The Design Research and Systems Book accompanies the Design Book giving proof to the projects in terms of numbers, calculations, and diagrammatic explanations.

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Delft University of Technology

Sensing Domesticity *From Mine to Mine* // Design Research and Systems

Sensing Domesticity
From Mine to Mine

Lauritz Bohne
Edward Zammit
Lea Scherer

// Design Research and Systems Book

Toxic Forest

Baquedano Oasis

London Mine

Sensing Domesticity
From Mine to Mine

// Design Research and Systems Book

Explore Lab 2021-2022

Lauritz Bohne 5397391
Lea Scherer 5397383
Edward Zammit 5375797

Guidance
// Heidi Sohn (Research)
// Georg Vrachliotis (Architecture)
// Ferry Adema (Building Technology)

Delft University of Technology
Faculty of Architecture and the
Built Environment
Department of Architecture
MSc. Architecture, Urbanism and
Building Sciences

Sensing Domesticity
From Mine to Mine

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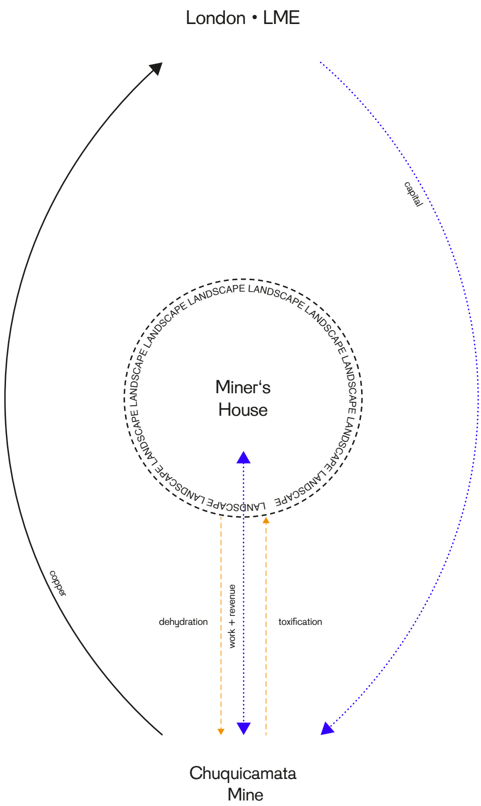
General Approach
system relations

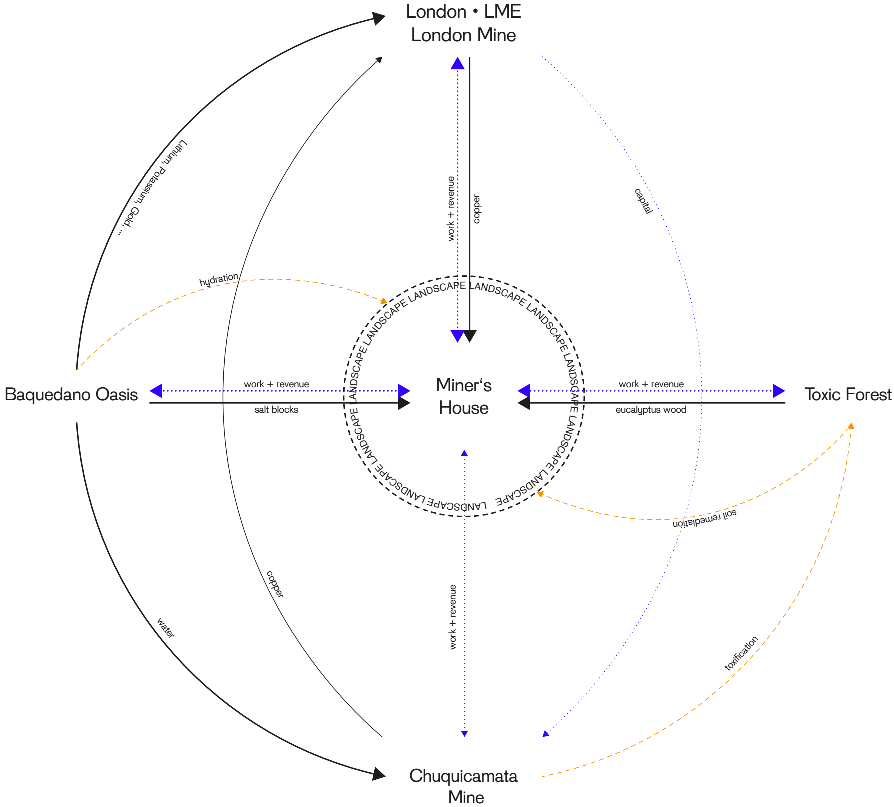
From Mine to Mine creates in a time of copper depletion transitions for the copper industry‘s different landscapes, developing new economic, ecologic and material relationships through systematic thinking.

The research has departed from the world‘s biggest open-pit copper mine Chuquicamata in Chile, which is economically dependent on the London Metal Exchange Market, the driving force behind the extraction of copper and the contamination and destruction of the Chilean Landscape and the housing it hosts. In times of copper depletion, the project designs new mines - The Toxic Forest, The Baquedano Oasis and The London Mine - that form transitions to a future, where these dependencies are turned around, the Chuquicamata mine is resolved and the landscape recovered.

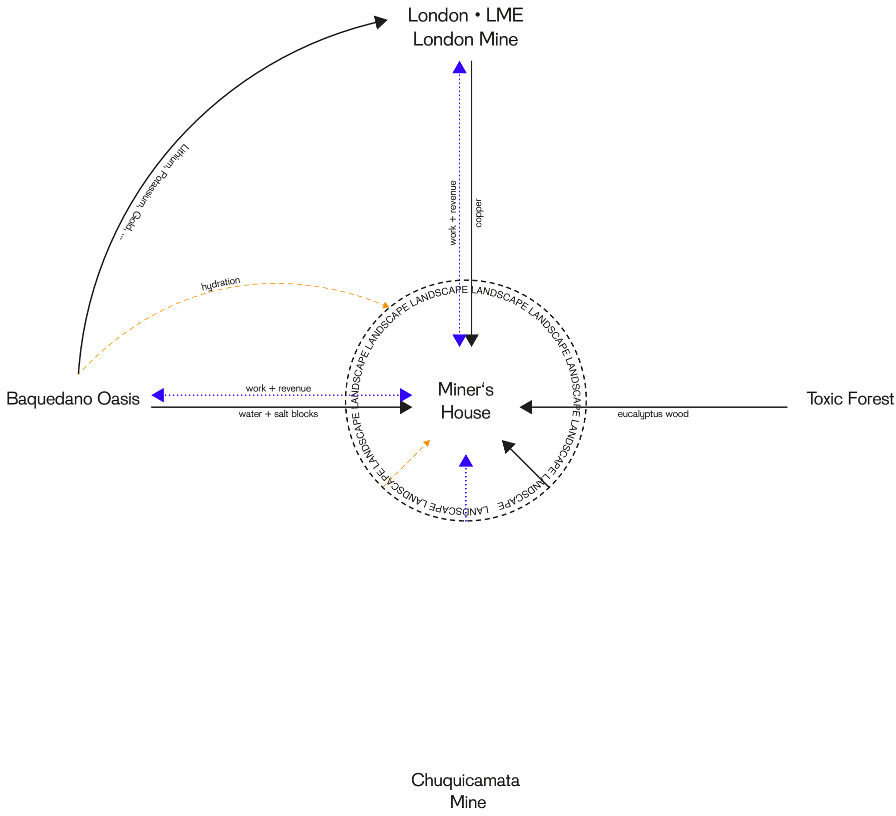


// today

economic relationship
material relationship
ecologic relationship



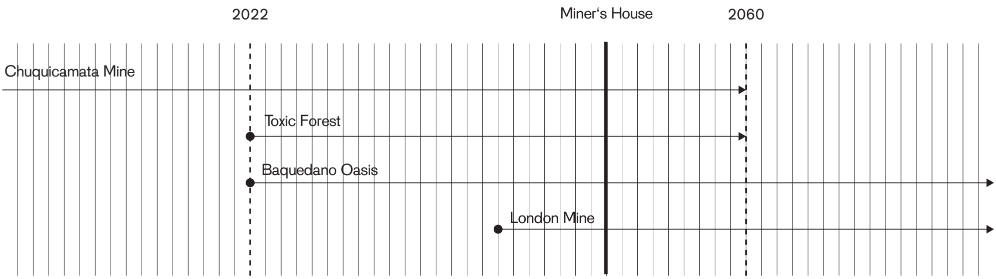
// towards copper depletion (2022-2060)



// after copper depletion (2060+)

General Approach
timeline

The introduced mines are neither completely congruent nor completely consecutive in time. However, the cycles that take place in the projects are at times mutually dependent, as can be derived from the previous diagrams.
The concept of the miner‘s house represents an intersection point of all mines at one shared moment in time: a section through the house is a section through the mines, that is, a section through the context they have created and the materials they yield.



// timeline of the mines

Toxic Forest

Toxic Forest
overview

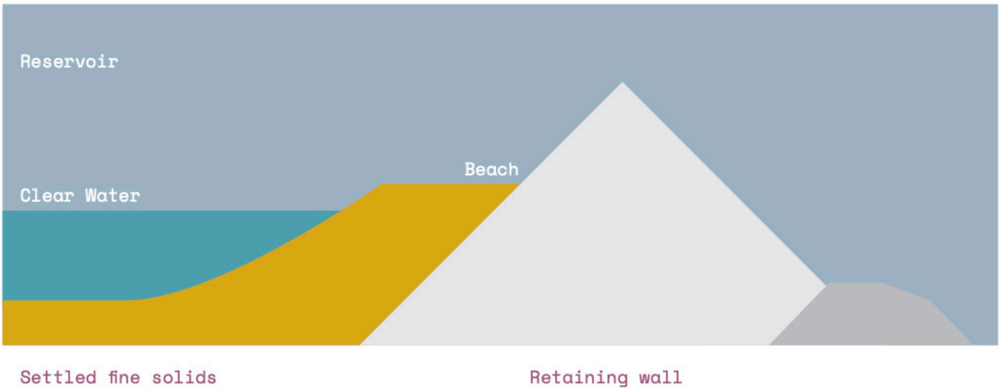
Problem
// water and soil contamination by the mining industry

Design
// stops soil contamination
// cleans the soil while recycling the water coming from the mine
// creates a new economic value in form of a new resource
// creates future accessibility to this to-be-cleaned land

The design elaborates on a system of architectural agents and phases in which the technology of the eucalyptus tree can operate to its maximum capacity - soaking in toxic water, cleaning the soil and recycling clean water by transpiration. In its afterlife, the wood of the eucalyptus can be felled and introduced as a new resource and building material.


Phase 2 SEEDING
seeddrones plant seeds
• Agent Seed Drone
heat corridor
Phase 3 SHADING
simulation of a forest,
creating conditions to grow
Phase 6 HARVESTING + REWORKING
• Agent PROTECTIVE FABRIC
4 m
cleaned soil
Phase 1 SENSING
monitoring and adjusting
the environment
heat corridor
Phase 5 ABSORBING
maximal absorption of 200L
of toxic water/tree/day
17 m
• Agent Sensing Pile
• Agent Seed, Mapping and Fertilizing Drone
• Agent Eucalyptus Globulus
• Agent Drone Tower
• Agent Fog Catcher
Phase 4 GROWING
forest fire
• Agent Pipe
Phase X BURNING
• Agent Eucalyptus Camaldulensis
radius up to 1.5km

The Problem
the tailing dam



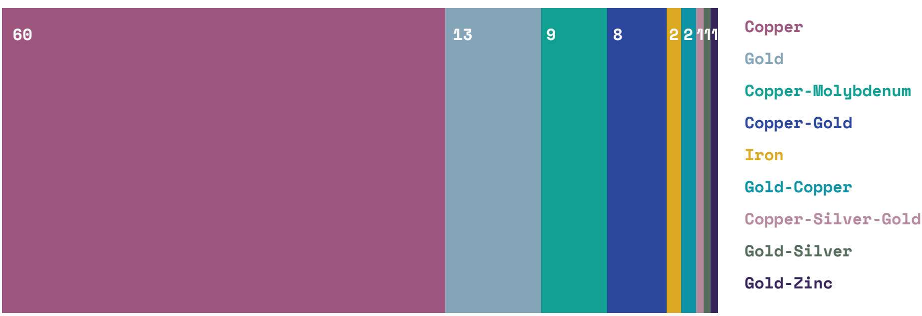
// 1 Tailing Dam © Corporacion Alta Ley

Background: *"The copper mining industry extracts large volumes of material, of which only a small fraction corresponds to the main element of economic interest that one seeks to recover. Once this material has been processed and the copper and, eventually, other elements of value have been extracted, waste known as tailings is produced (comprised of ground rock and water with trace chemical elements and reagents), which represent between 97% and 99% of the ore processed.*
The tailings are transported via pipelines to places especially conditioned for their final storage in tailings dumps, dams or reservoirs depending on the method used to build the retaining wall. [...] The fine solids settle in the reservoirs and a clear water lagoon is formed on the surface (Sernageomin, 2013)."

The Problem of Water and Soil Contamination: Tailing Dams *"pose a long-term challenge for mining operations, as they can cause an impact many years after the deposition of tailings. Deficient controls and the lack of mitigation of leakage can have negative effects on public health and people's the quality of life, polluting water bodies and soils and causing negative impacts on other economic activities such as agriculture and livestock farming."* (1)

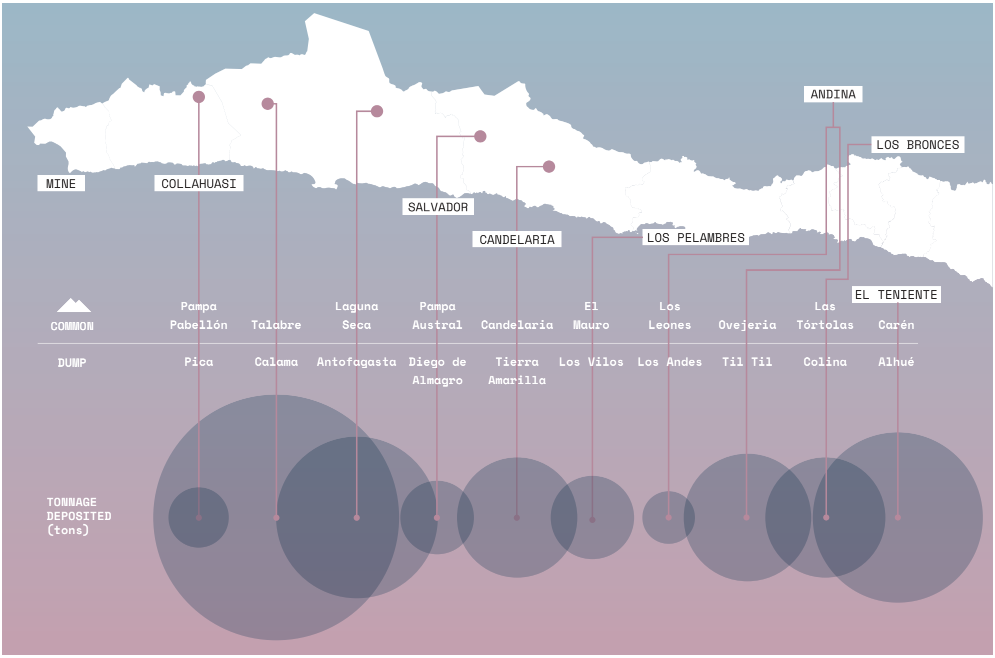
The Problem
copper industry and tailing dams

“Of the total active tailings dumps [in Chile], the majority belong to industries that produce Copper, Copper-Gold and Copper-Molybdenum, with a total of 78 dumps authorized to store 14 billion m3.
[...]
The main tailings-producing mine operations are in the large-scale mining category. Codelco is the main producer with 28% of the total tailings produced in the country. It is followed by the company Antofagasta Minerals (AMSA) with 16% and BHP Billiton with 13% (JRI, 2015).
Current production of tailings is concentrated mainly in the northern regions, with 62% of the total. The central region produces 37% of mine tailings, while production of tailings in the southern region is practically nonexistent (1%).
The main tailings producing mine operations in northern Chile are Escondida, Chuquicamata, Collahuasi, Caserones, Centinela, Candelaria, Ministro Hales and Salvador. Regarding central Chile, the main tailings producing operations are Los Pelambres, El Teniente, Andina, Los Bronces and El Soldado.
The largest operational tailings dumps by authorized tonnage in Chile are, from largest to smallest: Talabre, Chuquicamata; Laguna Seca, Escondida; Carén, El Teniente; Ovejería, Andina; El Mauro, Minera Los Pelambres; Sierra Gorda, Sierra Gorda; Pampa Pabellón, Collahuasi and Las Tórtolas, Los Bronces.” ②

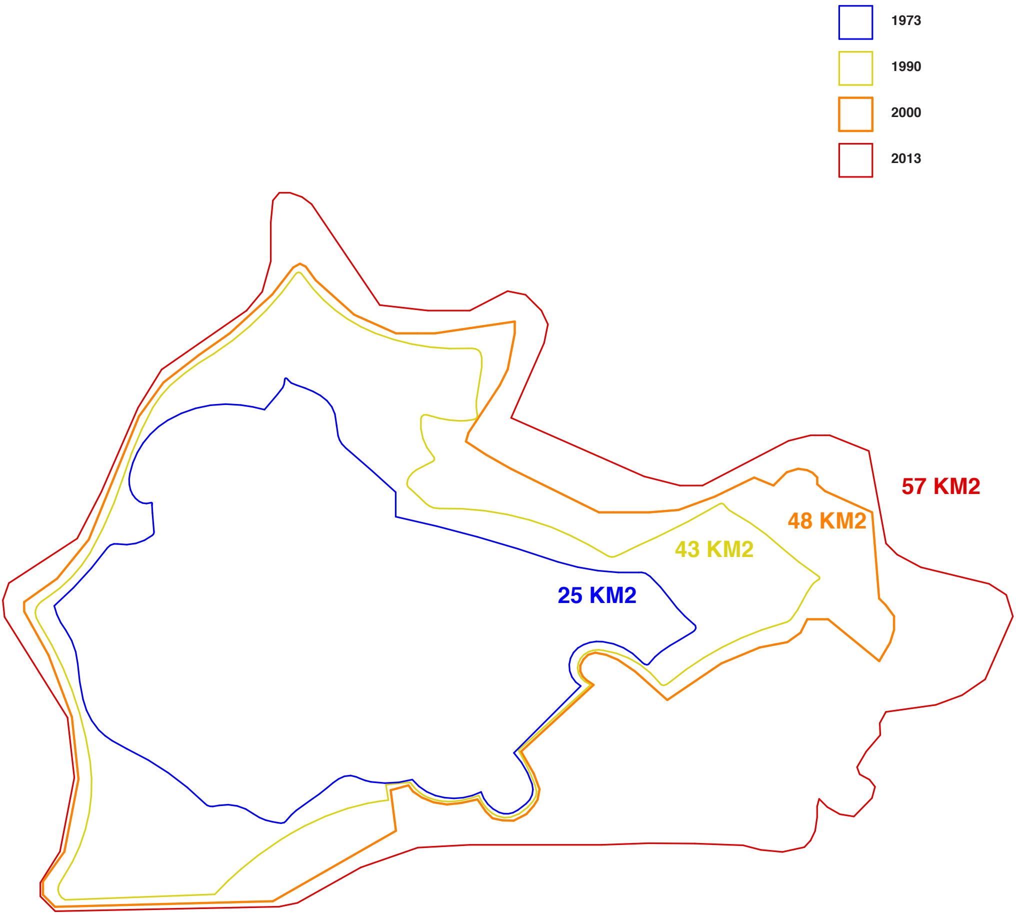


// 2 Numbers of Tailing dams according to metal produced © Corporacion Alta Ley

The Problem
chuquicamata tailing dam
tranque talabre



// 3 Top 10 Chilean tailing dams in operation based on tonnage deposited (2019) © Corporacion Alta Ley



// 4 Growth of Tranque Talabre over the years.

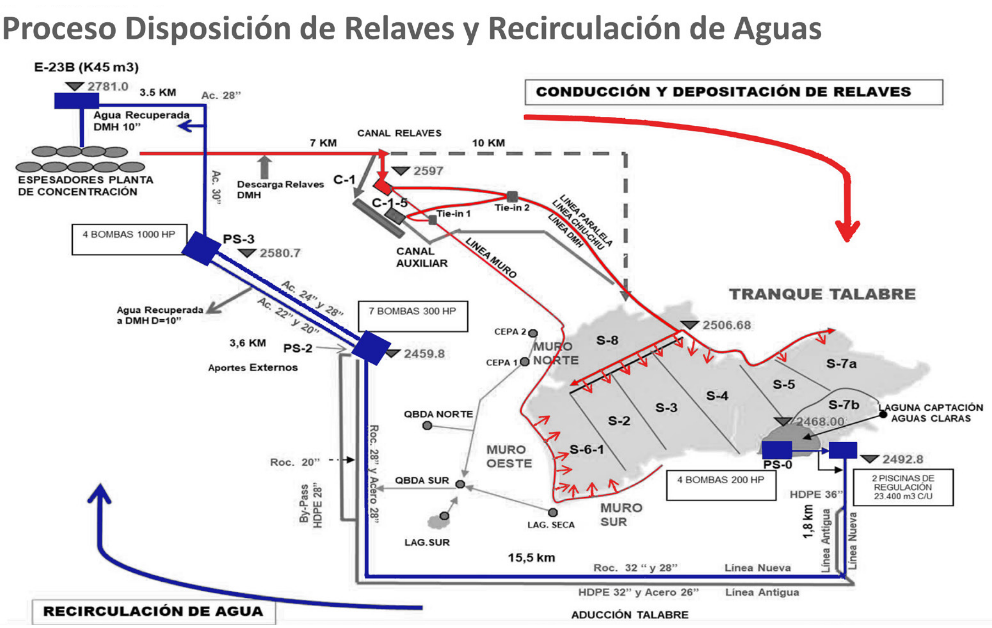
// 5 Satellite view on Chuquicamata Tailing Dam Tranque Talabre

// 6 Screenshots from Documentary “Kupfer Aus Chile - Glanz Der Erde“ on Chuquicamata Mine

The documentation *Kupfer Aus Chile - Glanz Der Erde, Teil 2 | Kupferabbau in Der Atacama-Wüste (RBB , 2004)* helped trace the waterpath from mine to tailing dam.

