco?

To save fresh water resources, a regulation was issued in San Francisco in 2015 that requires new development projects above a certain size to install and operate an on-site water reuse system. According to the latest amendment of the policy (Oct. 2021), new development projects of 100,000 gross square feet or more are required to install and operate an on-site water reuse system. The specific requirements are based on the project type (e.g., commercial vs. residential). For the purpose of this study, we will focus on the regulation for residential projects only.

Residential buildings are mandated to **collect and treat the following water sources: their greywater** (i.e., wastewater from sinks, showers, washing machines, dishwashers etc. **but not from toilets**) as well as their **condensate** (e.g., from air conditioners). This treated water has to be **reused for the following non-potable purposes in the buildings: clothes washing, toilet flushing, irrigation.**

However, there is an important exception to this policy. **Low-income housing** developments are **exempted** from the mandate. As a consequence, building low-income housing is less expensive compared with building projects that fall under the mandate, as no on-site water reuse system has to be installed. The exemption aims at encouraging developers to build low-income housing. For low-income housing projects that voluntarily install on-site water reuse systems, San Francisco's utility offers a funding scheme to offset costs. However, these funds can only support a very limited number of projects.

The **policy mandating on-site water reuse systems in San Francisco** has **different implications for different groups of society**, such as residents of buildings with on-site water reuse systems or the city of San Francisco and its population as a whole. These implications will be presented in the remainder of the questionnaire. We would like to know how the residents of San Francisco perceive these implications and the policy as a whole.

But before we proceed to these implications, we first would like to make sure that the information given on this page has been understood.

\*It is also possible to treat the water up to potable standard, but **this study refers to non-potable reuse only.**

For the remainder of the questionnaire, it is important that the information provided on the last page has been understood. Answering the following two questions correctly is therefore necessary for further participation in the questionnaire. If you are unsure about the answers, please go back to the previous page. There you will find all the information needed. These are not trick questions, we just want to make sure that the information has been understood.

**Please indicate which statements about on-site water reuse systems in general are correct**

(multiple answers possible)

- On-site water reuse systems collect and treat the water generated within a building.
- The water treated by on-site water reuse systems can be reused on-site (i.e., within or in the surrounding of a building) for non-potable purposes.
- On-site water reuse systems can help to save freshwater resources (by using treated water for non-potable purposes).

**Please indicate which statements about the policy in San Francisco are correct**

(multiple answers possible)

- Residential buildings covered by the mandate are required to collect and treat all their water (including wastewater from the toilet).
- Residential buildings covered by the mandate are required to collect and treat only their greywater and their condensate (not the wastewater from the toilet).
- Residential buildings covered by the mandate have to reuse the treated water for non-potable purposes, namely clothes washing, toilet flushing, and irrigation.

## Supplementary Note 2

### Items assessing perceived negativity or positivity of policy implications for different groups or entities of society

The policy mandating on-site water reuse systems in San Francisco has different implications for different groups or entities of society. These groups or entities include:

- 1) Residents of buildings with mandated on-site water reuse systems
- 2) Owners of buildings with mandated on-site water reuse systems
- 3) The city of San Francisco and its population
- 4) People with a low income living in San Francisco
- 5) The local and regional environment
- 6) Future generations living in San Francisco

On the following pages, you will find lists of implications that the policy mandating on-site water reuse systems has for each group or entity.

**For each implication, please rate how positive or negative you think this implication is for the respective group or entity.**

#### 1) Residents

**For residents of buildings with mandated on-site water reuse systems, the policy has – among others – the following implications:**

- Residents have to bear the recurring costs of operation, monitoring, and maintenance of the systems. Moreover, it is likely that the initial costs of installation are passed on to the residents by the builders (e.g., through higher rent or purchase prices of the apartments).
- Reusing water can cause a psychological burden to the residents. For example, water reuse can be perceived as disgusting.
- The reused water can be colored or turbid.
- In case of a failure of the on-site water reuse system, there is a health risk for residents.
- Residents will have lower drinking water bills because they have a lower fresh water consumption. Also, building owners pay a reduced fee to the utility for wastewater treatment. These savings are potentially passed on to the residents.
- Living in a “green” building can contribute to a more positive and sustainable image of the residents.