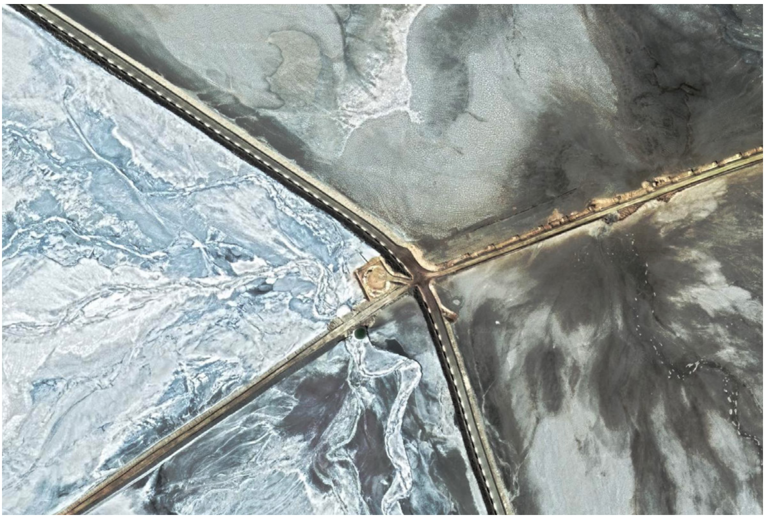
1 processing of copper concentrate in concentration plant
2 in large tanks, tensides are added to the debris/slurry and it is vigorously stirred; until it foams
3 the copper reaches the top, the debris settles; copper content up to 35 percent - enough for the smelter;
4 this torrential stream comes from the chemical processing of copper slimes; toxic water that is piped directly into the tailing dam in the desert for reprocessing;
5 maintenance of pumping and distribution stations
6 acidic floods
7 approaching the tranque talabre tailing dam
8 tranque talabre tailing dam: final station

Chuquicamata Tailing Dam on-site water distribution



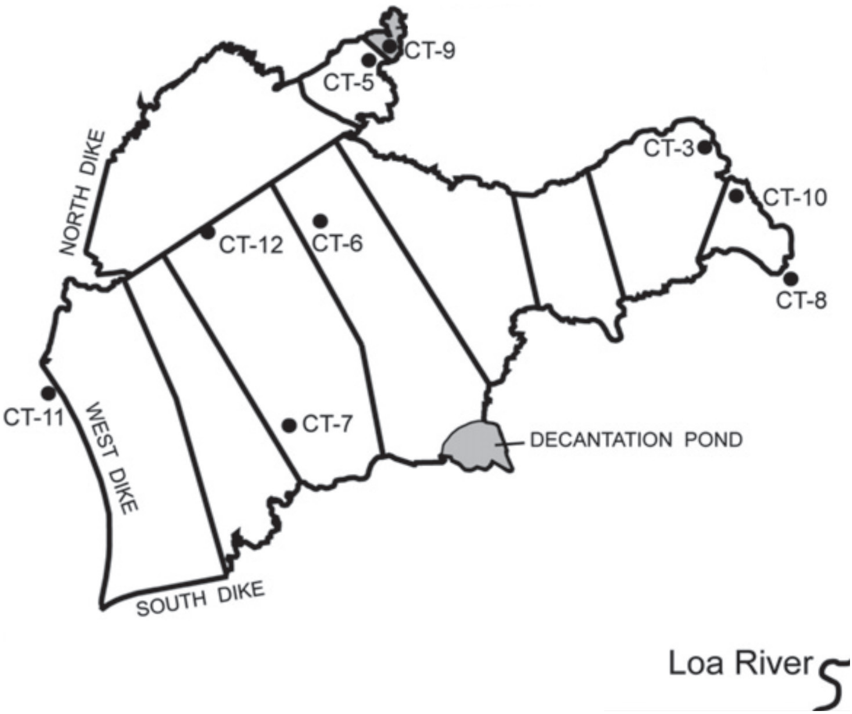
// 7 Tailing Disposal and Water Recirculation Process, Graphic adapted from Superintendencia del Medio Ambiente.

// 8 Toxic Water Distribution



// 9 Water Infrastructure on Site

Chuquicamata Tailing Dam soil composition



// 10 Location map showing soil sampling sites of Tranque Talabre
© Jochen Smunda et al.

Table 1
Whole rock analysis of tailings samples.

Sample	Depth	LOI	Na	Mg	Al	Si	P	K	Ca	Mn	Fe	Ti	S	Cl	V	Co	Cu	Zn	As	Rb	Sr	Zr	Mo	Ba	Pb
	m	*wt.%*	*wt.%*	*wt.%*	*wt.%*	*wt.%*	*wt.%*	*wt.%*	*wt.%*	*wt.%*	*wt.%*	*wt.%*	*wt.%*	*wt.%*	*wt.%*	*wt.%*	*wt.%*	*wt.%*	*wt.%*	*wt.%*	*wt.%*	*wt.%*	*wt.%*	*wt.%*	*wt.%*
CT-3	0.09	4.63	0.67	0.33	6.93	32.86	0.05	4.97	1.66	0.11	0.57	0.10	1.79	0.13	0.005	0.006	0.062	0.007	0.007	0.015	0.056	0.012	0.031	0.067	0.008
	0.18	4.78	0.72	0.47	7.69	31.72	0.06	5.52	1.69	0.10	0.68	0.11	1.64	0.08	0.005	0.007	0.081	0.007	0.000	0.019	0.057	0.012	0.026	0.063	0.006
	0.58	3.16	1.01	0.35	6.94	33.82	0.06	5.37	1.35	0.07	0.42	0.11	1.35	0.09	0.005	0.005	0.164	0.008	0.001	0.017	0.048	0.011	0.026	0.078	0.005
	1.39	4.22	1.09	0.32	7.05	32.79	0.05	5.36	1.57	0.10	0.82	0.12	1.42	0.13	0.006	0.013	0.138	0.008	0.002	0.019	0.053	0.013	0.016	0.052	0.005
	2.40	4.06	0.71	0.29	6.06	35.07	0.04	4.17	0.64	0.03	1.11	0.11	0.74	0.05	0.004	0.029	0.257	0.040	0.010	0.016	0.041	0.012	0.032	0.039	0.013
CT-5	0.05	4.85	1.99	0.58	7.48	30.59	0.05	4.59	0.33	0.04	3.80	0.13	2.18	0.95	0.006	0.004	0.109	0.054	0.037	0.017	0.050	0.015	0.079	0.079	0.014
	0.32	5.00	1.39	0.42	7.16	31.29	0.07	4.45	1.31	b.d.	2.70	0.13	2.51	0.1	0.006	b.d.	0.050	0.033	0.026	0.017	0.064	0.015	0.060	0.061	0.013
	0.48	2.69	1.05	0.30	6.54	34.89	0.06	4.41	0.78	0.04	1.07	0.10	1.28	0.05	0.003	0.007	0.255	0.029	0.017	0.016	0.043	0.010	0.056	0.064	0.012
	0.63	2.76	1.09	0.34	6.67	34.87	0.05	4.41	0.82	0.03	0.84	0.10	1.21	0.05	0.006	0.003	0.300	0.027	0.017	0.016	0.042	0.010	0.051	0.069	0.013
	0.77	3.63	0.63	0.37	7.19	33.38	0.06	4.50	0.77	0.02	1.57	0.10	1.35	0.08	0.006	b.d.	0.126	0.059	0.022	0.016	0.049	0.012	0.049	0.063	0.022
	1.68	3.02	0.73	0.40	6.98	34.50	0.05	4.36	0.61	0.04	0.95	0.11	1.07	0.08	0.004	0.011	0.313	0.037	0.013	0.016	0.041	0.012	0.045	0.059	0.015
	2.30	3.05	1.55	0.38	7.26	32.91	0.06	5.16	1.45	0.07	1.15	0.12	1.69	0.11	0.005	0.008	0.188	0.033	0.009	0.018	0.054	0.012	0.032	0.074	0.010
	2.51	2.62	1.60	0.29	6.16	35.61	0.05	4.32	0.72	0.03	0.94	0.11	0.88	0.04	0.005	0.020	0.237	0.036	0.009	0.017	0.045	0.013	0.035	0.048	0.014
	2.90	2.23	2.10	0.40	6.99	33.65	0.05	4.17	0.76	0.02	1.11	0.12	0.86	0.04	0.003	0.010	0.333	0.020	0.009	0.016	0.045	0.012	0.029	0.061	0.008
	3.60	2.85	2.30	0.44	7.04	32.74	0.06	4.17	0.78	0.03	1.57	0.12	0.95	0.07	0.004	0.012	0.261	0.030	0.015	0.016	0.050	0.013	0.027	0.069	0.007
CT-6	0.12	2.47	1.12	0.36	6.83	34.55	0.06	5.00	0.81	0.03	0.91	0.11	1.00	0.04	0.005	0.003	0.379	0.049	0.004	0.016	0.043	0.012	0.046	0.061	0.007
	0.26	3.08	1.08	0.31	6.65	34.62	0.06	4.74	1.03	0.04	0.78	0.11	1.11	0.07	0.004	0.010	0.085	0.029	0.000	0.015	0.049	0.017	0.024	0.073	0.008
	0.54	3.24	1.20	0.30	5.88	34.74	0.06	5.02	1.21	0.09	1.07	0.11	1.13	0.03	0.001	0.011	0.067	0.033	0.005	0.016	0.045	0.015	0.019	0.080	0.007
	0.62	3.47	1.08	0.36	7.32	32.88	0.05	5.26	1.13	0.03	1.43	0.11	1.43	0.11	0.004	0.003	0.136	0.036	0.015	0.016	0.051	0.013	0.026	0.083	0.007
	1.27	2.97	1.07	0.37	6.34	34.61	0.05	4.87	0.77	0.04	1.28	0.12	1.09	0.09	0.003	0.019	0.180	0.026	0.004	0.017	0.040	0.012	0.036	0.038	0.006
	2.71	2.90	1.06	0.28	5.93	33.22	0.07	3.74	0.63	0.09	4.23	0.16	1.13	0.07	0.004	0.017	0.529	0.335	0.021	0.013	0.055	0.024	0.080	0.074	0.019
	3.52	4.84	0.87	0.40	7.37	31.73	0.06	4.82	1.28	0.07	1.83	0.12	1.93	0.08	0.006	0.010	0.127	0.047	0.024	0.019	0.055	0.012	0.033	0.065	0.012
	3.78	5.34	1.40	0.52	7.86	30.49	0.07	5.21	1.27	0.03	2.33	0.13	2.04	0.13	0.006	0.008	0.137	0.036	0.021	0.021	0.056	0.011	0.051	0.053	0.011
	3.99	3.23	1.10	0.31	6.44	34.40	0.05	4.50	0.75	0.07	1.61	0.13	1.06	0.08	0.004	0.025	0.167	0.025	0.020	0.018	0.049	0.015	0.028	0.060	0.008
	4.62	3.36	1.64	0.38	6.86	33.37	0.07	4.71	0.81	0.03	1.92	0.12	1.22	0.26	0.004	0.017	0.283	0.044	0.013	0.019	0.055	0.013	0.059	0.063	0.013
	4.90	2.51	1.62	0.19	6.32	34.72	0.06	4.62	0.44	0.03	1.95	0.11	0.87	0.26	0.003	0.017	0.266	0.048	0.014	0.018	0.046	0.012	0.051	0.057	0.010
CT-7	0.02	3.66	1.48	0.40	7.48	32.24	0.06	4.94	0.98	0.02	1.95	0.13	1.73	0.54	0.005	0.007	0.114	0.031	0.003	0.018	0.050	0.013	0.021	0.069	0.005
	0.10	3.51	1.50	0.39	7.19	33.08	0.06	4.86	1.09	0.03	1.45	0.12	1.68	0.12	0.005	0.009	0.155	0.026	0.004	0.018	0.046	0.013	0.019	0.075	0.005
	0.16	5.55	1.04	0.50	8.65	29.96	0.07	5.15	1.48	0.02	1.87	0.12	1.90	0.12	0.006	b.d.	0.100	0.040	0.008	0.020	0.052	0.009	0.024	0.057	0.006
	0.24	3.32	2.16	0.43	7.51	32.91	0.06	5.05	1.07	0.03	1.23	0.11	1.54	0.24	0.004	b.d.	0.211	0.028	0.002	0.018	0.043	0.012	0.031	0.086	0.005
CT-12		4.63	0.63	0.41	7.44	31.79	0.06	5.39	1.81	0.12	0.69	0.11	1.89	0.07	0.005	b.d.	0.139	0.013	0.012	0.018	0.064	0.010	0.026	0.055	0.009

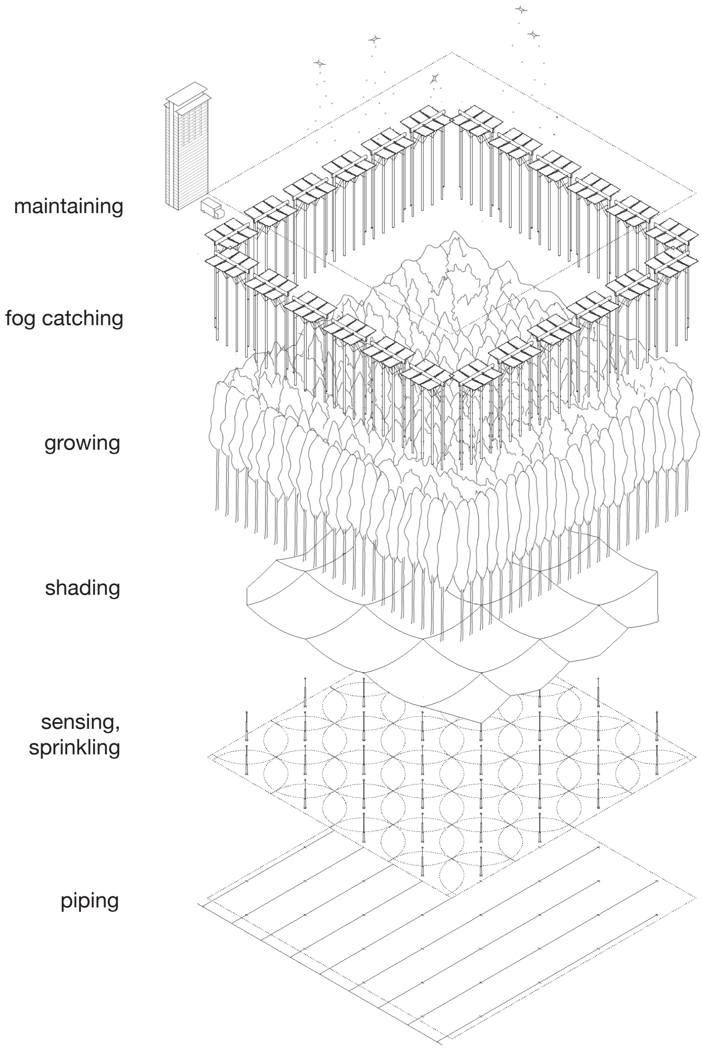
// 11 Soil Samples and their composition elements. © Jochen Smunda et al.

The Intervention
the toxic forest

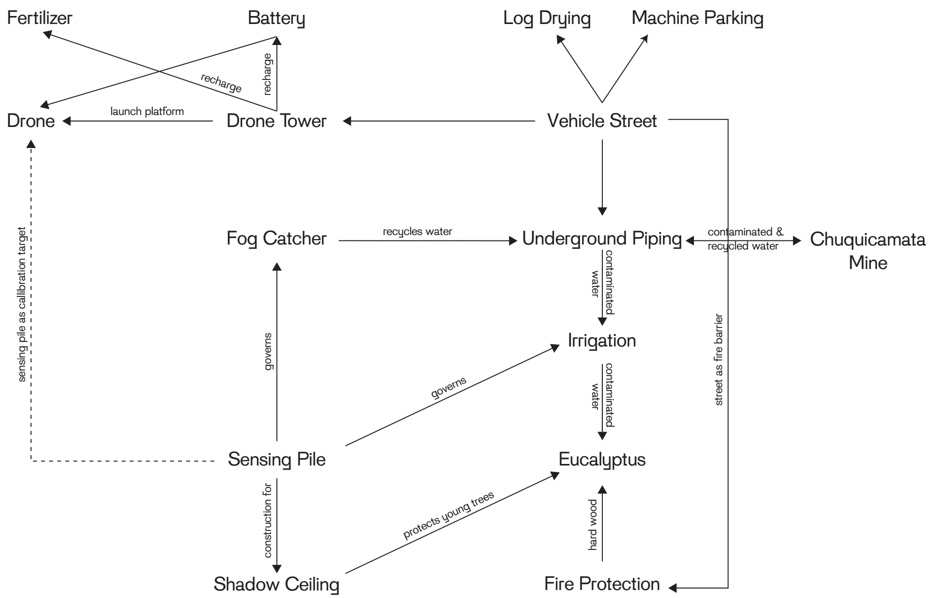
// 12 Eucalyptus Trees in Los Vilos, Province of Coquimbo, Chile
© Ignacio Acosta

“To dispose of these toxic water residues, water-intensive monocultures of eucalyptus have been created. Eucalyptus specimens from Australia have been imported because they grow rapidly and reach great heights. But most importantly, these are the thirstiest trees on earth. In addition, these forests are highly dependent on the regular supply of water from the mine.” (3)

The Toxic Forest
system diagrams

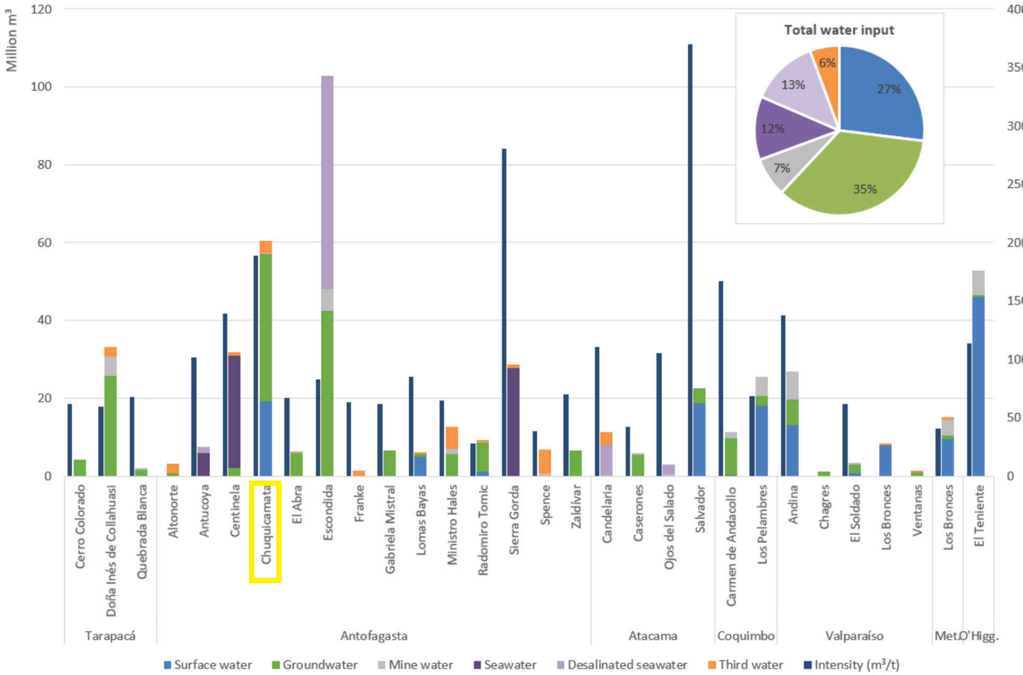


// Exploded Axonometry of 1HA in the Toxic Forest



// Agents of the System

The Toxic Forest calculation: number of trees and hectare



// 13 Water abstraction by water source and water intensity, in the 31 copper mines in Chile 2018. Graphic adapted from Stephan Lutter and Stefan Giljum.

From the water consumption of the mine, the number of trees needed to cope with this consumption and toxic water can be calculated.

60 000 000m3 water consumption per year
= 60 000 000 000 l
= 60 000 000 000 l /365 =
164 383 562 liter per day

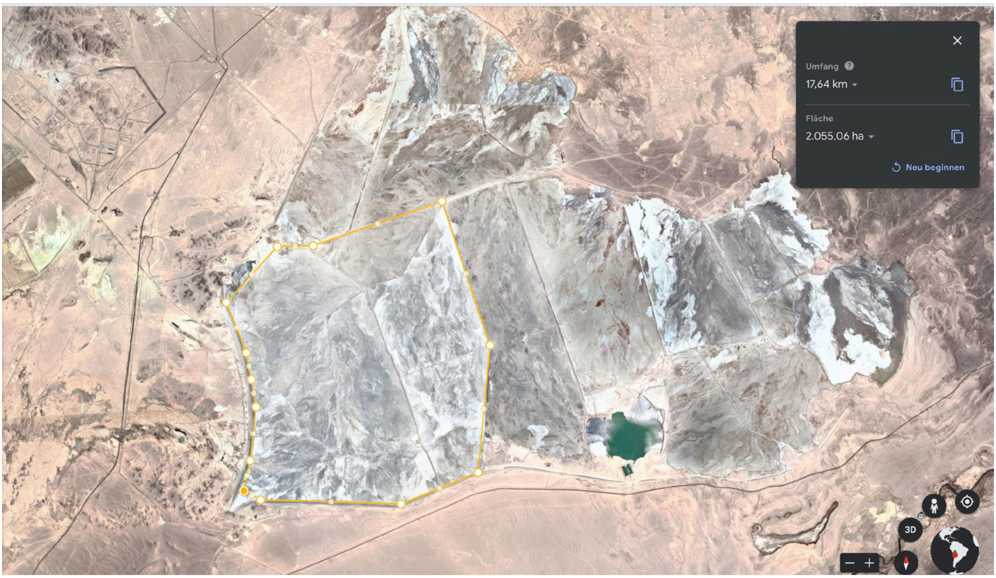
1 tree water consumption: 200l/day (4)

164 383 562 liter per day / 200 = 821 918 trees

Assuming that in a eucalyptus plantage the seeding of the trees happens within a 4x4 meter grid, the numbers of hectare needed can be calculated. (5)

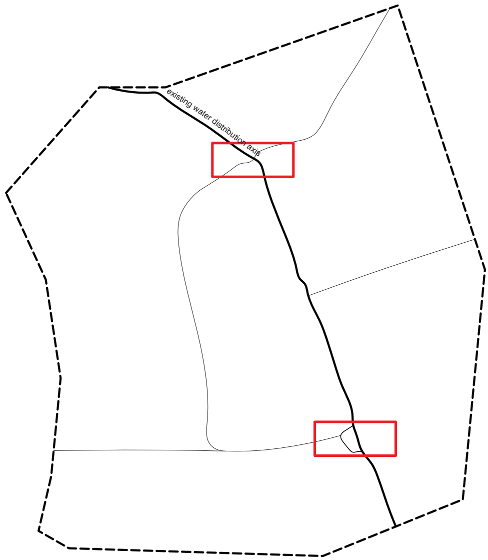
number of trees per hectar: 1 hectar = 100x100m
Seeding of trees every 4 meter
--> 400 trees per hectare

821 918 trees / 400 = 2055 HA

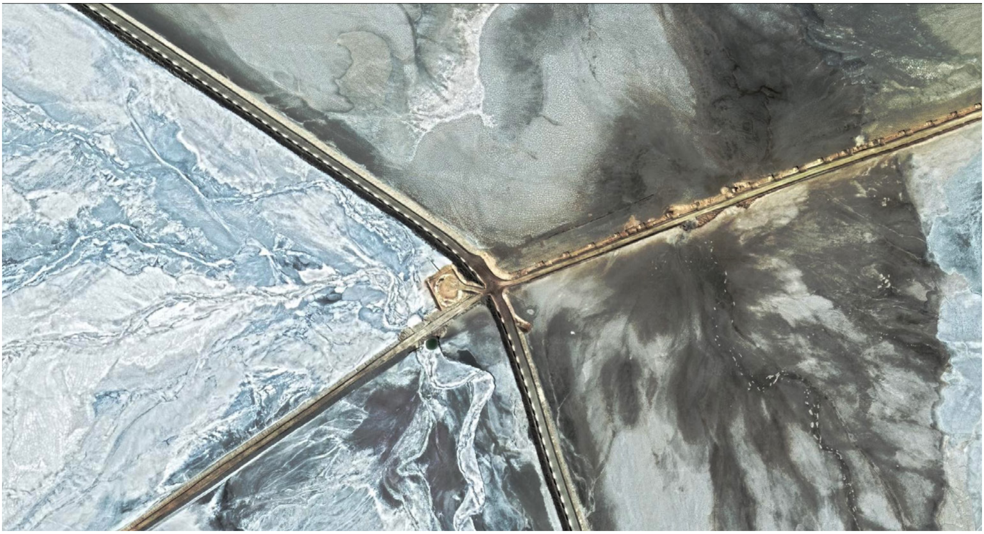


// 14 Chosen Area for Hectare Distribution

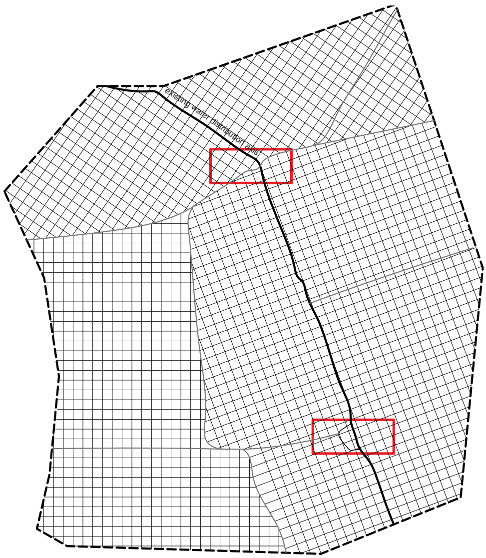
The Toxic Forest
analysis for hectare distribution



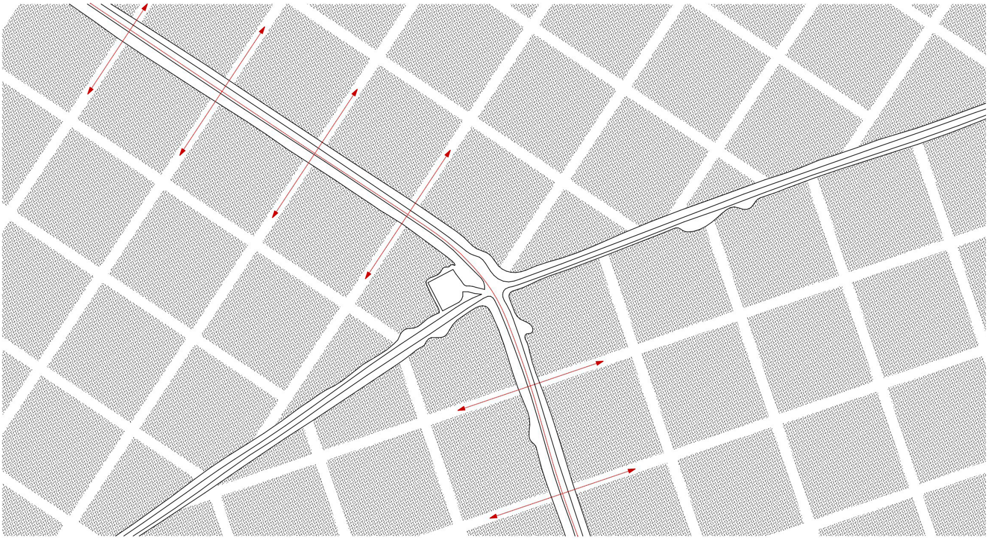
// Identification of the existing piping by analysis of Google Earth images.

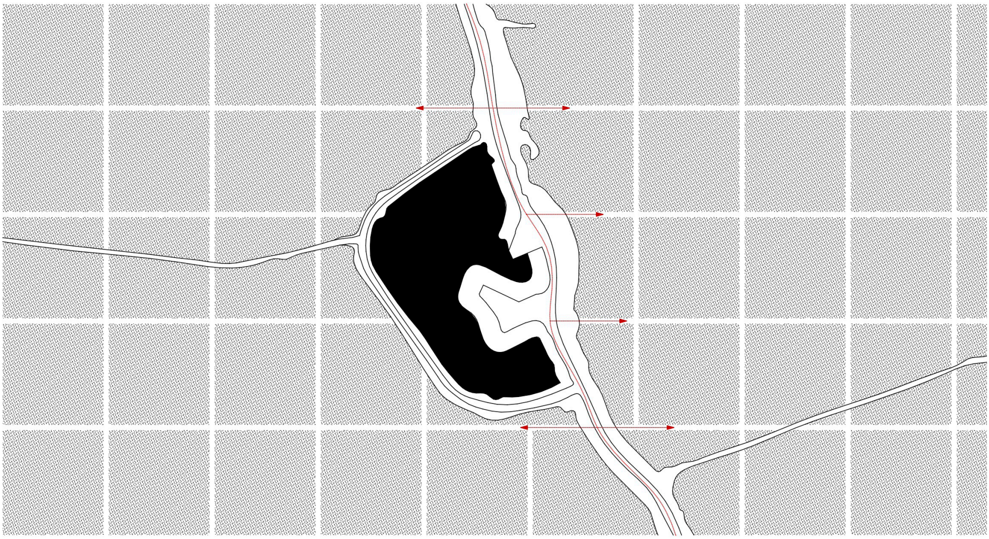


// 15 Identification of the existing piping by analysis of Google Earth images.



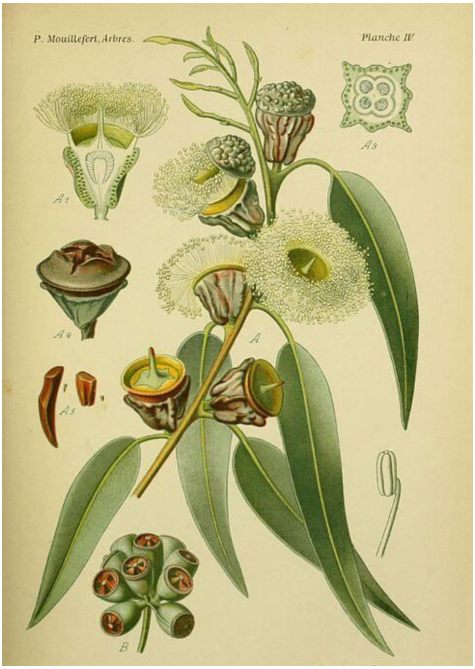
// Distribution of the HA accordingly, making use of the directionality of the existing infrastructure.





// Distribution of the HA accordingly, making use of the directionality of the existing infrastructure.

Tree as Technology
the eucalyptus



// 16 Anatomy of Eucalyptus Globulus

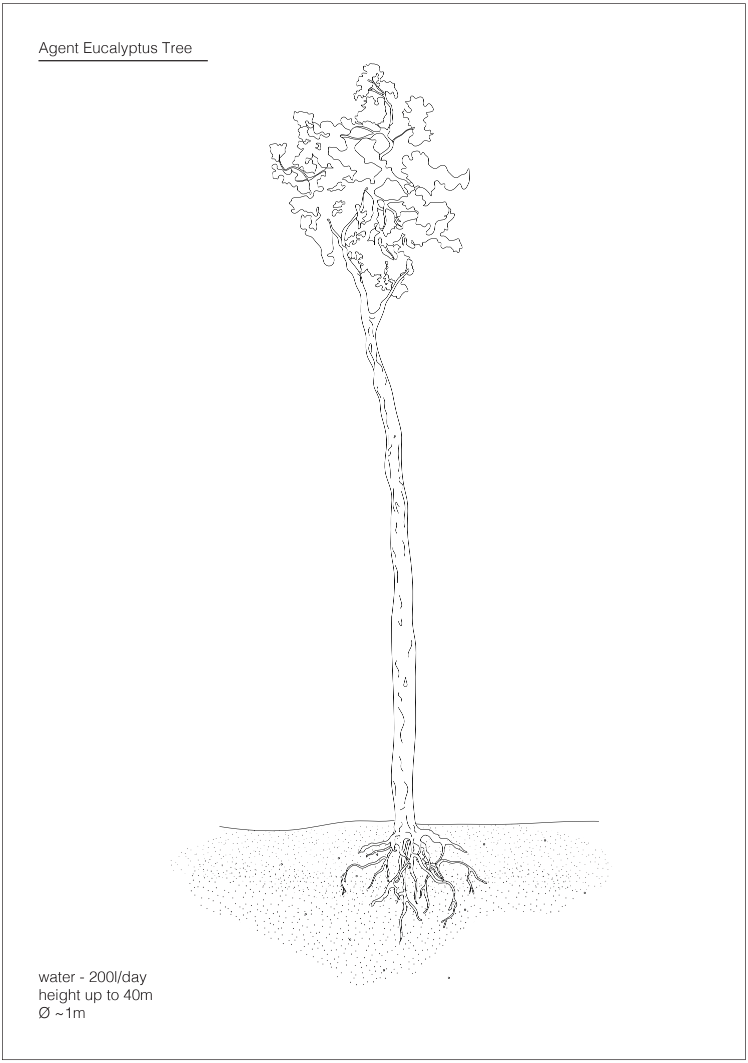
Species part of the Toxic Forest:

Eucalyptus Globulus ⑥

grows until 40m
trunk 1-2m
soft wood but still used as flooring
very often used in plantages outside of australia

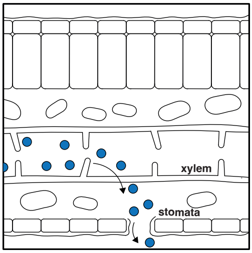
Eucalyptus Camaldulensis ⑦

grows until 30m
trunk 1-2m
hard wood, suitable for construction and furnishing (floor, frames)
red dark wood
loves floodings
fire

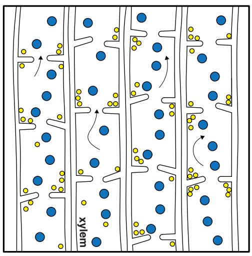


// Agent Eucalyptus Globulus

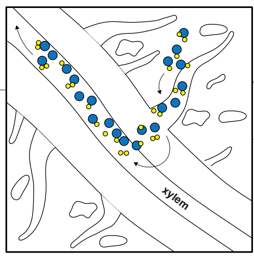
Tree as Technology
hydrological cycle



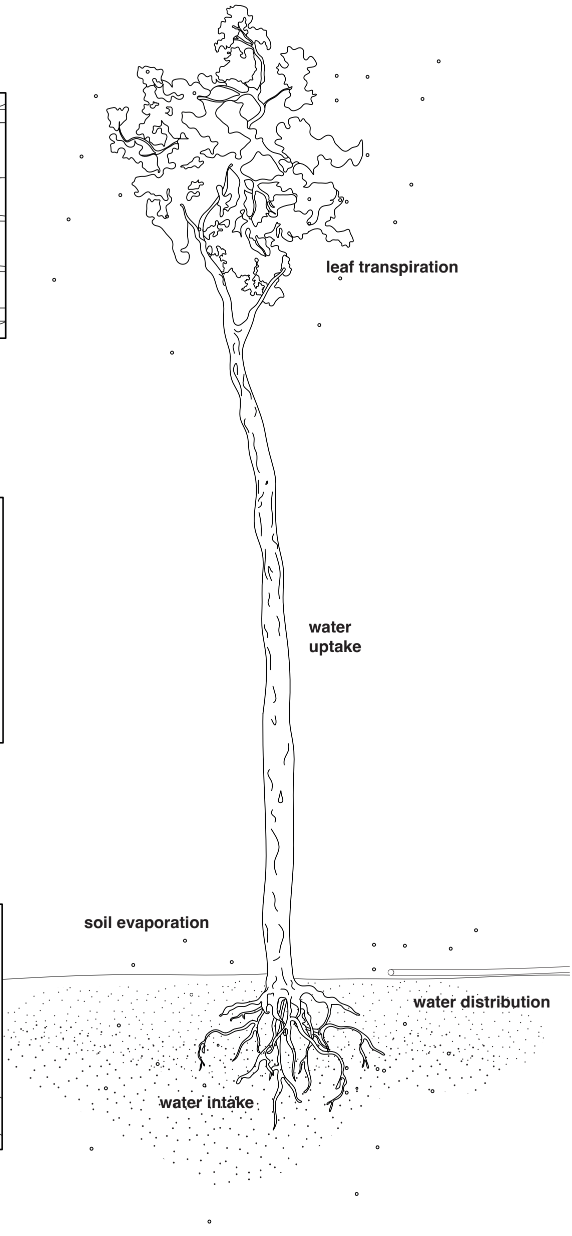
3 leaf • transpiration draws water from the leaf

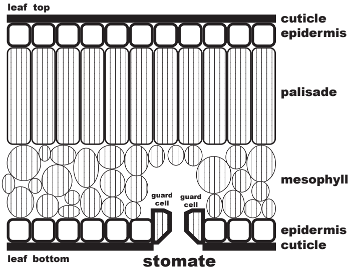


2 stem • cohesion and adhesion draw toxic water up the xylem, toxic particles settle

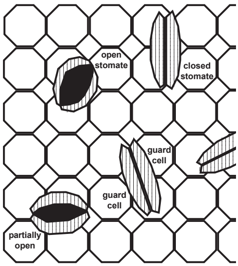


1 root • Negative water potential draws toxic water into the root

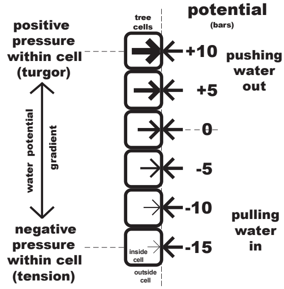




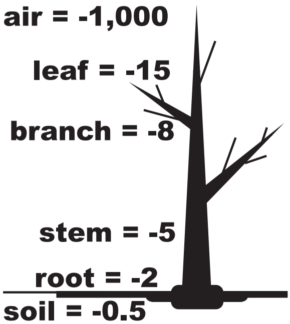
Idealized diagram showing open and closed stomates on underside of a tree leaf blade.



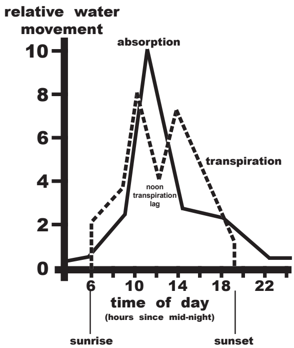
Idealized diagram showing open and closed stomates on underside of a tree leaf blade. The geometric pattern background represents leaf epidermis cells covered by a waxy cuticle.



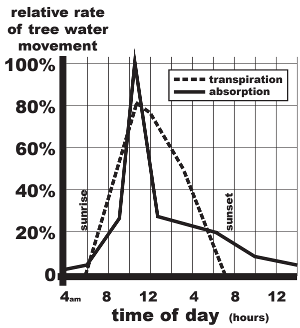
Simplified view of water potential gradient from pressure (positive water potential) to tension (negative water potential) within tree cells.



Example water potentials in bars from atmosphere to soil through a tree. Water moves (is pulled by tension) from more positive water potential regions (soil) to more negative water potential regions (leaf).



Root absorption, leaf transpiration and relative amount of water being moved by each process. Root absorption continues through the night.



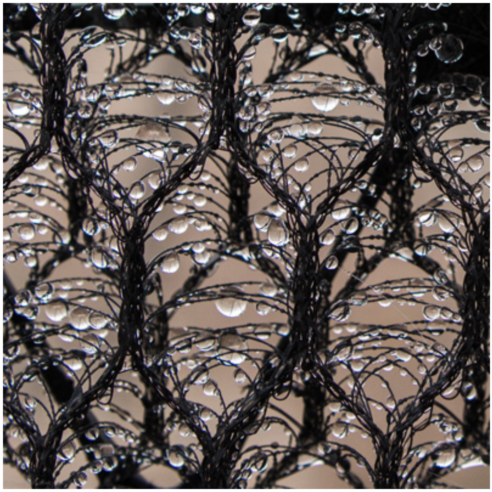
Example of relative rate of water movement from transpiration and root absorption within a tree.

// 17 Diagrams Showcasing
A Tree's Hydrologcial Cycle
© Kim D. Coder

"A key factor that helps create the pull of water up the tree is the loss of water out of the leaves through a process called transpiration. During transpiration, water vapor is released from the leaves through small pores or openings called stomates. Stomates are present in the leaf so that carbon dioxide--which the leaves use to make food by way of photosynthesis--can enter. The loss of water during transpiration creates more negative water potential in the leaf, which in turn pulls more water up the tree. So in general, the water loss from the leaf is the engine that pulls water and nutrients up the tree." (8)

Tree as Technology transpiration and water recycling

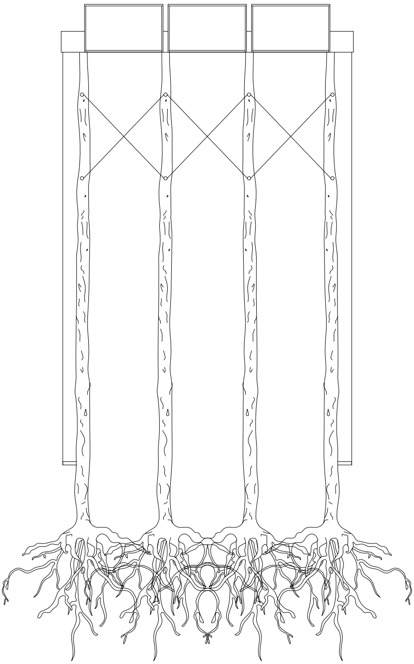
// 18 Fogcatching Structures - Harvesting Water From the Air



// 19 Fogcatcher Fabric - Harvesting Water From the Air

The Toxic Forest implements and redesigns a technology used in Chile for collecting water vapour from the air: the fog catcher. Movable fabric panels with fine polyolefin meshes are mounted on cut trees and can extract up to 10 percent of the water available in the air. The fog catcher becomes a "water recycling plant."[9]

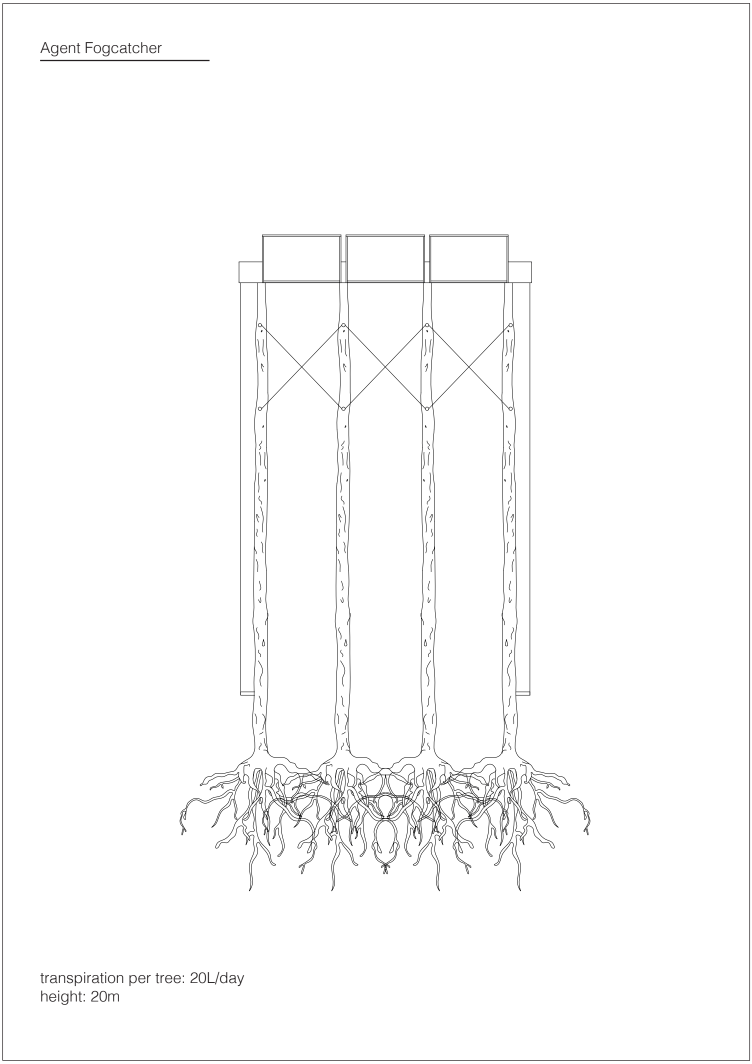
Agent Fogcatcher



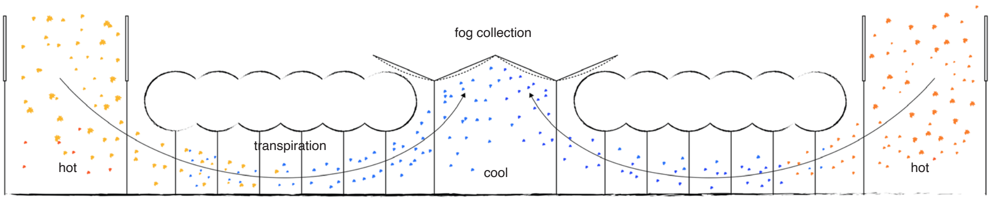
transpiration per tree: 20L/day
height: 20m

// Agent Fog Catcher - A Water Recycling Plant

Tree as Technology
heat corridors

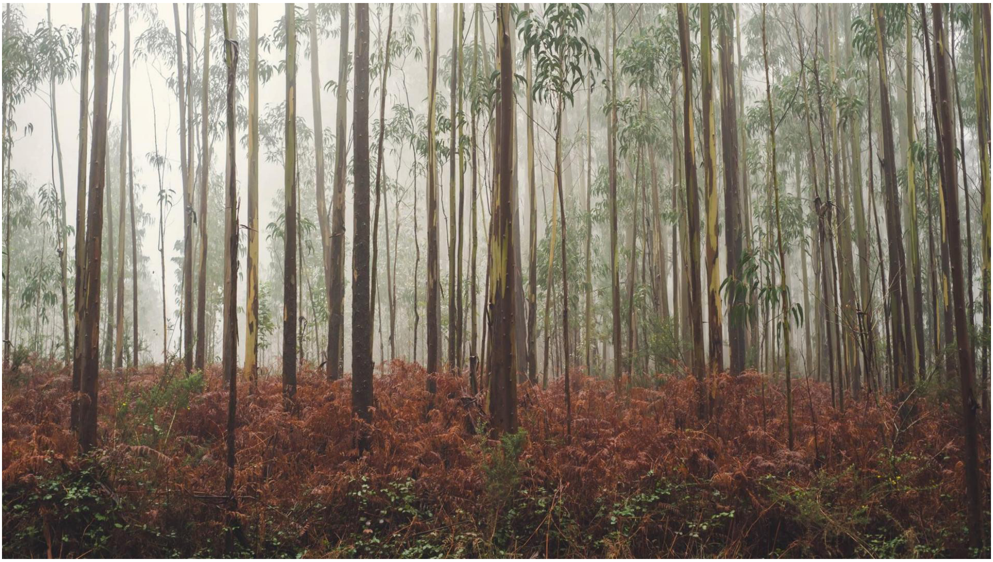


// Agent Fog Catcher - A Water Recycling Plant



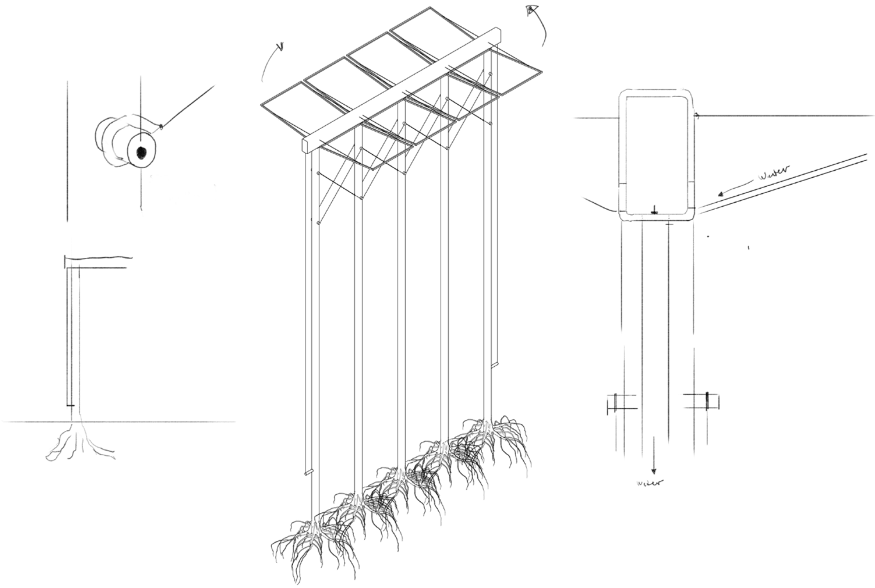
// Regulated heat corridors create thermic winds
to transport transpiration to fog catcher.