*It is possible that the policy will have further implications, but based on the current knowledge, these are less certain. Please rate how positive or negative you would find the following implications if they were to occur.*

- In case of natural disasters, such as droughts or earthquakes, residents **may** have more reliable non-potable water supply and wastewater treatment.

- In a drought, residents of buildings with on-site water reuse **may** not be subject to restrictions on outdoor irrigation if they use non-potable water to do so.
- On-site systems are not managed and maintained by the water utility (as is the centralized system), but by the building manager. This **could** lead to a reduced maintenance and water quality for residents of buildings with on-site reuse compared with residents of San Francisco using the centralized system only.

*For each implication, the following item was answered by participants (for the less certain implications, the phrasing was changed from ‘..., this is...’ to ‘..., this would be...’):*

**In your opinion: For residents of buildings with on-site reuse, this is...**

very negative	neither negative nor positive	very positive				
<input type="checkbox"/> <sub>1</sub>	<input type="checkbox"/> <sub>2</sub>	<input type="checkbox"/> <sub>3</sub>	<input type="checkbox"/> <sub>4</sub>	<input type="checkbox"/> <sub>5</sub>	<input type="checkbox"/> <sub>6</sub>	<input type="checkbox"/> <sub>7</sub>

## 2) Owners of buildings covered by the mandate

**For owners of buildings covered by the mandate, the policy has – among others – the following implications:**

- The installation of on-site water reuse systems leads to higher construction costs. These costs have to be carried by the owners – either directly if they construct themselves or through a higher purchase price if they are not the constructors. However, these costs can likely be passed on to the tenants through higher rents.
- Building owners pay a reduced fee to the utility for wastewater treatment. These savings are potentially passed on to the tenants.
- In case of technical issues with the system, repair costs may arise. This financial risk is carried by the building owners.
- Buildings with an on-site water reuse system can be advertised as more innovative and sustainable. Therefore, they can be rented out at higher prices.
- Building or renting out a “green” building can contribute to a more positive and sustainable image of the building owners.

*For each implication, the following item was answered by participants:*

**In your opinion: For owners of buildings covered by the mandate, this is...**

very negative	neither negative nor positive	very positive				
<input type="checkbox"/> <sub>1</sub>	<input type="checkbox"/> <sub>2</sub>	<input type="checkbox"/> <sub>3</sub>	<input type="checkbox"/> <sub>4</sub>	<input type="checkbox"/> <sub>5</sub>	<input type="checkbox"/> <sub>6</sub>	<input type="checkbox"/> <sub>7</sub>

### 3) The city of San Francisco and its population

**For the city of San Francisco and its population, the policy has – among others – the following implications:**

- The implementation of on-site water reuse systems increases San Francisco's wastewater treatment capacity by taking load off the centralized system. This is needed to accommodate the city's continued growth.
- On-site water reuse systems provide additional water supply and offset demands on valuable potable water supplies. This increases the resiliency of San Francisco's water supply during droughts.
- Through the increased demand of on-site water reuse systems, a local, green economy is built (for example for construction or installation of on-site systems). This leads to the creation of new, green jobs.
- In case of system failures, untreated or partially treated water may be released into the environment (e.g., through irrigation). Therefore, there is a slight public health risk from on-site water reuse systems.

*It is possible that the policy will have further implications, but based on the current knowledge, these are less certain. Please rate how positive or negative you would find the following implications if they were to occur.*

- On-site water reuse systems can reduce the fresh water demand of the city, which can prevent the construction of expensive new drinking water supply options. This **may** result in savings for the utility (and thus the city) and lead to more stable prices for wastewater treatment and fresh water supply.
- Residents of buildings with on-site reuse pay a reduced fee to the utility for wastewater treatment. As a consequence, the fees that the remaining residents of San Francisco have to pay for the centralized water and wastewater system **may** increase.
- A reduced load in the centralized system reduces the flow rate of the wastewater in the systems. This **may** lead to smell in some areas of the city or may require the wastewater agency to install additional equipment to mitigate the problem.