Tree as Technology
water recycling plant



// 20 Fog in a Eucalyptus Forest

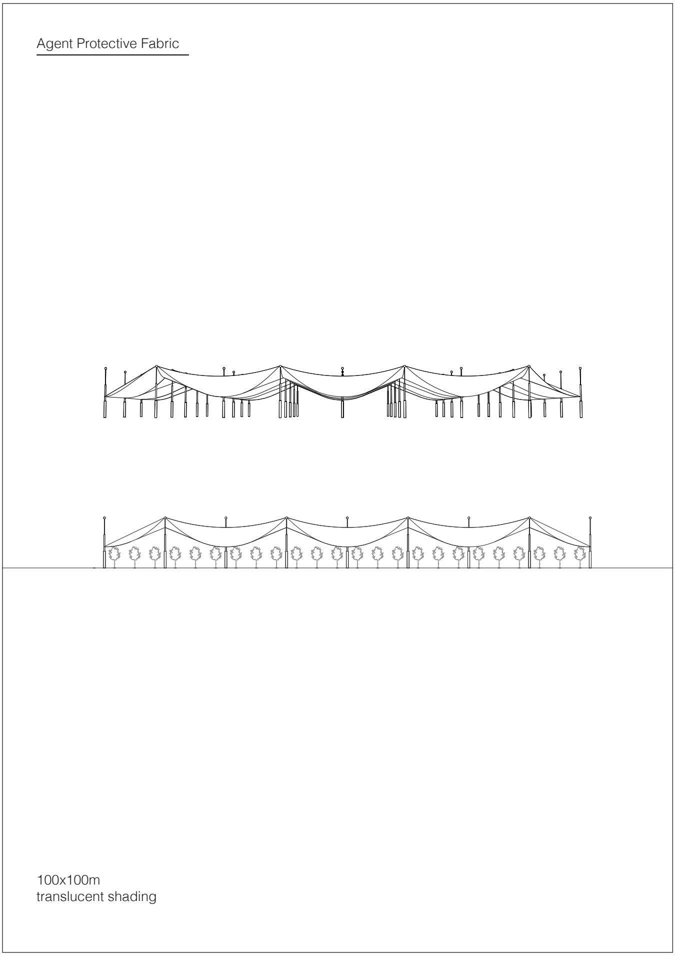
Eucalyptus trees transpire up to 30 percent of the water absorbed. With maximal 200L absorption a day, we can speculate on 40L of transpiration per tree per day.



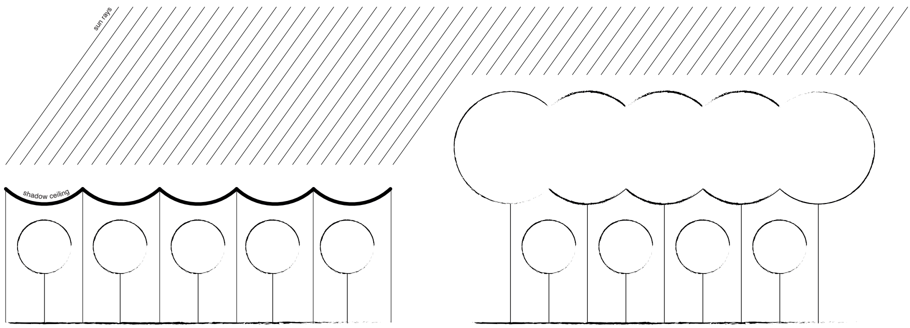
// Fogcatcher - Flow of Water

The agent of the fog catcher works as “water recycling plant”: 10% of the 40L can be recycled per tree, which means 1600 L of clean water per hectare and day can be recycled and pumped back to the mine for reuse.

Climate Regulation
shadow ceiling



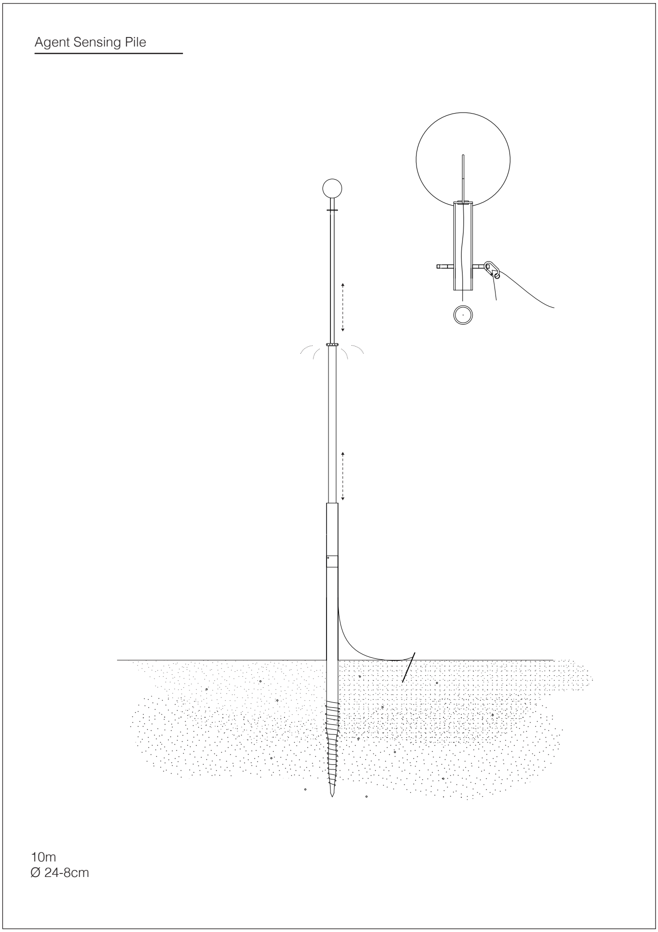
// Agent Shadow Ceiling - A Protective Fabric



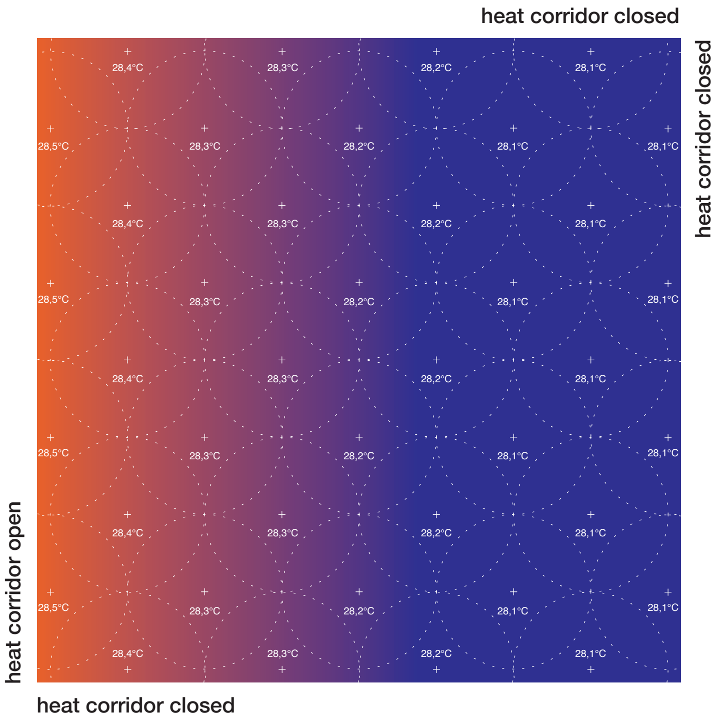
// Shadow Ceiling Imitating Mother Forest

// Mother Forest

Climate Regulation
sensing pile



// Agent Shadow Ceiling - A Protective Fabric



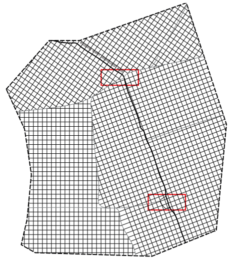
// Position, sensed temperature and
sprinkling radius of sensing pile within 1 HA.

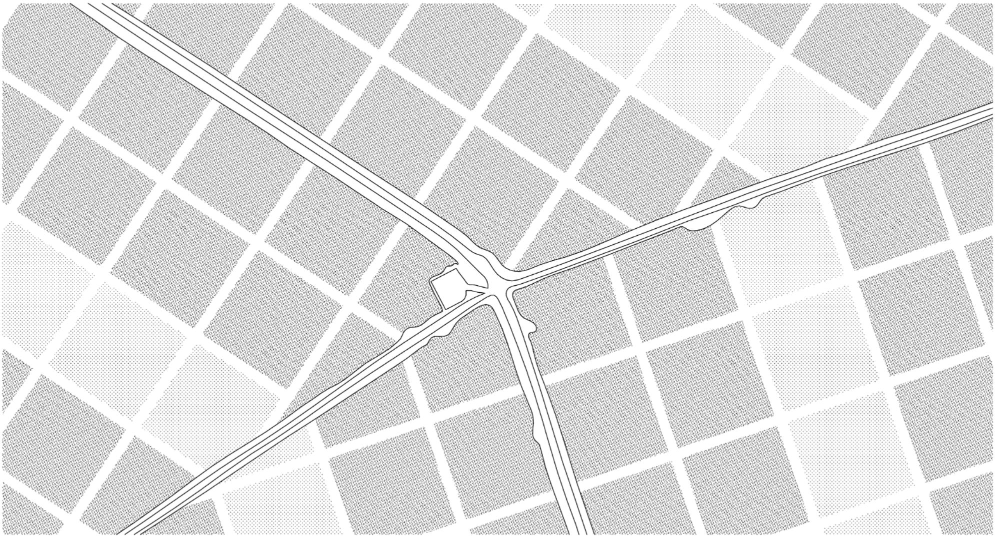
Climate Regulation
forest fire

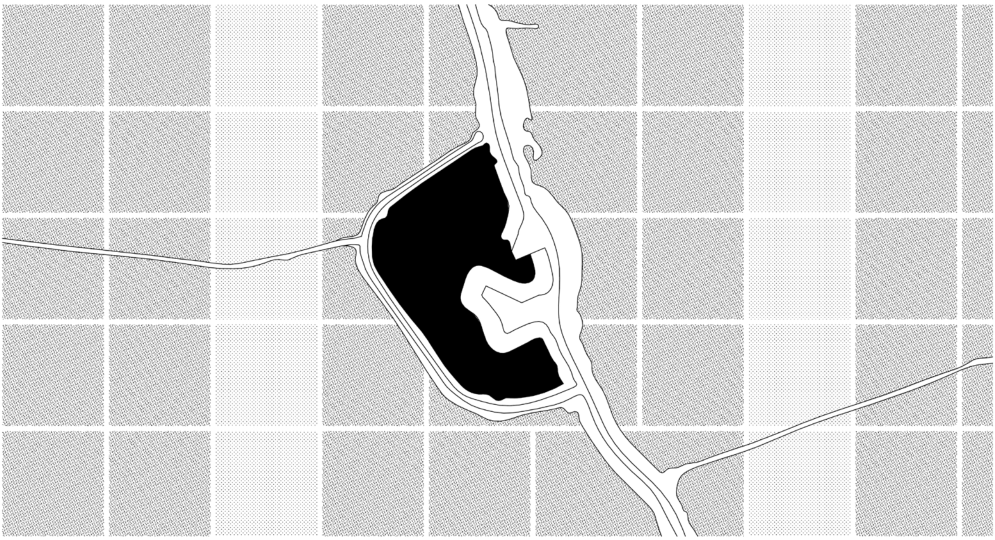
„The wood fibres in high-density logs are more closely compacted than low-density wood; when ignited, high-density wood burns more slowly as the flames cannot travel quickly through the tight grains of the wood.“ ⑩

The Toxic Forest makes use of the hardwood property of the eucalyptus camaldulensis, to be applied as forest fire break.

Def. Forest Firebreak: *“A forest firebreak is a 100 to 300-meter wide area covered with less burnable trees. [...]In the event of a fire, a forest firebreak is intended to convert full fires into ground fires that are easier to fight, or to prevent the spread of ground fires, and to remove the energy of the fire roller. In order to protect larger forest areas, especially in areas with forest fire hazard class A, these bolts are connected to form a system. In such a system, the main ledgers run from north to south, since the wind blows predominantly from the west or east in the event of a fire.”* ⑪







1 HA
eucalyptus camaldulensis

4 HA
eucalyptus globulus

1 HA
eucalyptus camaldulensis

Drone Technology
drones and forestation

// 21 Use of drones, aerial mapping software and ecological science to reforest areas at a rapid pace.

// 22 A WWF staff member pilots a seed drone to reforest Australia‘s forests.

Drones in the Toxic Forest fulfil 3 different kinds of tasks: multispectral mapping, spraying of fertilizer, as well as seeding.

Multispectral Mapping Drone
gathers data and monitors
the growth of the trees

Fertilizing Drone
gives seedlings nutritients
and support in the first crucial
years

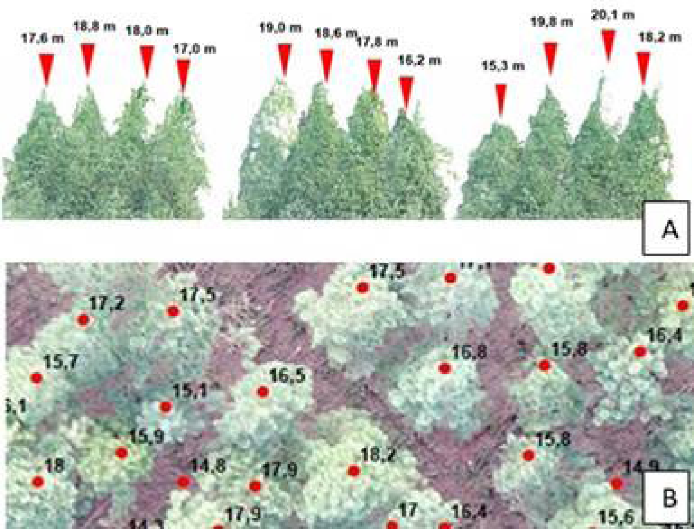
Seeding Drone
mounted with pneumatic
firing devices to fire pods
in defined location

The seeds are packed in nutrient-rich pods and distributed on-site by the seeding drone. The young trees are monitored and surveilled by the mapping and fertilizing drones.

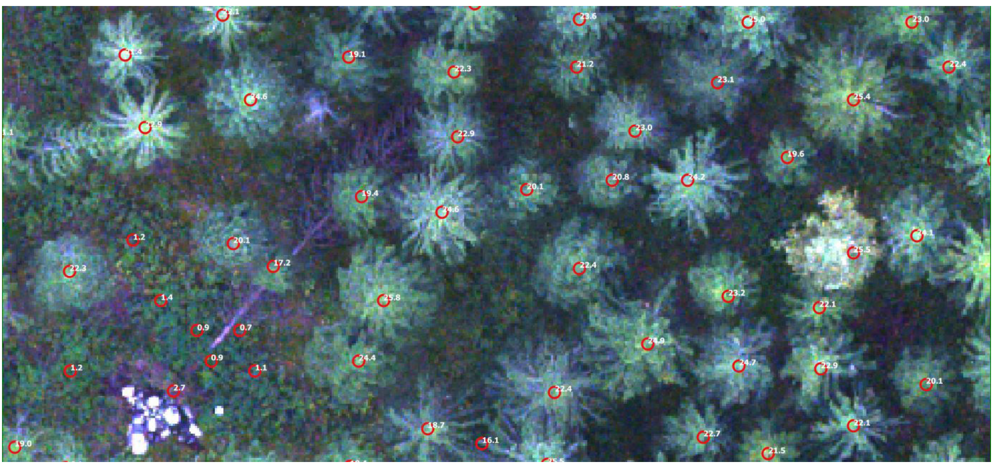
// 23 Different Drone Types and Seed Pots

Drone Technology
orientation targets

Drones use volume targets for registering TLS (Terrestrial Laser Scanning) and UAV (Unmanned Areal Vehicle) point clouds.

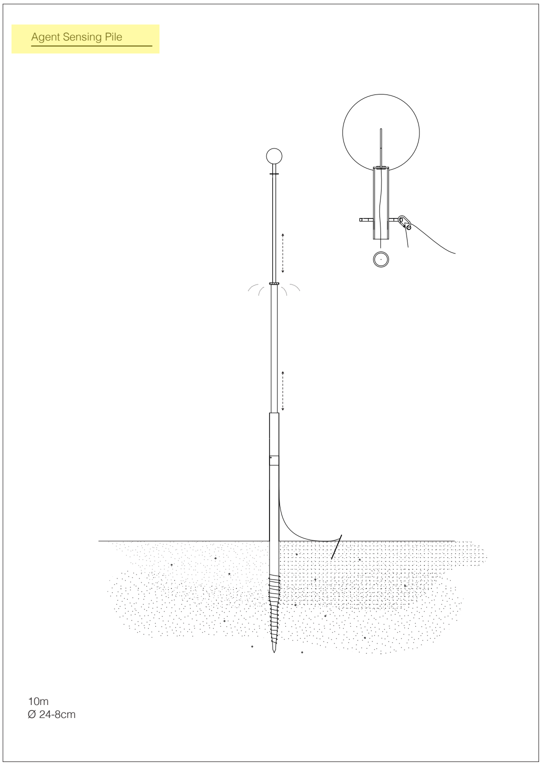


// 24 Automatic Detection of Planted Trees and Their Heights Using Photogrammetric Rpa Point Clouds

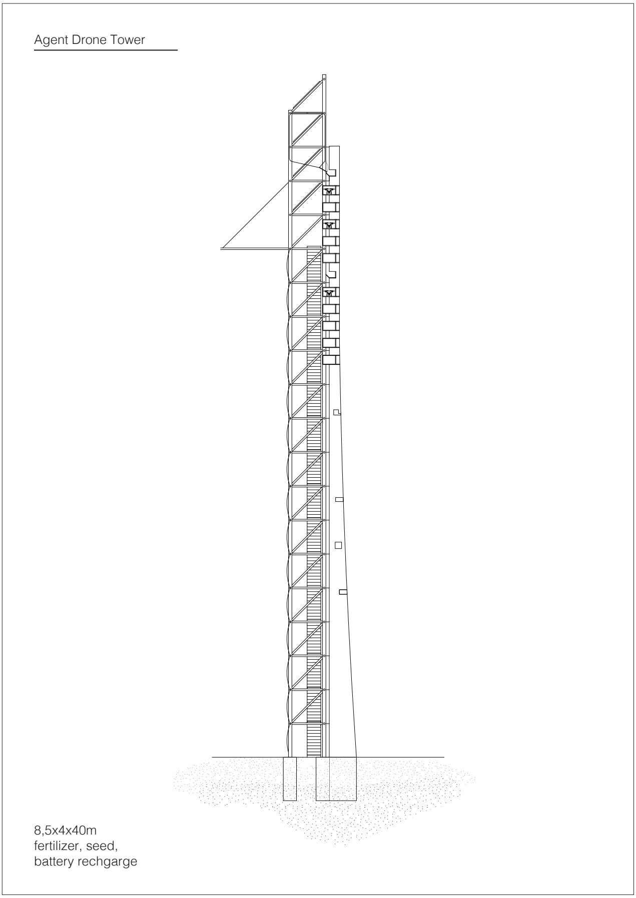


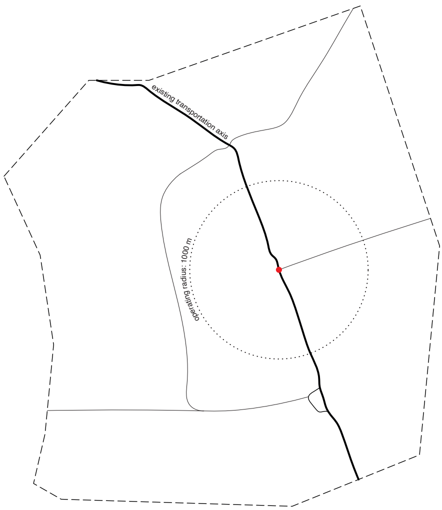
// 25 Static laser scanner with reference spheres.