*For each implication, the following item was answered by participants (for the less certain implications, the phrasing was changed from '..., this is...' to '..., this would be...'):*

**In your opinion: For the city of San Francisco and its population, this is...**

very negative	neither negative nor positive	very positive				
<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3	<input type="checkbox"/> 4	<input type="checkbox"/> 5	<input type="checkbox"/> 6	<input type="checkbox"/> 7

#### 4) People with a low income living in San Francisco

**For people with a low income living in San Francisco, the policy has – among others – the following implications.**

Low-income housing developments are exempt from the policy. Therefore, such projects usually refrain from implementing on-site systems.

- Through the exemption, building low-income housing is less expensive compared with building projects that fall under the mandate, as no on-site water reuse system has to be installed. Therefore, the exemption ensures that low-income housing is continued to be built in San Francisco and is available on the housing market for people with a low income.

Through the exemption, most people with a low income will live in houses **without** on-site water reuse systems. This has the following implications:

- People with a low income cannot profit from the direct monetary benefits of the systems (through a reduced drinking water bill).
- People with a low income cannot profit from the direct **non-monetary** benefits of the systems, including a potentially more reliable non-potable water supply in case of droughts.
- People with a low income are not burdened by installation costs and costs of operation, monitoring, and maintenance of on-site water reuse systems. Therefore, their rents will not increase as a consequence of mandated on-site water reuse systems.
- People with a low income are not burdened by **non-monetary** costs of on-site water reuse systems, including a health risk in case of system failures.

*It is possible that the policy will have a further implication, but based on the current knowledge, this is less certain. Please rate how positive or negative you would find the following implication if it would occur.*

- Through the policy, some amount of the city's wastewater is reused, which saves fresh water resources. This **may** lead to more stable water prices, of which particularly people with a low income living in San Francisco would benefit from.

*For each implication, the following item was answered by participants (for the less certain implication, the phrasing was changed from '..., this is...' to '..., this would be...'):*

**For people with a low income living in San Francisco, this is...**

very negative	neither negative nor positive	very positive
<input type="checkbox"/> <sub>1</sub> <input type="checkbox"/> <sub>2</sub> <input type="checkbox"/> <sub>3</sub> <input type="checkbox"/> <sub>4</sub> <input type="checkbox"/> <sub>5</sub> <input type="checkbox"/> <sub>6</sub> <input type="checkbox"/> <sub>7</sub>		

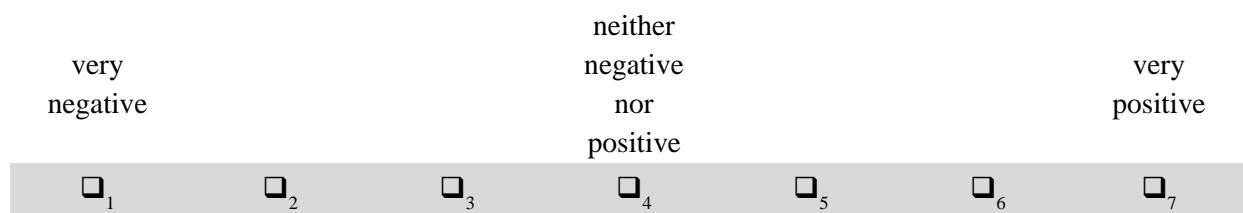
## 5) The local and regional environment

**For the local and regional environment, the policy has – among others – the following implications:**

- As water is reused, less water has to be imported from the Sierra Nevada, taken from ground water or surface water reservoirs, or desalinated. This benefits the environment, as more water stays in the local and regional ecosystems.
- In case of failures of on-site water reuse system, there is an environmental risk. Untreated or partially treated water used for irrigation may contaminate plants, soil, and ultimately the aquatic environment.

*For each implication, the following item was answered by participants:*

**In your opinion: For the local and regional environment, this is...**



## 6) Future generations living in San Francisco

**For future generations living in San Francisco, the policy has – among others – the following implications:**

- With advancing climate change, droughts will become more likely in the future. Installing on-site water reuse systems contributes to a more resilient infrastructure for future generations.
- Over time, the increasing demand for on-site systems because of the policy leads to more innovation in this sector. Moreover, the policy drives the market to make the technology cheaper and it builds a workforce that can install the systems. Future generations can benefit from this development of advanced water reuse technologies.