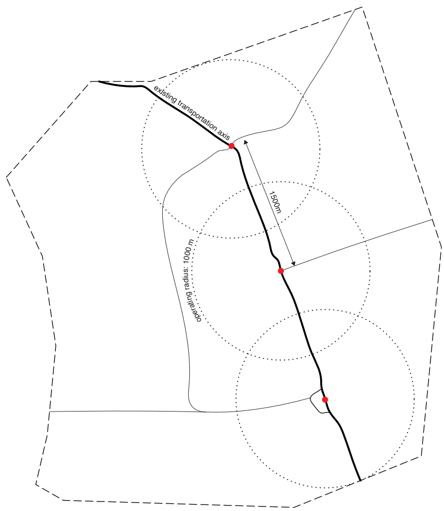
// 26 Reference Sphere
© Geosurvey



Drone Technology
drone tower

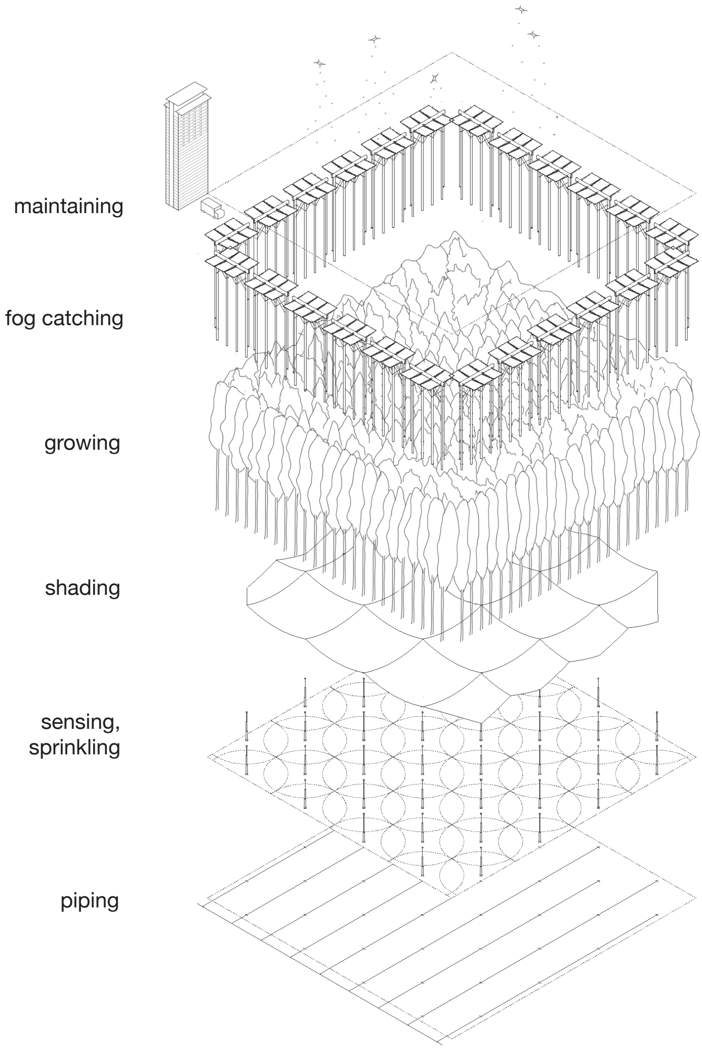


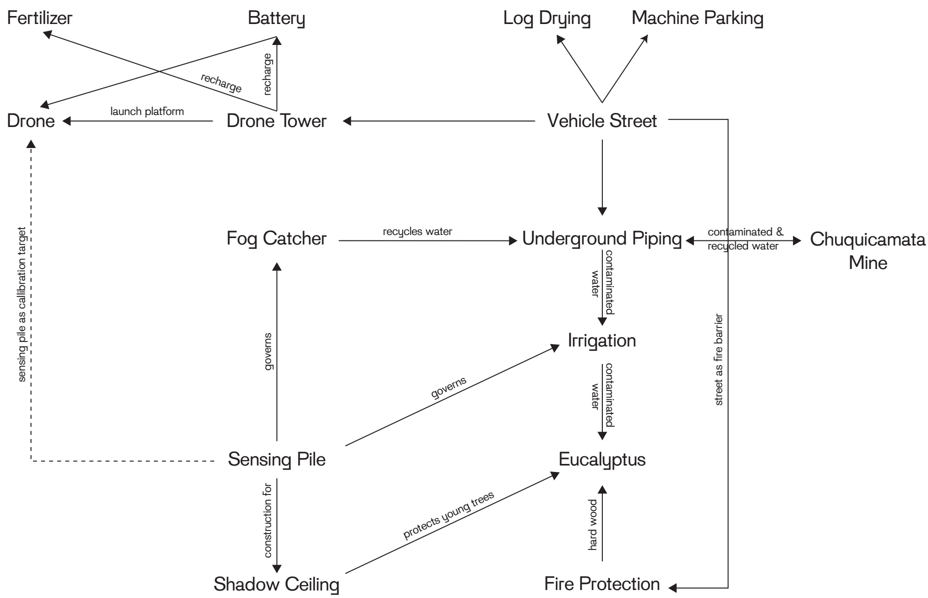




Each tower holds 50 drones.
The drone towers are situated along the main axis of transport to allow the accessibility for the charging with new seeds and fertilization, and are distributed at distances according to the radius of operability of the drones.

The Toxic Forest
system diagrams




Fertilizer
Battery
Log Drying
Machine Parking
recharge
recharge
Drone
launch platform
Drone Tower
Vehicle Street
sensing pile as calibration target
Fog Catcher
recycles water
Underground Piping
contaminated & recycled water
Chuquicamata Mine
contaminated water
Irrigation
governs
governs
contaminated water
street as fire barrier
Sensing Pile
Eucalyptus
construction for
protects young trees
hard wood
Shadow Ceiling
Fire Protection

The Toxic Forest
footnotes

(1) Corporacion Alta Ley, “Corporacion Alta Ley - Technological Roadmap 2015-2035,” 2019, https://corporacionaltaley.cl/roadmap/, pp. 90

(2) ibid.

(3) Acosta, Ignacio. “The Copper Geographies of Chile and Britain: A Photographic Study of Mining,” 2016, pp.147

(4) “Grass Is Greener: Why Bamboo Trumps Useful Eucalyptus,” Afribam, 2012, https://www.afribam.com/index.php?option=com_content&view=article&id=33%3Agrass-is-greener-why-bamboo-trumps-useful-eucalyptus&catid=14&Itemid=105.

(5) Rainer Tump, “Raubbau Mit Gütesiegel,” Afrika Süd, accessed June 9, 2022, https://www.afrika-sued.org/ausgaben/heft-4-2012/raubbau-mit-guetesiegel/.

(6) Orwa et al., “Eucalyptus Camaldulensis,” 200AD, pp. 1-5, http://apps.worldagroforestry.org/treedb/AFTPDFS/Eucalyptus_camaldulensis.PDF.

(7) “Eucalyptus Globulus Dry Forest and Woodland: Coastal Facies (Woodland),” Tasveg, 2016, https://nre.tas.gov.au/Documents/DGL_coast_woodl_R3V2.pdf.

(8) Ham Keillor-Faulkner, “How Do Large Trees, Such as Redwoods, Get Water from Their Roots to the Leaves?,” Scientific American, February 8, 1999, https://www.scientificamerican.com/article/how-do-large-trees-such-a/.

(9) David L. Chandler, “How to Get Fresh Water Out of Thin Air,” MIT News | Massachusetts Institute of Technology, 2013, https://news.mit.edu/2013/how-to-get-fresh-water-out-of-thin-air-0830.

(10) Grant, “What Wood Burns the Longest?,” The Firewood Company, March 25, 2021, https://tfwc.co.za/resources/what-wood-burns-the-longest/.

(11) Susanne Kaulfuss, “Waldbauliche Maßnahmen Zur Waldbrandvorbeugung,” Wald, Forstpraxis, Waldwirtschaft, June 9, 2022, https://www.waldwissen.net/de/waldwirtschaft/schadensmanagement/waldbrand/waldbauliche-waldbrandvorbeugung#c87392.

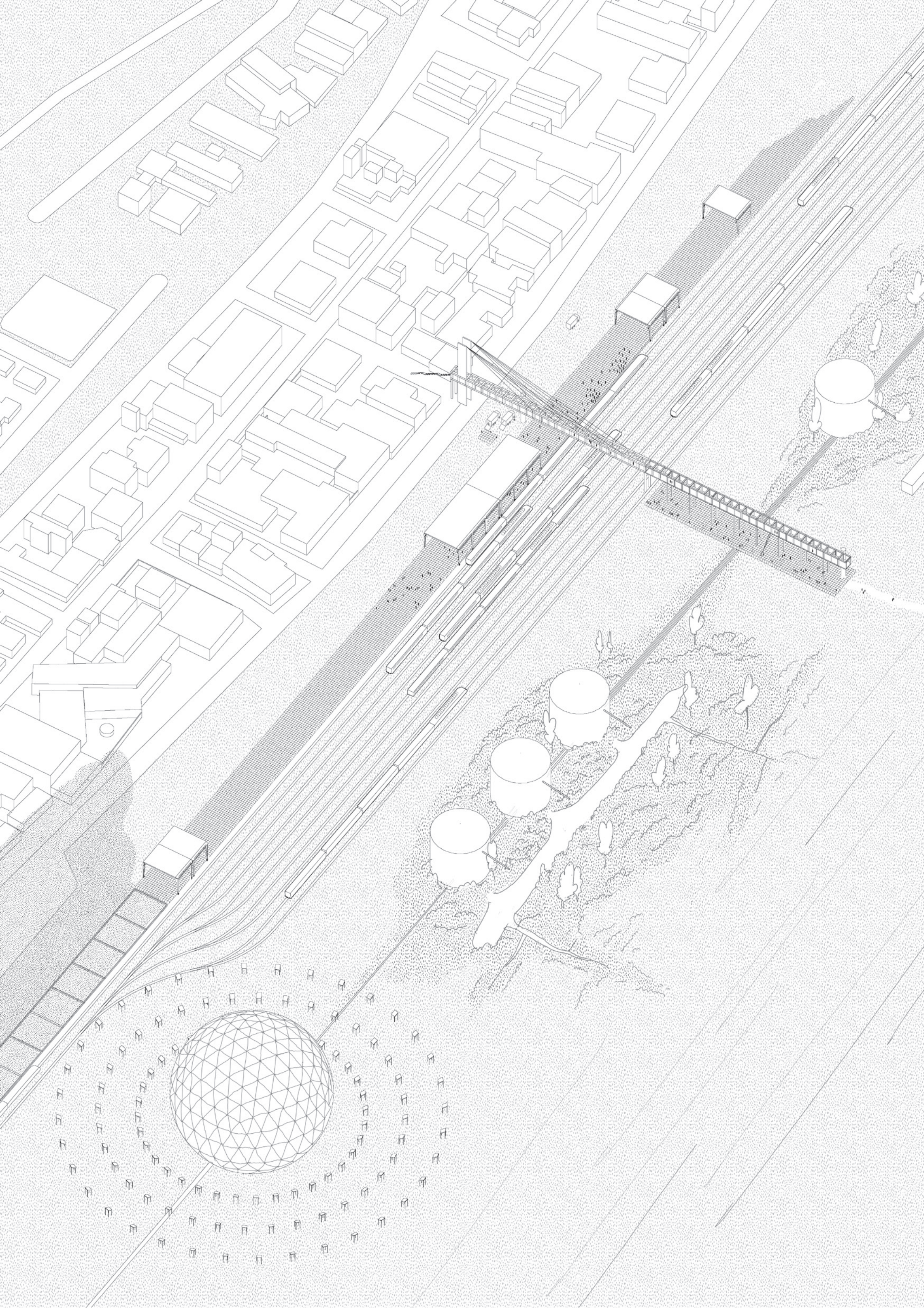
Baquedano Oasis

Baquedano Oasis
overview

Problem
// enormous water consumption by the mining industry

Design of a Desalination Station
// finds an ecological way of turning seawater into potable water
// creates economic incentives for a new water industry.

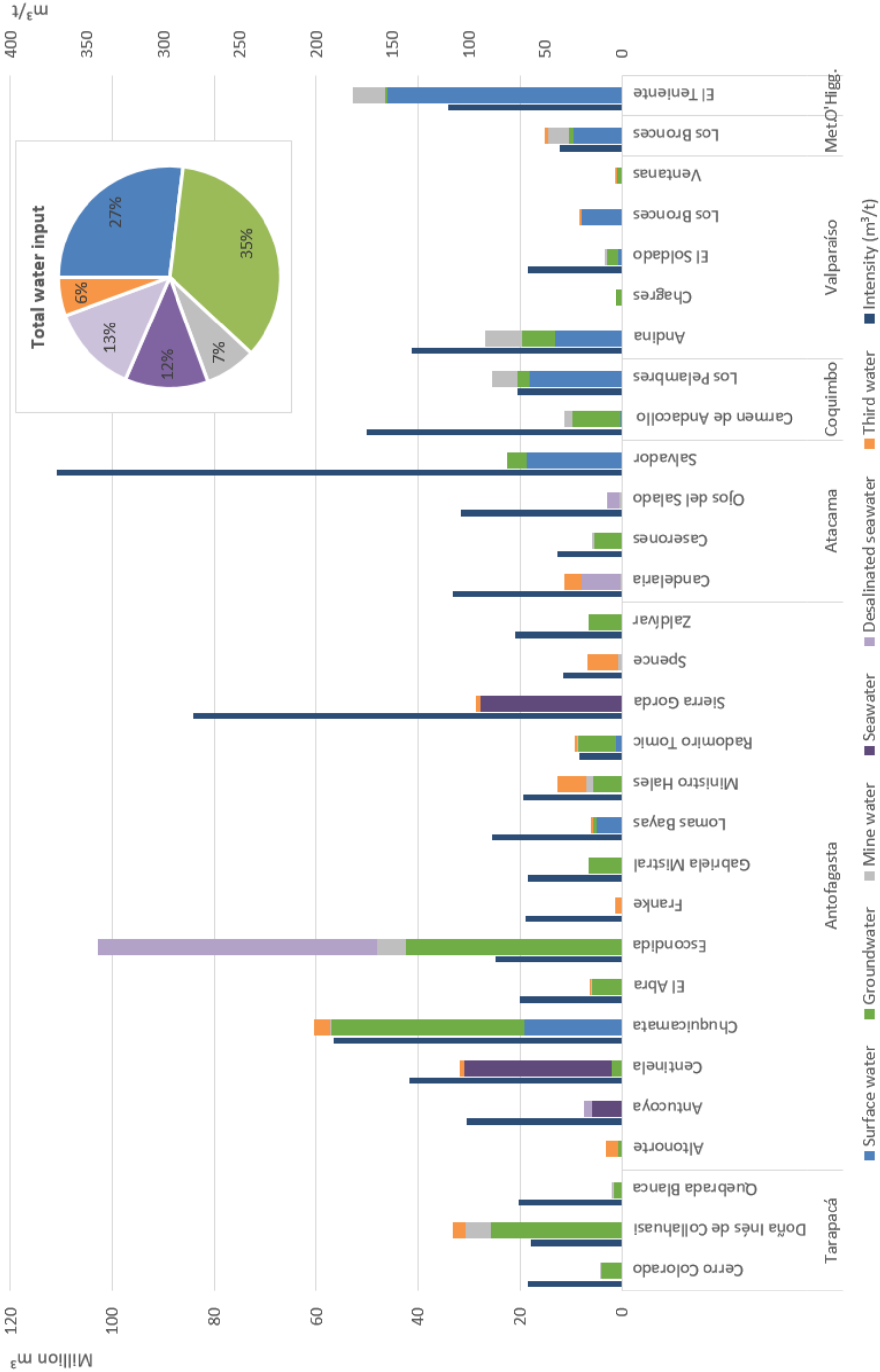
By designing a “platform“ for the actual bi-product of Desalination, Brine, the product water gets favorabale production opportunities. The resulting dependency between product and bi-product is reversed and allows the project to speculate about a future in which water as “waste“ unfolds its powers in the middle of the Atacama desert.



The Problem
water consumption in mining industry

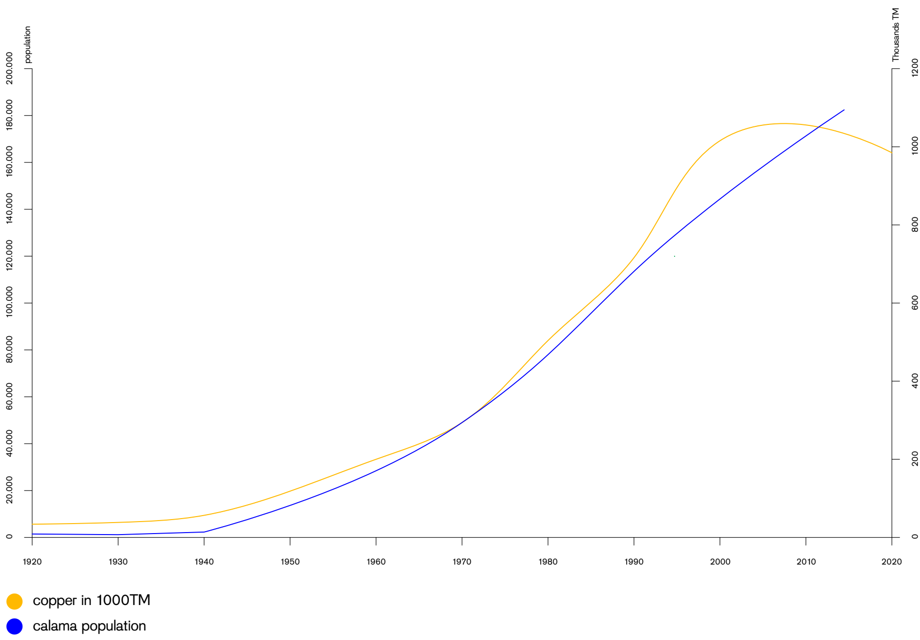
“Mining companies in Chile, the world’s leading copper producer, face an increasingly expensive struggle to find water as they seek to increase production to satisfy soaring global demand.
[...]
Chile‘s two biggest copper mines -- state-owned Codelco‘s Chuquicamata and BHP Billiton‘s BHP.AHBLT.L Escondida -- are in the Atacama desert, the world‘s driest, in northern Chile, where nearly 80 percent of Chile‘s copper is mined.
[...]
Mining companies are voracious water consumers, accounting for about 70 percent of water consumption in northern Chile, and devouring up to 500 gallons (2 cubic meters) a second to wash ore and for other operations during a mine’s life of up to 30 years.
[...]
‘Access to water supplies is one of the highest priorities for the Chilean mining industry,‘ Mining Minister Karen Poniachik told Reuters during the the 6th annual World Copper Conference, also known as CESCO International Copper Week. ‘It’s especially worrisome in northern Chile.‘
[...]
Codelco President Jose Pablo Arellano said, ‘There’s growing pressure on water resources.‘“ (1)

The Problem
chuquicamata water consumption



// 1 Water abstraction by water source and water intensity, in the 31 copper mines in Chile 2018. Graphic adapted from Stephan Lutter and Stefan Giljum.

Dependency on Chuquicamata copper extraction and population growth



// 2 Population Growth of Calama and
Increasing Extraction of Chuquicamata Mine

Chuquicamata Mine

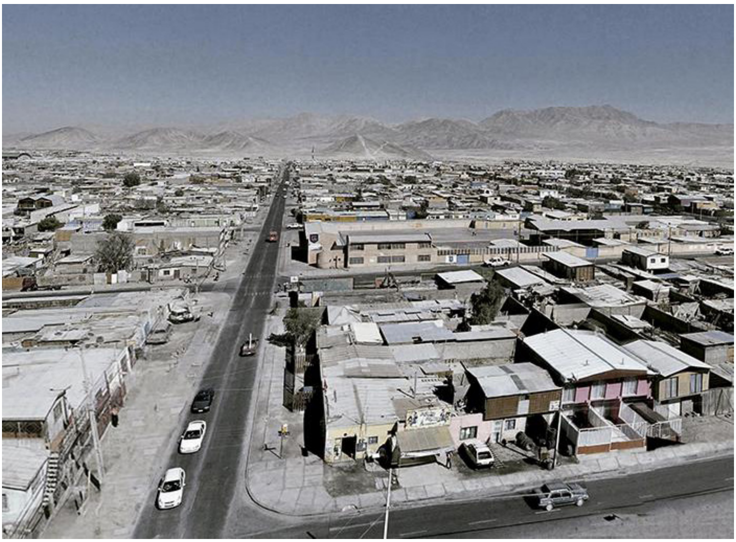
Calama

Calama Oasis

// 3 Collaged Satellite Image Showing the Neighboring Dependencies

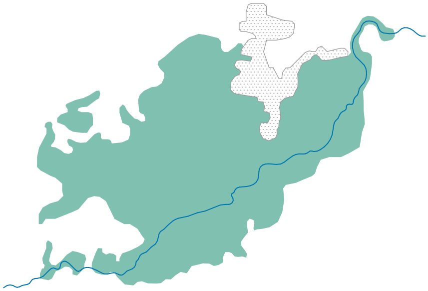
Dependency on Calama
growth and depletion of calama oasis

// 4 Aerial view of Calama Oasis in 1966.