*It is possible that the policy will have further implications, but based on the current knowledge, these are less certain. Please rate how positive or negative you would find the following implications if they were to occur.*

- On-site water reuse systems can reduce the strain of the centralized system. This **may** lead to financial savings for the utility (and thus the city), which would benefit future generations.
- As water is reused on-site, less water has to be imported from the Sierra Nevada, taken from ground water or surface water reservoirs, or desalinated. This **may** save fresh water resources for future generations.

*For each implication, the following item was answered by participants (for the less certain implications, the phrasing was changed from ‘..., this is...’ to ‘..., this would be...’):*

**In your opinion: For future generations living in San Francisco, this is...**

very negative	neither negative nor positive	very positive				
<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3	<input type="checkbox"/> 4	<input type="checkbox"/> 5	<input type="checkbox"/> 6	<input type="checkbox"/> 7

**Supplementary Table 1***Correlations of policy implications and fairness for residents of buildings with mandated on-site systems*

	CI	1	2	3	4	5	6	7	8	9	10
1. Implication financial costs											
	UL										
	LL										
2. Implication psychological burden		.28*									
	UL	.12									
	LL	.44									
3. Implication impaired water quality		.33*	.55*								
	UL	.18	.44								
	LL	.48	.65								
4. Implication health risk		.36*	.43*								
	UL	.23	.29	.42							
	LL	.49	.55	.68							
5. Implication monetary savings		-.03	.15*	.02	-.13						
	UL	-.19	.003	-.14	-.28						
	LL	.13	.30	.17	.02						
6. Implication improved image		.17*	.20*	.09	.11	.44*					
	UL	.01	.04	-.06	-.02	.27					
	LL	.31	.35	.23	.23	.59					
7. Implication water resilience natural disasters		.05	.07	.06	-.13*	.45*	.43*				
	UL	-.12	-.09	-.09	-.28	.31	.25				
	LL	.20	.23	.20	-.0003	.59	.59				
8. Implication water resilience droughts		.07	.03	-.09	-.14	.37*	.33*	.52*			
	UL	-.09	-.14	-.23	-.27	.22	.15	.39			
	LL	.22	.18	.05	.005	.52	.50	.63			
9. Impaired service compared with non-users		.32*	.30*	.36*	.38*	.01	.06	.03	-.10		
	UL	.15	.13	.21	.24	-.16	-.10	-.15	-.26		
	LL	.46	.46	.51	.51	.17	.21	.18	.06		
10. Fairness for residents of buildings with mandated on-site systems		.54*	.38*	.28*	.33*	.31*	.40*	.22*	.18*	.42*	
	UL	.41	.21	.12	.19	.15	.26	.07	.03	.29	
	LL	.64	.53	.43	.46	.45	.52	.36	.32	.54	

Note. CI = confidence interval, LL = lower limit, UL = upper limit. \* significant based on confidence intervals (95%) with BCa-Bootstrapping with 10,000 replications.

**Supplementary Table 2***Correlations of policy implications and fairness for owners of buildings with on-site systems*

	CI	1	2	3	4	5	6
1. Implication financial costs							
	UL						
	LL						
2. Implication financial savings		.34*					
	UL	0.18					
	LL	0.48					
3. Implication financial risk		.34*	0.03				
	UL	0.16	-0.16				
	LL	0.50	0.22				
4. Implication increased property value		.35*	.40*	0.10			
	UL	0.19	0.24	-0.06			
	LL	0.49	0.53	0.25			
5. Implication improved image		.29*	.41*	0.10	.50*		
	UL	0.12	0.24	-0.08	0.35		
	LL	0.43	0.55	0.26	0.63		
6. Fairness for owners of buildings with on-site systems		.48*	.40*	.38*	.38*	.48*	
	UL	0.35	0.23	0.24	0.22	0.35	
	LL	0.59	0.54	0.50	0.53	0.59	

Note. CI = confidence interval, LL = lower limit, UL = upper limit.

\* significant based on confidence intervals (95%) with BCa-Bootstrapping with 10,000 replications.

**Supplementary Table 3***Correlations of policy implications and fairness for the city of San Francisco and its residents*

	CI	1	2	3	4	5	6	7	8
1. Implication higher treatment capacity	UL								
	LL								
2. Implication increased resiliency		.73*							
	UL	.62							
	LL	.82							
3. Implication creation of green jobs		.61*	.70*						
	UL	.50	.61						
	LL	.71	.78						
4. Implication public health risk		.16*	-.004	-.10					
	UL	.005	-.17	-.24					
	LL	.30	.15	.05					
5. Implication financial savings for city		.66*	.71*	.65*	.01				
	UL	.56	.62	.55	-.15				
	LL	.75	.79	.74	.16				
6. Implication increased costs for centralised system		.13	.09	-.01	.42*	.13			
	UL	-.06	-.07	-.15	.28	-.02			
	LL	.29	.24	.13	.55	.27			
7. Implication smell in some areas		.06	-.05	-.08	.60*	.05	.52*		
	UL	-.11	-.22	-.24	.48	-.11	.37		
	LL	.21	.11	.07	.70	.19	.65		
8. Fairness for the city of San Francisco and its residents		.57*	.52*	.46*	.30*	.52*	.50*	.31*	
	UL	.41	.37	.33	.16	.38	.36	.16	
	LL	.69	.65	.58	.42	.63	.61	.45	

*Note.* CI = confidence interval, LL = lower limit, UL = upper limit. \* significant based on confidence intervals (95%) with BCa-Bootstrapping with 10,000 replications.

**Supplementary Table 4***Correlations of policy implications and fairness for people with a low income living in San Francisco*

	CI	1	2	3	4	5	6	7
1. Implication low-income housing built	UL							
	LL							
2. Implication no monetary benefit of on-site systems		.26*						
	UL	.10						
	LL	.40						
3. Implication no non-monetary benefit of on-site systems		.18*	.68*					
	UL	.00	.50					
	LL	.34	.82					
4. Implication stable rents		.49*	.02	-.01				
	UL	.32	-.15	-.18				
	LL	.62	.18	.16				
5. Implication no non-monetary costs		.52*	.11	.01	.65*			
	UL	.38	-.07	-.17	.53			
	LL	.65	.28	.18	.76			
6. Implication stable water prices		.48*	-.03	-.09	.57*	.53*		
	UL	.35	-.18	-.24	.43	.40		
	LL	.61	.12	.06	.69	.65		
7. Fairness for people with a low income living in San Francisco		.63*	.35*	.35*	.43*	.36*	.36*	
	UL	.51	.19	.20	.27	.19	.22	
	LL	.73	.49	.49	.58	.51	.49	

Note. CI = confidence interval, LL = lower limit, UL = upper limit.

\* significant based on confidence intervals (95%) with BCa-Bootstrapping with 10,000 replications.

**Supplementary Table 5***Correlations of policy implications and fairness for future generations living in San Francisco*

	CI	1	2	3	4	5
1. Implication resilient infrastructure						
	UL					
	LL					
2. Implication market development & innovation		.68*				
	UL	.57				
	LL	.78				
3. Implication financial savings		.71*	.70*			
	UL	.60	.59			
	LL	.79	.79			
4. Implication water savings		.66*	.70*	.71*		
	UL	.57	.58	.62		
	LL	.75	.79	.80		
5. Fairness for future generations living in San Francisco		.62*	.62*	.67*	.59*	
	UL	.48	.51	.55	.48	
	LL	.73	.71	.77	.68	

*Note.* CI = confidence interval, LL = lower limit, UL = upper limit.

\* significant based on confidence intervals (95%) with BCa-Bootstrapping with 10,000 replications.