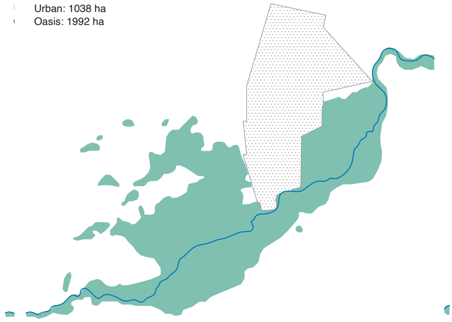


// 5 Aerial view Calama in 2021

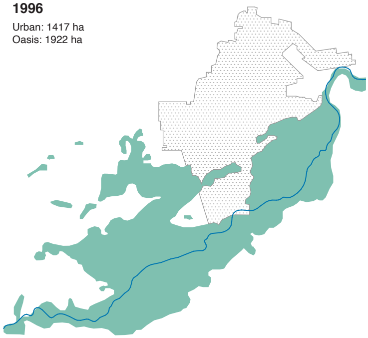
1961
Urban: 396 ha
Oasis: 3561 ha



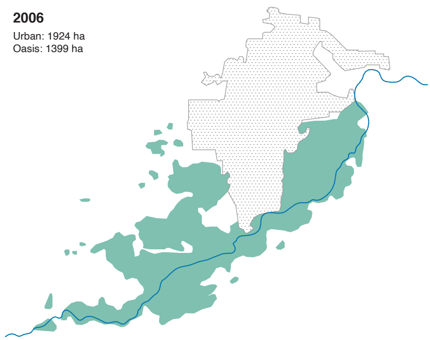
1986
Urban: 1038 ha
Oasis: 1992 ha



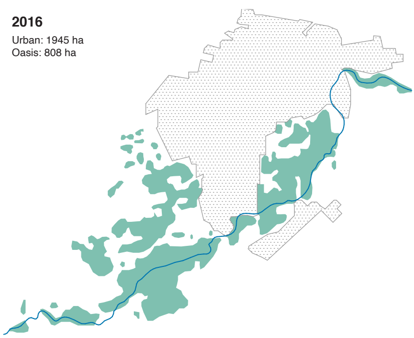
1996
Urban: 1417 ha
Oasis: 1922 ha



2006
Urban: 1924 ha
Oasis: 1399 ha

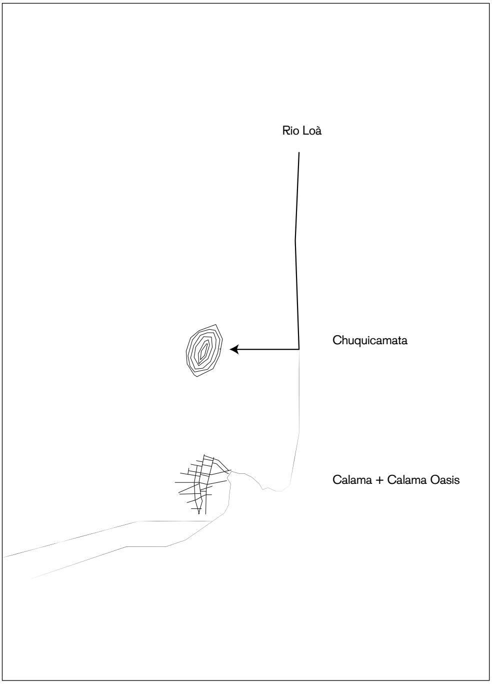


2016
Urban: 1945 ha
Oasis: 808 ha

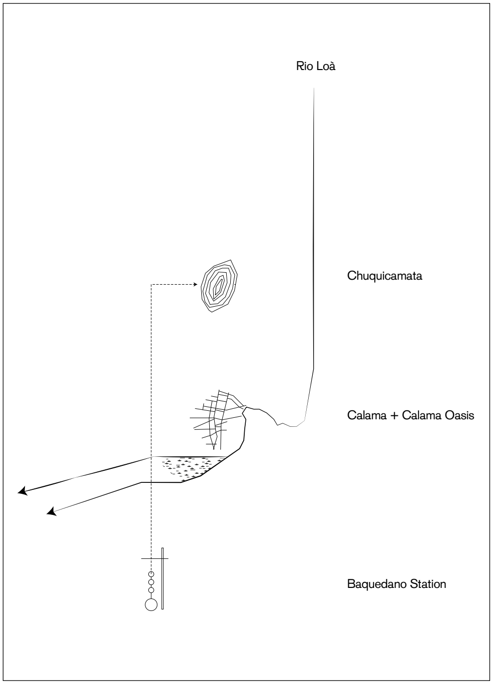


// 6 Decrease in Size of Calama Oasis and Growth of Calama Over the Years

Proposal for a new water dependency

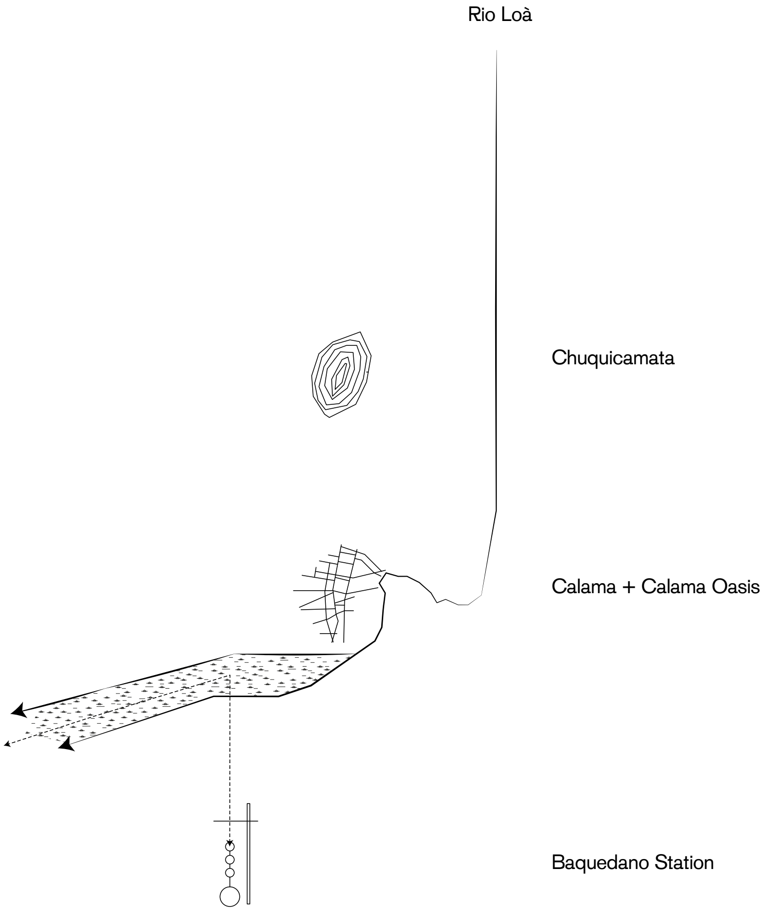


// A. Water Dependency Today

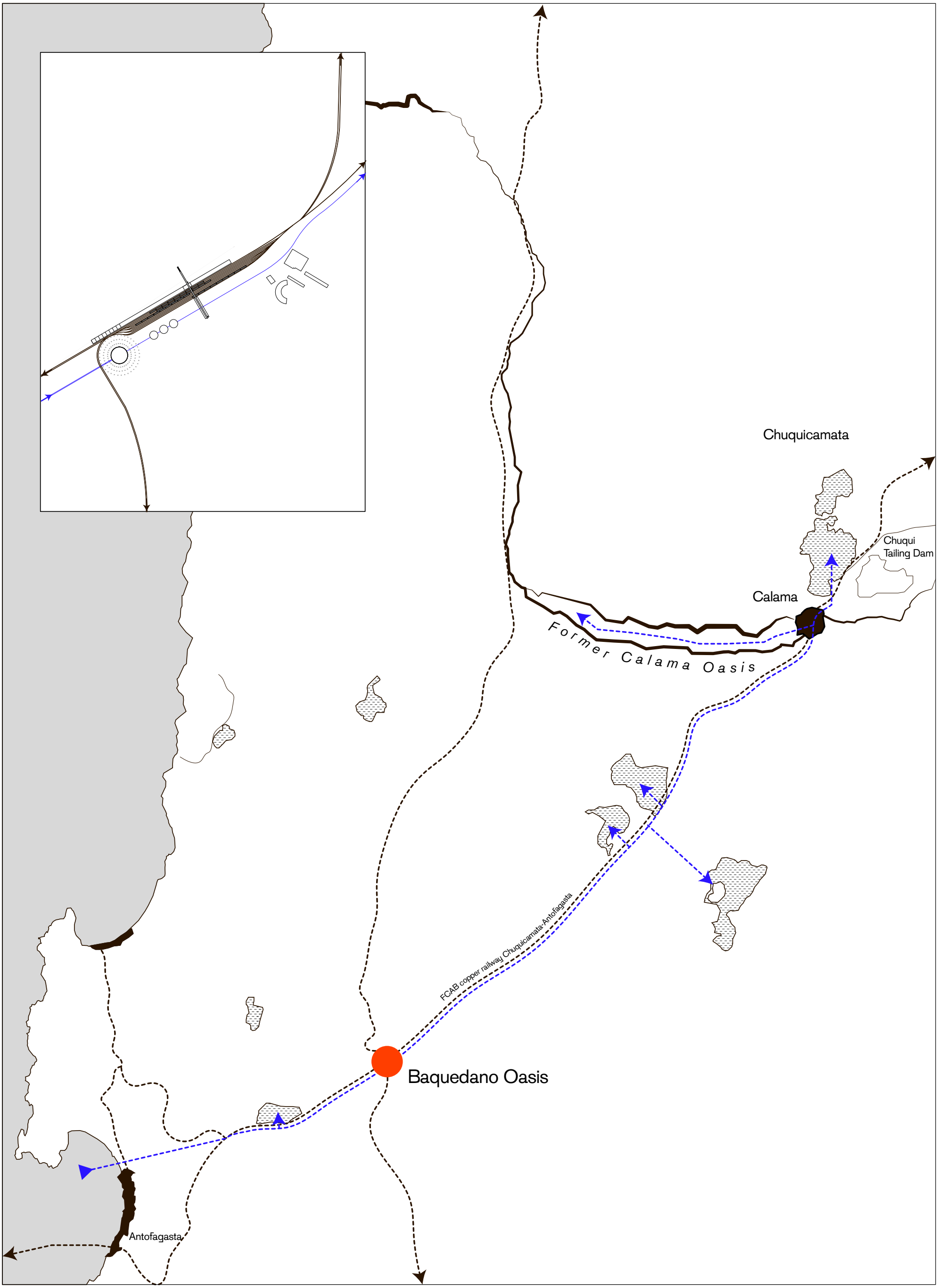


// B. Intervention changes water dependencies in transition to complete depletion of mine 2060.

Water Dependencies of Chuquicamata Mine, Calama and Calama Oasis A) With the enormous water consumption of Chuquicamta Mine (20mio. m3/a) of the River (Rio Loà), Calama Oasis dried out over the last couple of years. B) With the implementation of Baquedano Station, desalinated water is guided to the mine. The river returns to its old strength and allows the oasis to rehabilitate. C) After complete depletion of the mine water is abundantly available. The oasis can continue to grow, allowing numerous economic and life-sustaining opportunities. This will not only preserve the oasis, but also Calama, which sto strongly economic dependent on the mine itself.

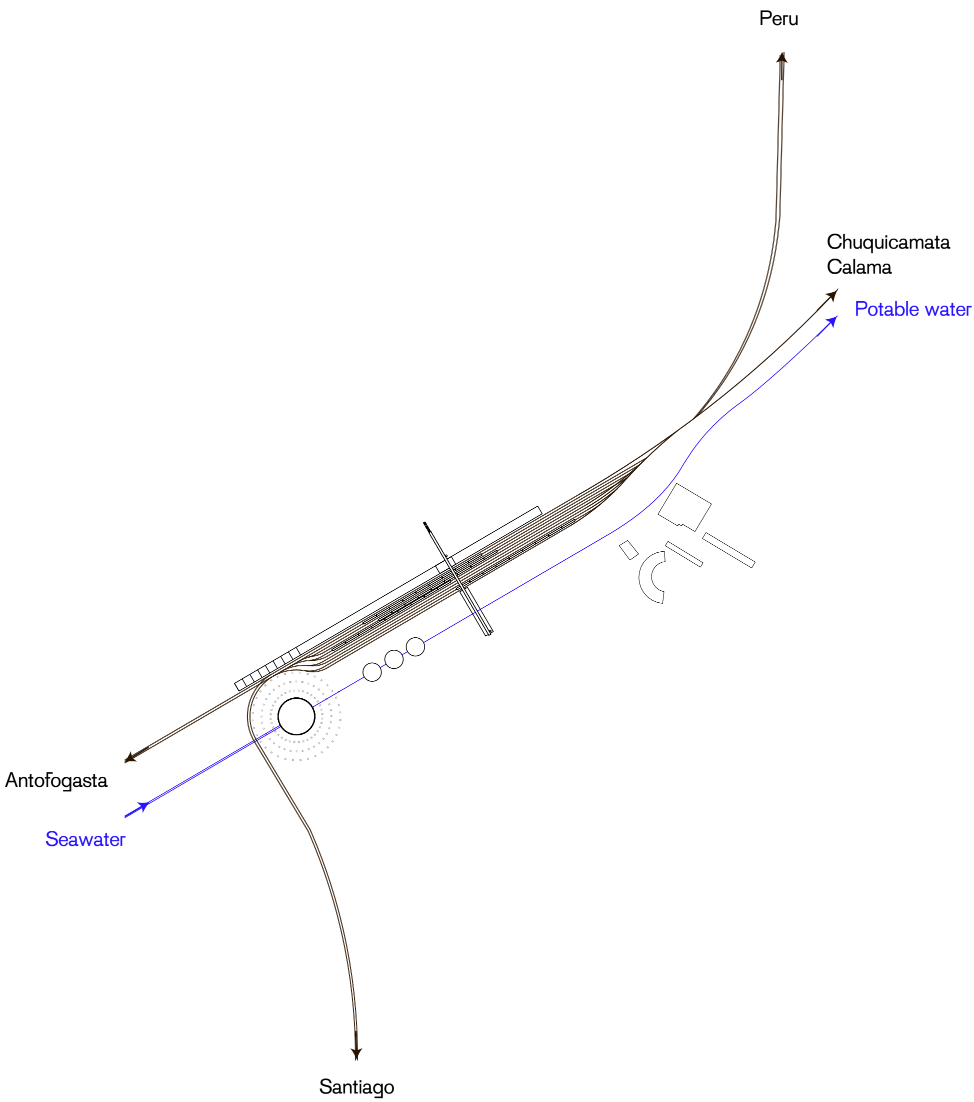


// C. Water Abundancy After Complete Depletion of Chuquicamata (2060+).



Location   Rail distribution brine   Water distribution

// Intervention on Territorial Scale: Water and Rail Distribution



// Intervention on Site: Water and Rail Distribution

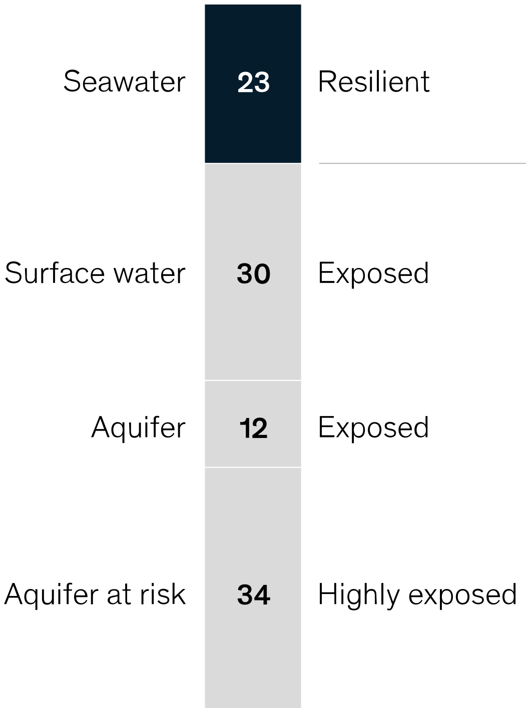
Desalination

Seawater desalination is the extraction of water from seawater (salt water) by reducing its salinity. Desalination can be based on various processes that remove salts and minerals from the water. One of its biggest challenges is the treatment of brine. For every liter of fresh water 1.5 l of brine is been leftover. (2)

// 7 Seawater Desalination Products

Desalination the need for desalination in the atacama desert

In extremely dry northern Chile, home to the country‘s mining industry, most of the water supply needed for mining operations is exposed to climate risks. Seawater seems to be the only reliable source.



76 %

of water used in mining operations is exposed to climate risks

// 8 Water Exposed to Climate Risks

Brine
environmental impact

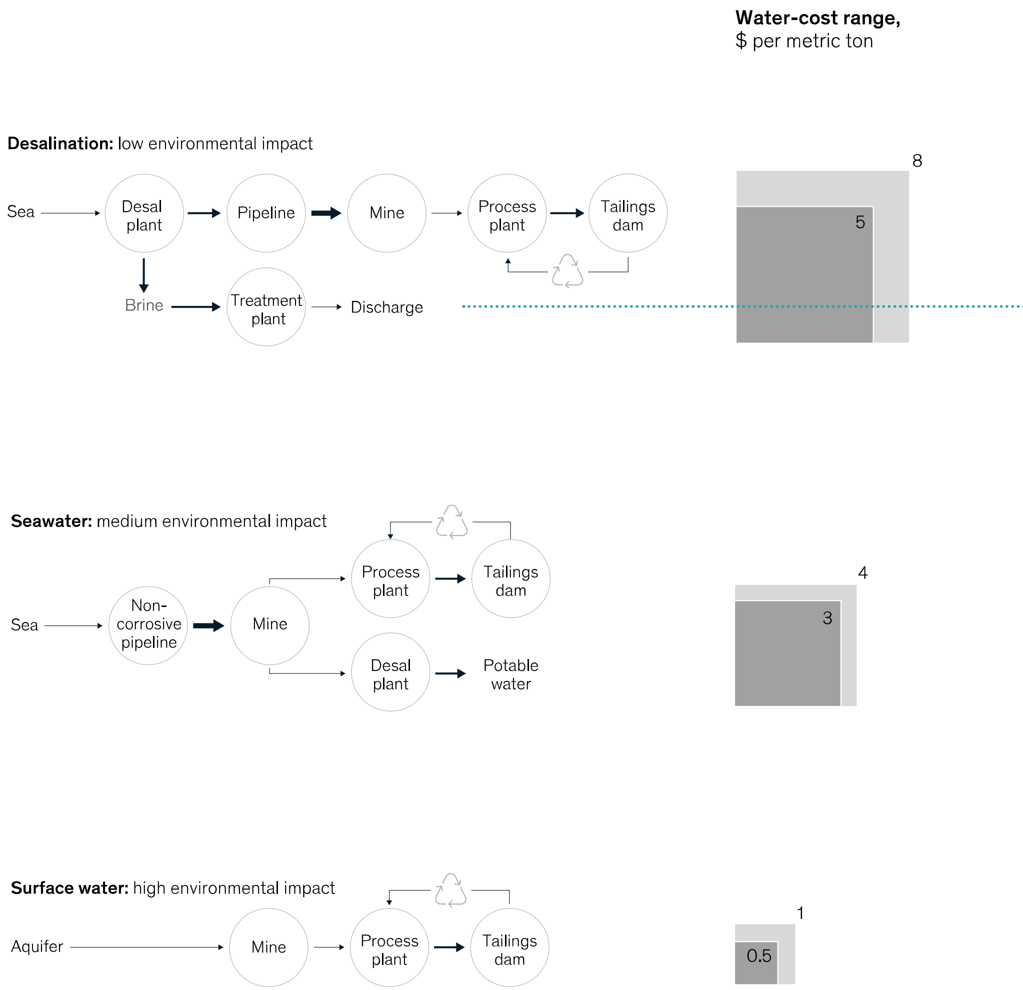
what if the by-product brine was not pumped back into the sea but implemented elsewhere?

“About 97% of the world’s water is saline and just 1% is fresh. As this fresh water comes under increasing pressure from climate change and population growth, more countries are building desalination plants to make salt water drinkable, and to supply industry and agriculture. A recent paper by researchers at three universities, including the UN University Institute for Water, Environment and Health (UNU-INWEH), paints a worrying picture of the environmental impact of the chemical-laden brine that results from this process.“

“For every litre of fresh water output, the researchers say, desalination plants produce on average 1.5 litres of brine. Though the exact amount varies according to the salinity of the feed water, the desalination method and local conditions, the researchers estimate that globally, plants now discharge 142 million cubic metres of brine a day – a 50% increase on previous assessments.“

“Since almost 80% of brine from desalination is produced within 10km of the coast, it is typically discharged directly into oceans or emitted into surface water, sewers, or wells, according to the paper. The brine poses major risks to ocean life and marine ecosystems by greatly raising the salinity of the seawater it flows into, and by polluting oceans with toxic chemicals used as anti-scalants and anti-foulants, including copper and chlorine. ‚Brine underflows deplete dissolved oxygen in the receiving waters,‘ says lead author Edward Jones, from Wageningen University in the Netherlands. ‘High salinity and reduced dissolved oxygen levels can have profound impacts on benthic organisms (such as worms, clams, crabs, lobsters and sponges that live in the seabed), which can translate into ecological effects throughout the food chain.‘“

“Brine needs to be better managed to deal with a dramatic rise in the number of desalination plants worldwide, the researchers said. Starting from a few, mostly Middle Eastern facilities in the 1960s, today nearly 16,000 desalination plants are operational in 177 countries.“ (3)

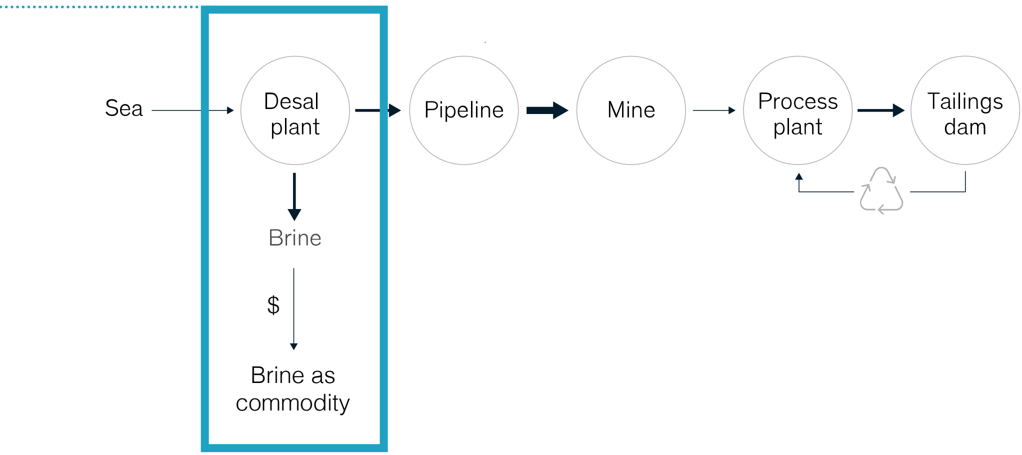


// 9 Water Sources and Their Environmental Impact

According to a study conducted by McKinsey in 2021 desalination is still the environmentally friendliest solution for the mining industry but also the most cost-intensive.

What would be the price for water if the ecologic problematic byproduct brine was turned into a profitable commodity?