**Supplementary Table 6***Correlations of policy implications and fairness for the local and regional environment,*

	CI	1	2	3
1. Implication water savings				
	UL			
	LL			
2. Implication reduced pollution		-.16*		
	UL	-.32		
	LL	-.005		
3. Fairness for local and regional environment		.48*	.34*	
	UL	.33	.21	
	LL	.60	.45	

*Note.* CI = confidence interval, LL = lower limit, UL = upper limit.

\* significant based on confidence intervals (95%) with BCa-Bootstrapping with 10,000 replications.

**Supplementary Table 7***Correlations of perceived fairness for the five societal groups and the environment with policy acceptance*

	CI	1	2	3	4	5	6	7
1. Fairness for residents of buildings with mandated on-site systems	UL							
	LL							
2. Fairness for owners of buildings with mandated on-site systems		.42*						
	UL	.25						
	LL	.56						
3. Fairness for the city of San Francisco and its population		.48*	.58*					
	UL	.34	.43					
	LL	.60	.70					
4. Fairness for people with a low income living in San Francisco		.29*	.21*	.30*				
	UL	.10	.04	.13				
	LL	.46	.36	.45				
5. Fairness for future generations living in San Francisco		.41*	.48*	.61*	.15			
	UL	.26	.33	.47	-.02			
	LL	.54	.60	.71	.31			
6. Fairness for the local and regional environment		.50*	.50*	.62*	.30*	.48*		
	UL	.35	.33	.48	.14	.33		
	LL	.62	.64	.73	.43	.61		
7. Policy Acceptance		.46*	.56*	.75*	.23*	.62*	.55*	
	UL	.27	.41	.64	.06	.46	.35	
	LL	.62	.68	.83	.39	.74	.70	

Note. CI = confidence interval, LL = lower limit, UL = upper limit.

\* significant based on confidence intervals (95%) with BCa-Bootstrapping with 10,000 replications.

**Supplementary Table 8***Multicollinearity statistics for regression analysis explaining perceived fairness*

Predictors:		Tolerance	VIF
Perceived negativity or positivity of policy implications for...			
Residents covered by policy			
Intercept	.79	1.27	
Financial costs	.63	1.59	
Psychological burden	.54	1.84	
Impaired water quality	.57	1.76	
Health risk	.67	1.50	
Financial savings	.69	1.45	
Improved image	.68	1.48	
Water resilience	.79	1.26	
Impaired service compared with non-users	.79	1.27	
Owners of buildings with mandated on-site systems			
Intercept			
Financial costs	.73	1.37	
Financial savings	.74	1.35	
Financial risk	.88	1.14	
Increased property value	.68	1.47	
Improved image	.69	1.44	
City of San Francisco and its population			
Intercept			
Higher treatment capacity	.39	2.59	
Increased resiliency	.32	3.13	
Creation of green jobs	.43	2.31	
Public health risk	.58	1.72	
Savings for city	.41	2.47	
Increased costs for centralised system	.69	1.44	
Smell in some areas	.55	1.83	

**Supplementary Table 8 (continued)***Multicollinearity statistics for regression analysis*

Predictors:	Perceived negativity or positivity of policy implications for...	Tolerance	VIF
Low-income residents of San Francisco			
Intercept			
Low-income housing built	.60	1.66	
No benefit of on-site systems	.90	1.11	
No non-monetary costs	.51	1.95	
Stable rent & water prices	.48	2.10	
Future generations			
Intercept			
Resilient infrastructure	.42	2.39	
Market development & innovation	.40	2.49	
Financial savings	.36	2.74	
Water savings	.40	2.52	
Environment			
Intercept			
Water savings	.98	1.02	
Pollution risk	.98	1.02	

*Note. VIF = Variance inflation factor*

**Supplementary Table 9***Multicollinearity statistics for regression analysis explaining policy acceptance*


---

Predictors: Perceived fairness of policy for:	Tolerance	VIF
Intercept		
Residents of buildings with mandated on-site systems	.67	1.50
Owners of buildings with mandated on-site systems	.61	1.65
The city of San Francisco and its population	.43	2.31
Low-income residents of San Francisco	.87	1.15
Future generations living in San Francisco	.59	1.71
The local and regional environment	.53	1.88

---

*Note. VIF = Variance inflation factor*