Desalination: low environmental impact



// 10 Brine as Economic Potential in Desalination Process

Brine
byproduct as economic opportunity

„Only a marginal volume of brine is currently being used directly in specific applications, such as microalgae biotechnology (ITC, 2020). [...]
During this past decade, political statements, the industry sector and social actors have all introduced the notion of Circular economy as a vital concept for our society. The desalination industry is particularly focused on the potential of brine, due to its chemical composition. Contrary to popular belief, seawater is much more than just water and sodium chloride. In fact, in absolute terms, certain elements can be found in higher volumes in the ocean rather than mineral reserves on land; such as magnesium (Loganathan, Naidu & Vigneswaran, 2017), which was classified as one of the Critical raw materials by the European Commission on 2017; as a result of both its importance for the economy of Europe and its import dependence. Lithium is another clear example (Yang, Zhang, Ding, He & Zhou, 2018), which demand has increased radically during the past years, because of its use in Li-ion batteries.“ (4)

“Multiple minerals and metals can be extracted from brine. In addition to the ones mentioned in the previous paragraph, calcium carbonates and sulphates used in the construction industry can be obtained by chemical precipitation (Ramasamy, 2019). Acids and bases, such as hydrochloric acid and sodium hydroxide, can also be produced from brine by electrochemical technologies like bipolar membrane electro dialysis (Kumar, Phillips, Thiel, Schöder & Lienhard V, 2019). Similarly, another valuable product, sodium hypochlorite, has also been obtained through an electrochemical process (Malvi Technologies LLC, 2017). Furthermore, less expected elements like uranium (Wiechert et al., 2018), cesium and rubidium (Chen et al., 2020) could also be extracted from the brine by adsorption and ion exchange processes.“ (5)

chloride (18 980 ppm)
sodium (10 561 ppm)
magnesium (1 272 ppm)
sulphur (884 ppm)
calcium (400 ppm)
potassium (380 ppm)
bromine (65 ppm)
inorganic carbon (28 ppm)
strontium (13 ppm)
boron (4.6 ppm)
silicon (4 ppm)
organic carbon (3 ppm)
aluminium (1.9 ppm)
fluorine (1.4 ppm)
nitrogen in the form of nitrate (0.7 ppm)
organic nitrogen (0.2 ppm)
rubidium (0.2 ppm)
lithium (0.1 ppm)
phosphorous in the form of phosphate (0.1 ppm)
copper (0.09 ppm)
barium (0.05 ppm)
iodine (also 0.05 ppm)
nitrogen in the form of nitrite (also 0.05 ppm)
and nitrogen in the form of ammonia (0.05 ppm)
arsenic (0.024 ppm)
iron (0.02 ppm)
organic phosphorous (0.016 ppm)
zinc (0.014 ppm)
manganese (0.01 ppm)
lead (0.005 ppm)
selenium (0.004 ppm)
tin (0.003 ppm)
caesium (0.002 ppm)
molybdenum (0.002 ppm)
uranium (0.0016 ppm)
gallium (0.0005 ppm)
nickel (also 0.0005 ppm),
thorium (0.0005 ppm)

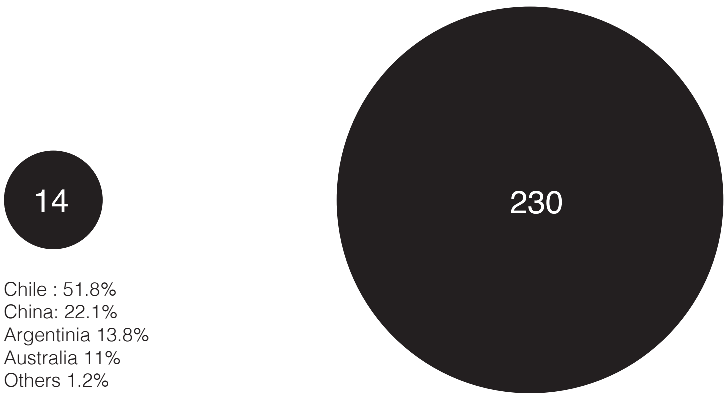
cerium (0.0004 ppm)
vanadium (0.0003 ppm)
lanthanum (also 0.0003 ppm)
yttrium (also 0.0003 ppm)
mercury (once more 0.0003 ppm)
silver (also 0.0003 ppm)
bismuth (0.0002 ppm)
cobalt (0.0001 ppm)
gold (0.000008 ppm).

“Altogether, there are some 50 quadrillion tons (that is, 50 000 000 000 000 000 t) of minerals and metals dissolved in all the world’s seas and oceans. To take just uranium, it is estimated that the world’s oceans contain 4.5-billion tons of the energy metal.“ (6)

The list of products that can be sourced from these minerals is even longer. The most important are

Salt
Potassium Chloride as fertilizer
Magnesium Chloride as fertilizer
Calcium in building construction, for example as alloy
Salt pannels for construction
Salt Batteries
Lithium Batteries
Industrial cleanser
Caddle salt block
...

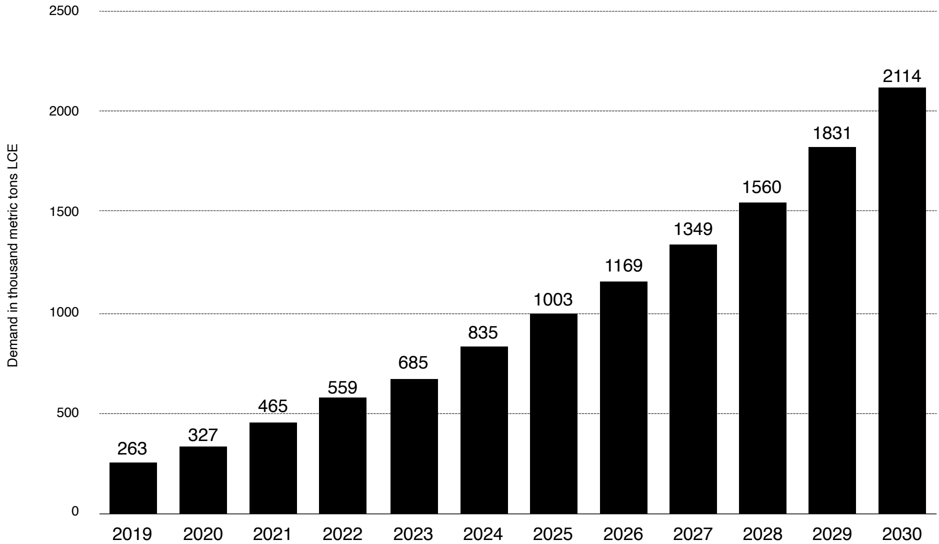
Brine
byproduct as economic opportunity - lithium



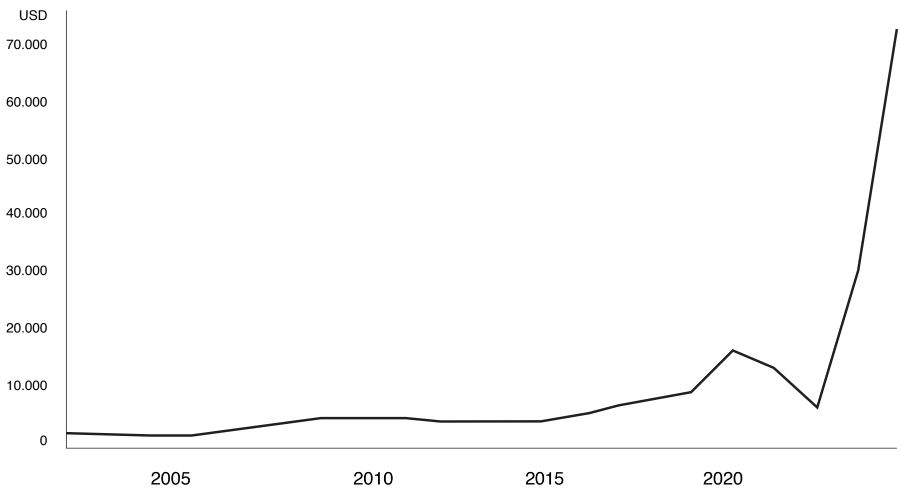
// 11 Amount of Lithium on Land and in Ocean in Million Tons

The oceans contain about 5,000 times more lithium than the land but at extremely low concentrations of about 0.2 parts per million (ppm). (7)

“Essentially, out of one well in a week, from about 4,300 gallons (16275l) of produced water, you could get enough lithium to make batteries for, like, 1.6 million iPhones or 200 Tesla Model Ss.“ (8)



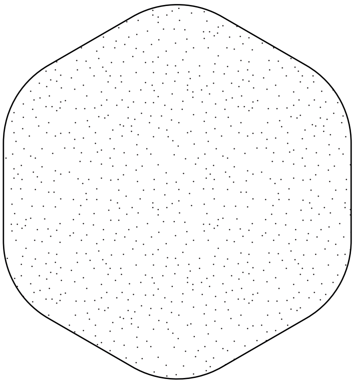
// 12 Brine as Economic Potential in Desalination Process



// 13 Lithium Price Forecast until 2030

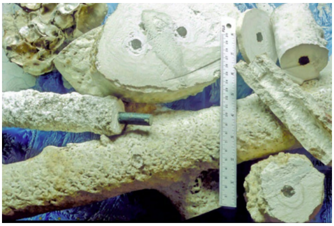
Brine

byproduct as economic opportunity - construction material



Property	Value/ Form
Salt cristallisation	cubic shape
Bulk density	2.165 g/cm^3 at 25°C 2.17 g/cm^3 at 20°C
Porosity	lower than 3.8%
Melting point	801°C
Specific Heat Capacity	0.853 - 1224 J/(gK)
Thermal Conductivity	6 to 6.5 W/mK
Solubility	75.3% at 20°C

// 14 Karshif salt block construction



// 15 Biorock

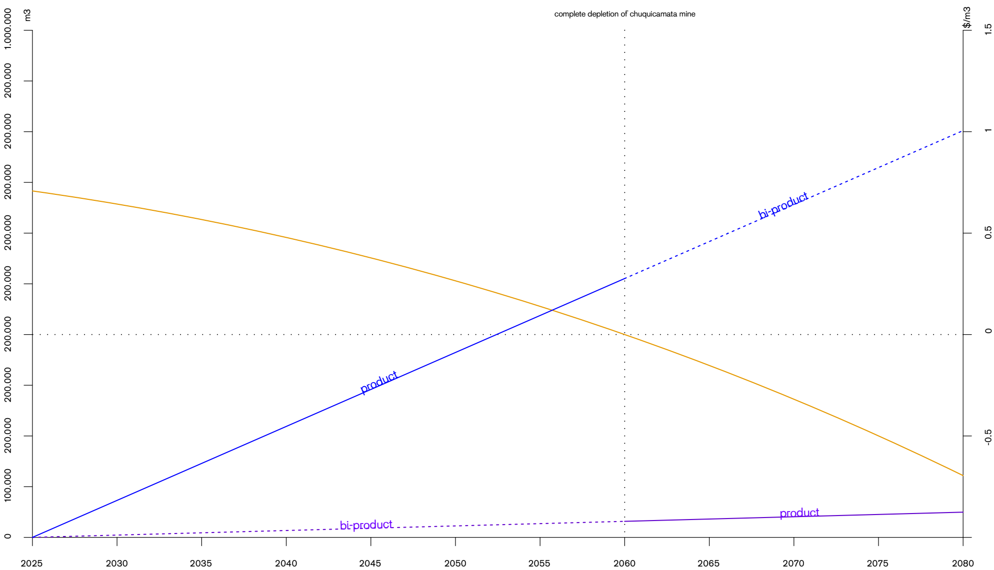
// 16 Salt block house, Bolivia, Salar Talar

// 17 Atelier Luma, Salt Tiles

// 18 Atelier Luma, Salt Tiles

Structure	Material	Advantages	Limitations
Interior wall	Karshif salt block > 75% salt	.simple technology .low cost .high fire protection	.handwork (local technique) needed .time consuming .salt stones have different shapes .available only in siwa oasis .poor mechanical properties .soluble in water
	Salt block from salt lakes > 95% salt	.high resorce efficiency. smoorth white surface. low pollutant emmisions .integration of electric cable possible	.application only possible in very dry, hot climate condi-tions > atacama . possible to connect rectangular blocks with diffrent mortar mixes
Exterior wall	Salt block from salt lakes > 95% salt	.humidity and temperature storage possible . natural white material .antibacterial	.walls have to be protected from water . walls are very thick, only small opening
	Salt concrete > 53% salt	. easy to mix and to build with no skilled craftswor . good mechanical properties . higher resistency to water than other salt materials	. no other apllication known as built in salt caves
Wall covering	Salt stucco % ?	.for interior and exterior applications	.much handwork . combination with naturalgum (rare and expensive)
Interior floor	Only salt 100% salt	. easy to refill . cheap	. hard to clean . soluable in water

A New Water Economy
from product to
byproduct



// Diagram of expected price development of water, with stable production of water and brine

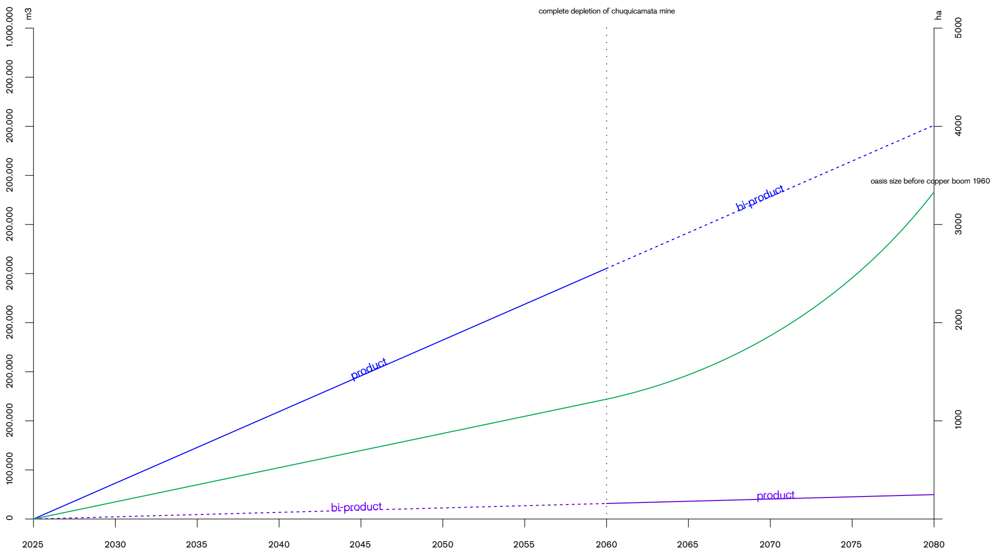
Assuming the price decreases by low production cost after constructing the main structure (only one-time investment and stable energy from sun) and increasing prices of scarce resources in brine like lithium. The production is meant to become profitable around the moment of complete depletion of chuquicamata mine, when water demand drops.

water in m3 — 40m3/day * 365 = 14600m3/a — 14600m3/a * 55a = 803000m3

brine block in m3 — 1,66m3/day * 365 = 608.33m3/a — 608.33m3/a * 55a = 33458.33m3

price $/m3 water

oasis in ha



// 20 Diagram of expected development of Calama Oasis in Ha.

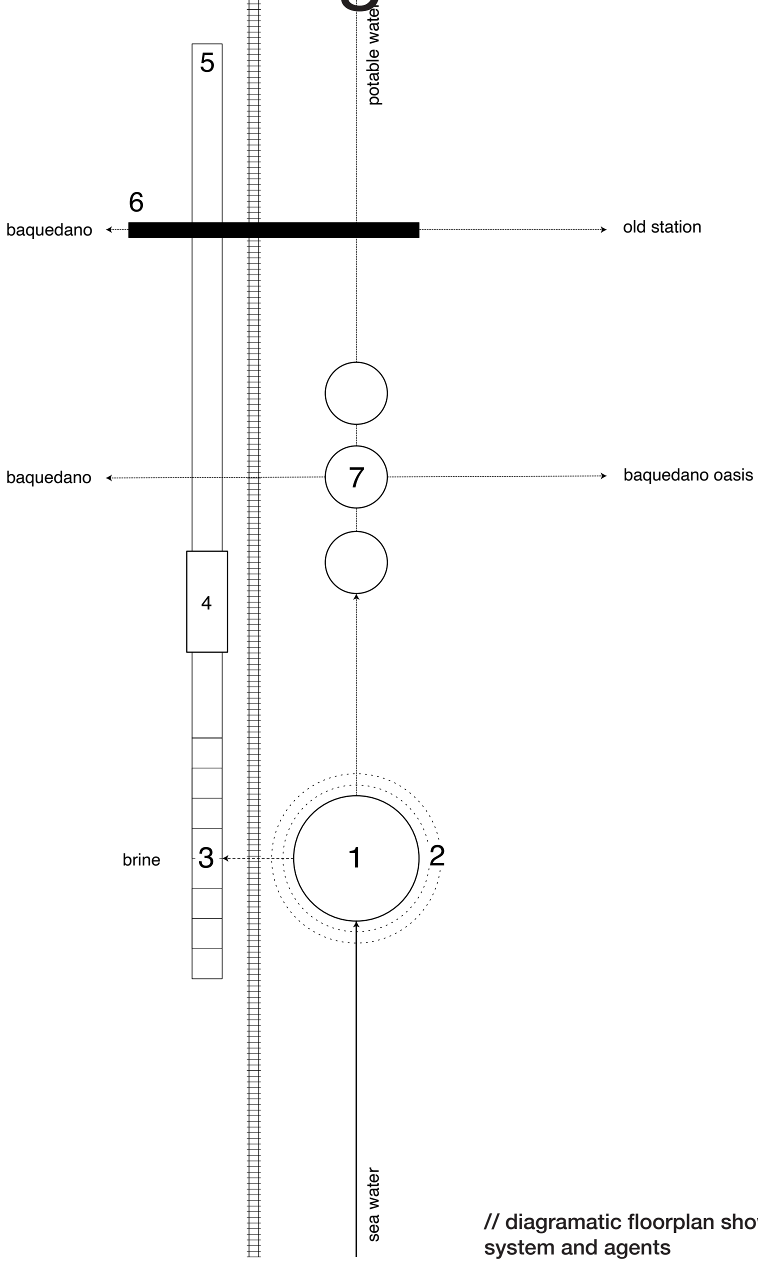
After complete depletion of chuquicamata min water is abundantly available and can serve the oasis to grow to its original size (in 1960) and eventually become even bigger.

A New Water Economy

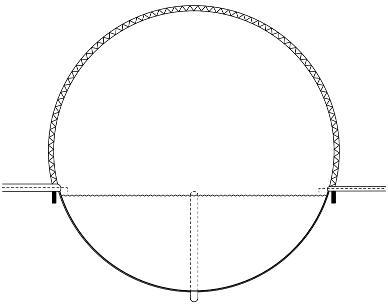
from product to by-product: growth of oasis

// 19-21 When water infrastructure meets fertile atacama soil.

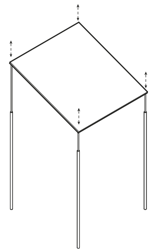
The Intervention
system and agents



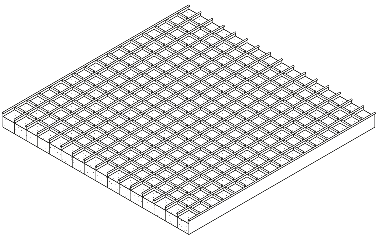
// diagramatic floorplan showing system and agents



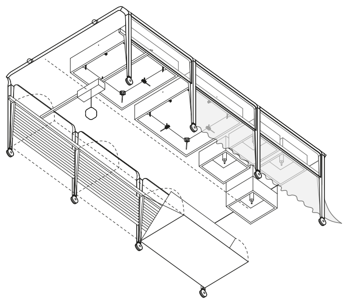
1 the evaporation dome



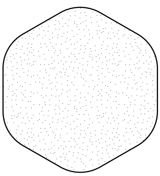
2 the heliostat



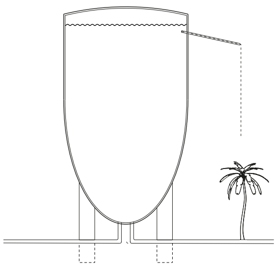
3 the evaporation pond



4 the moving factory

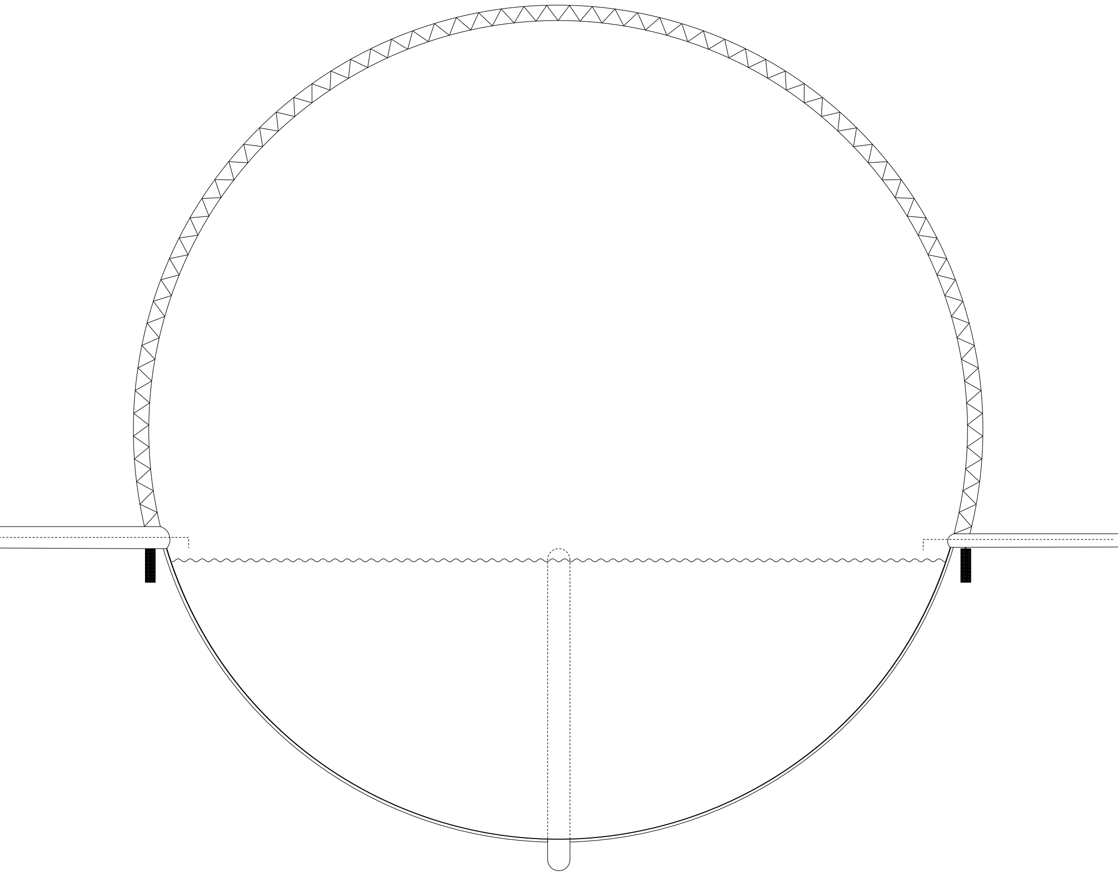


5&6 the brine block station



7 the water tank

The Intervention
agent evaporation dome

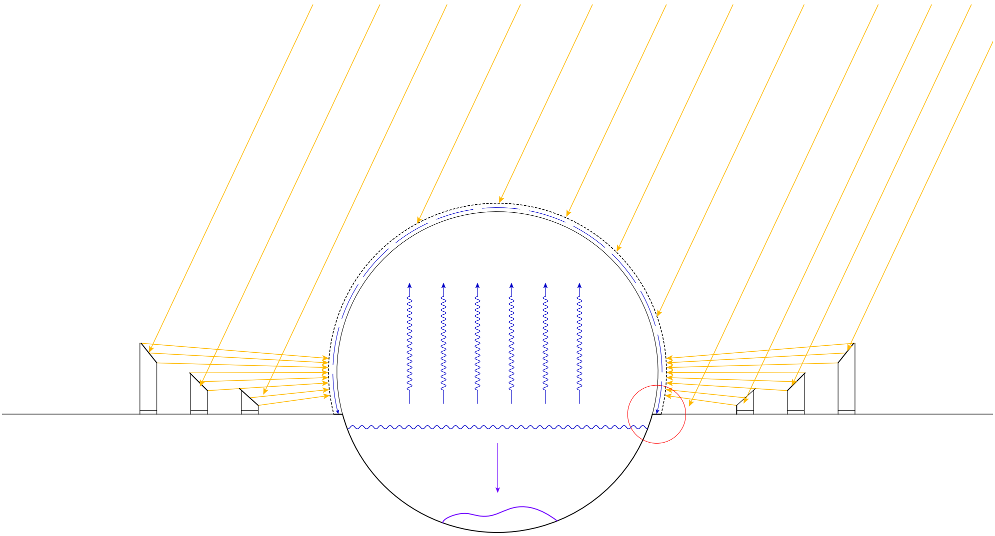


80m Diameter (max.)
80.000L - 100.000L seatwater/day
40.000L Freshwater/day
60.000L Brine/day

In practice, a single dome would meet the ongoing water needs of 8,000 people, based on World Health Organisation figures, including their needs in terms of water for agriculture and farm animals. (9)

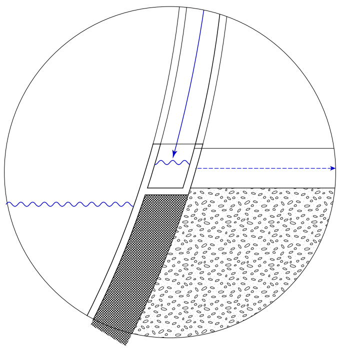
Every day 54.794m3 of water from River Rio Loa is consumed by the Chuquicamata mine. (10) To cover the whole consumption from the river, around 1000 domes are required.

The Intervention
agent evaporation dome



// Process Diagram of Heating up the Dome

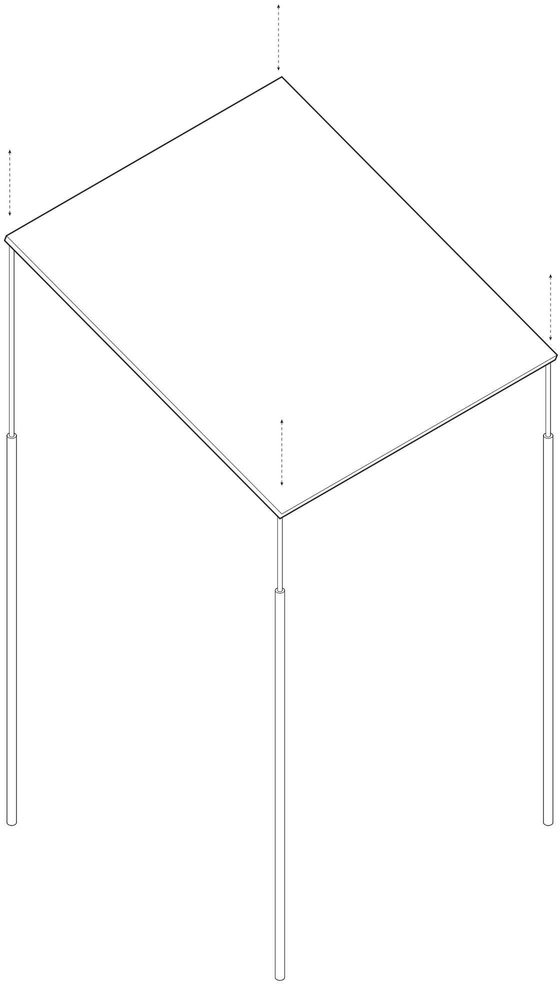
Sunlight is reflected onto the dome to heat its copper structure. Saltwater is separated from freshwater by evaporation. Due to its density, brine seeps onto the ground.



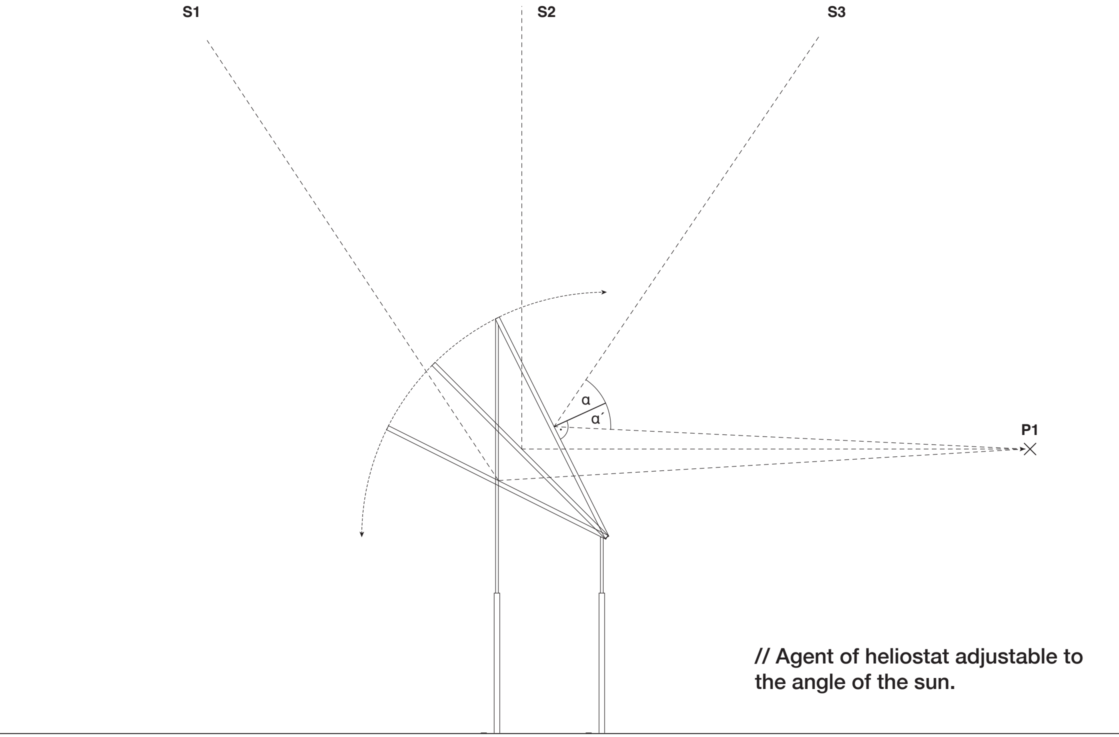
// Collection of Evaporated Water

Potable water is pumped out after it has been collected in the gutter on the inside of the dome.

The Intervention
agent heliostat



// Agent of heliostat adjustable to
the angle of the sun.



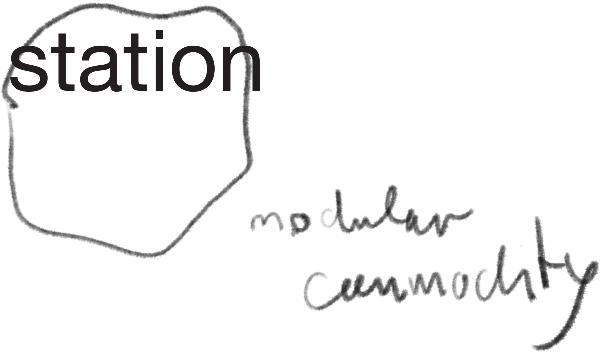
// Agent of heliostat adjustable to the angle of the sun.

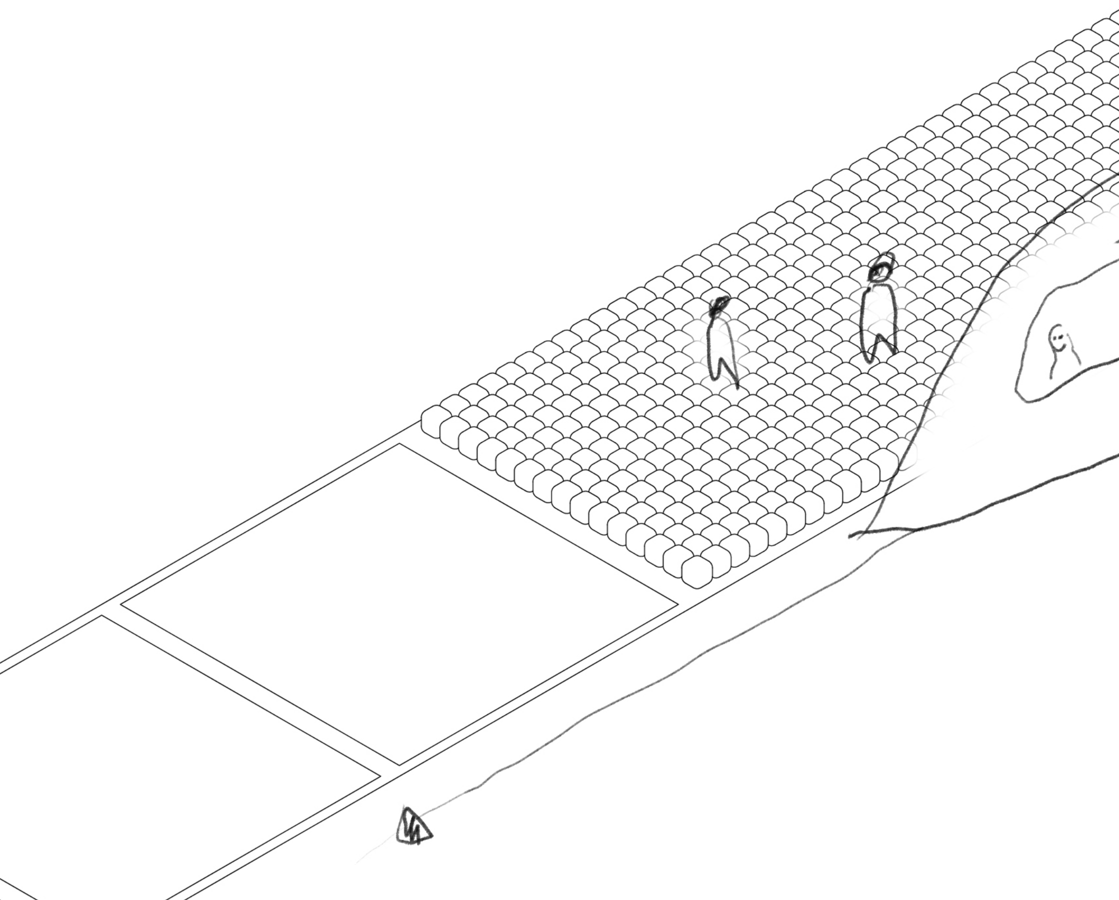
The heliostat is an apparatus with a mirror that always reflects the sunlight (S1,S2,S3) onto the same fixed point (P1), regardless of the change in the sun's position in the sky.

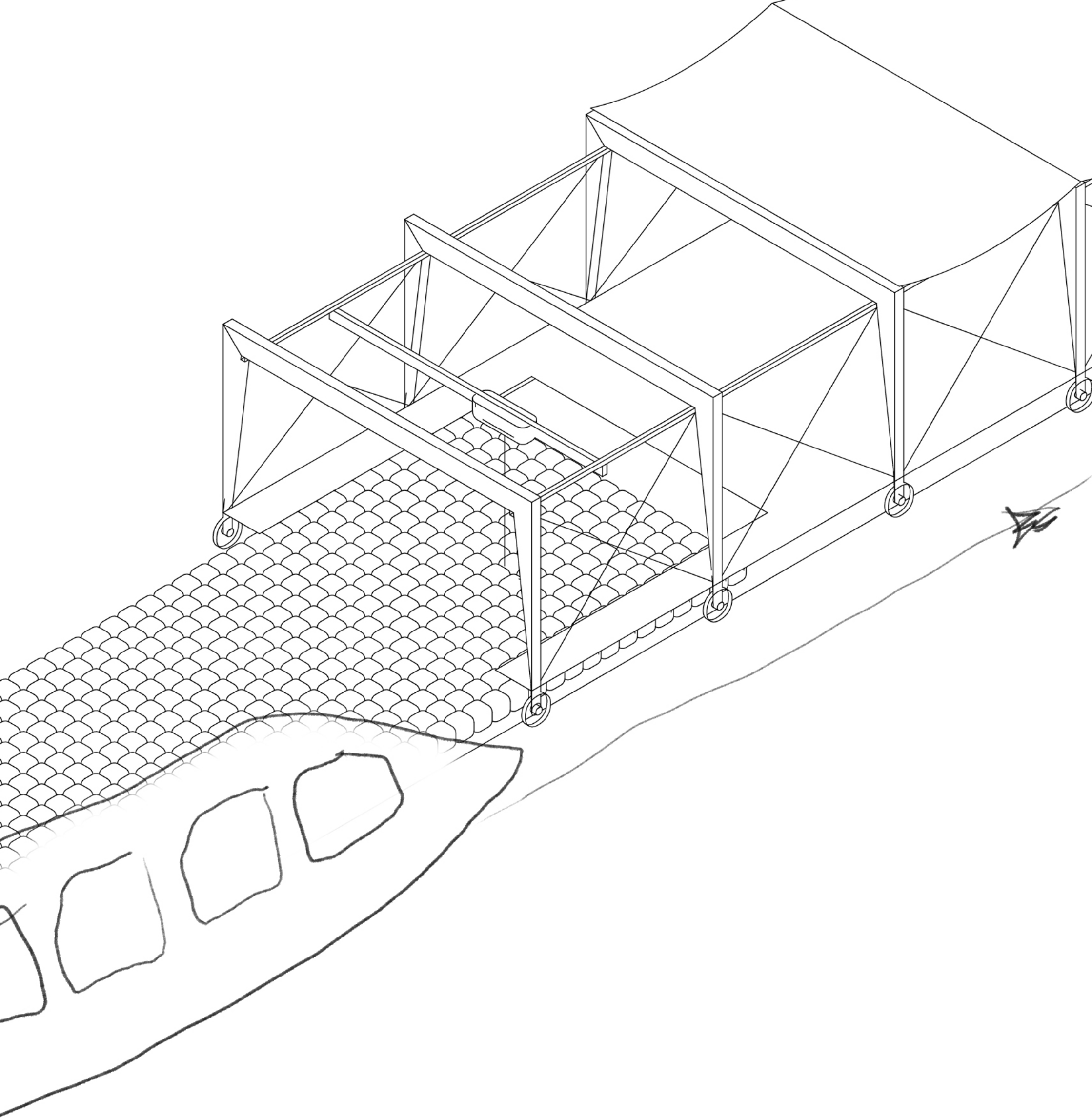
With 120 Mirrors pointing at the dome simultaneously the dome is heated up with:
2m*3m*120 mirror*(2500 to 3389kw/h) = 1.800.000 to 2.440.080kw/h

The Intervention

train station







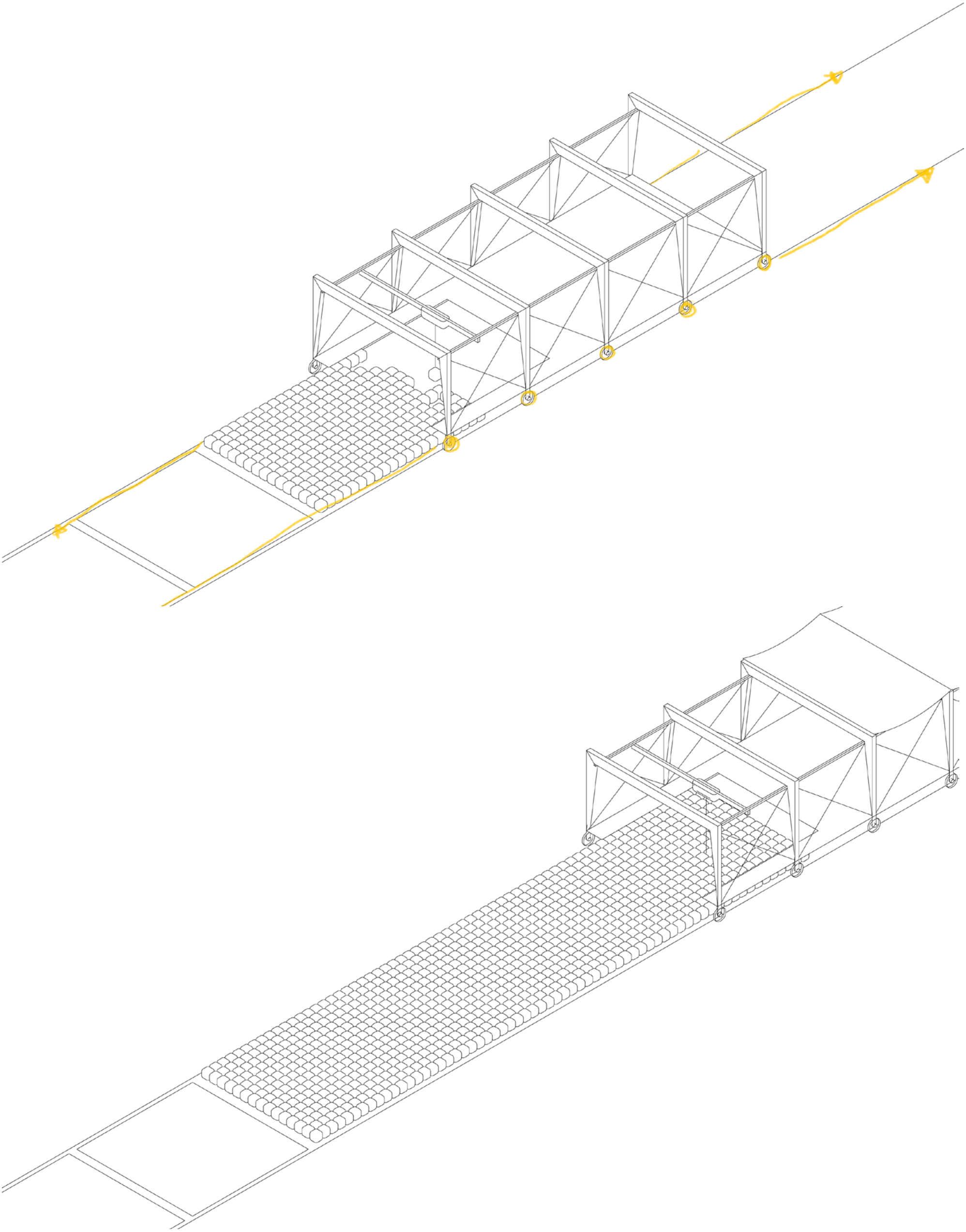
The Intervention
calculation of platform growth

The platform of the station grows simultaneously with the water/ brine production. Every day around 100.000l sea water is converted to 40.000l pottable water. The leftover brine is compressed to brine blocks, that make up the platform's station.

100.000L seawater = 103.000kg
Salt in Seawater: ca. 35g/kg (11)
35g/kg *103.000kg = 3.605.000g = 3.605kg

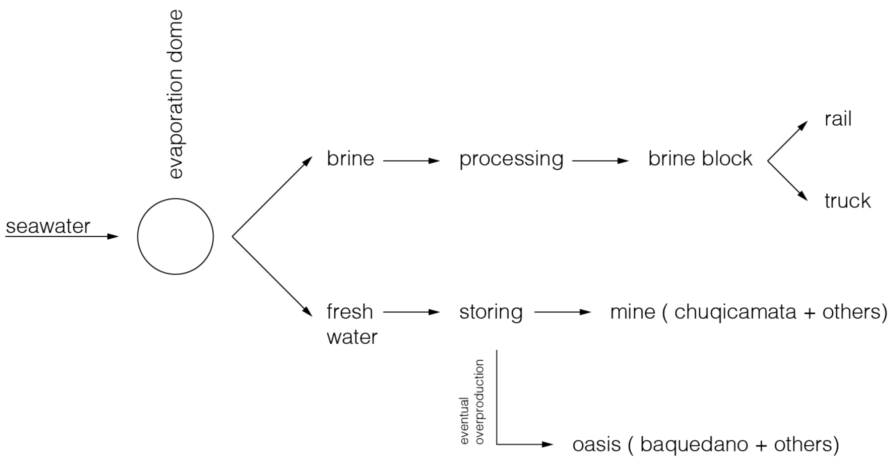
Bulk density of salt block: 2170kg/m3 (12)
Compressed Salt block/day*dome:
3605kg/2170kg/m3 = 1,66 m3

with a width of 16 meter - the platforms grows 1m/10days
(with 1000 domes --> 100m/day)

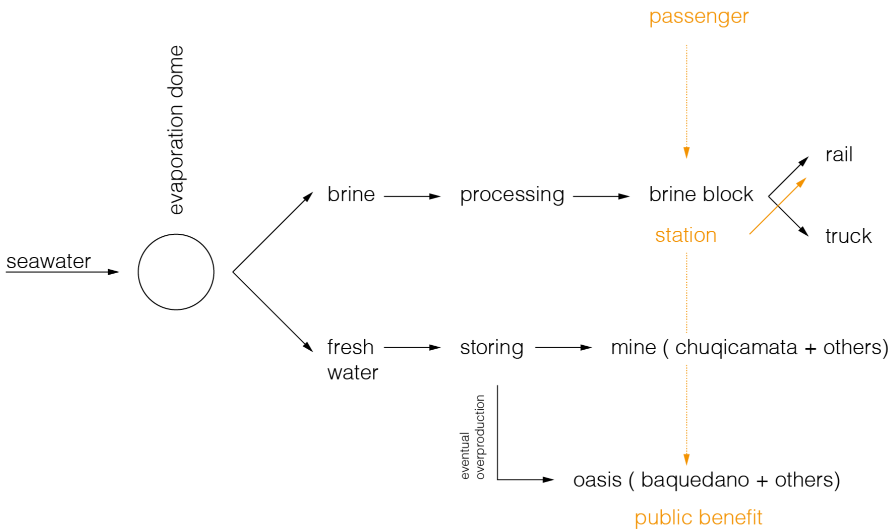


// The moving factory builds up
the brine station.

The Intervention
process overview



// Process Diagram



// **Process Diagram + Passenger Flow**

The Baquedano Oasis
footnotes

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(7) Sixie Yang et al., “Lithium Metal Extraction from Seawater,” Joule (Cell Press, July 26, 2018), https://www.sciencedirect.com/science/article/pii/S2542435118302927.

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(10) Stefan Giljum and Stephan Lutter, “Copper Production in Chile Requires 500 Million Cubic Metres of Water,” fineprint global, January 13, 2020, https://www.fineprint.global/publications/briefs/chile-copper-water/.

(11) “Pacific Ocean,” Encyclopædia Britannica (Encyclopædia Britannica, inc.), accessed April 16, 2022, https://www.britannica.com/place/Pacific-Ocean.

(12) “Density of Common Salt in 285 Units and Reference Information,” Density of Common salt in 285 units and reference information, accessed April 16, 2022, https://www.aqua-calc.com/page/density-table/substance/common-blank-salt.

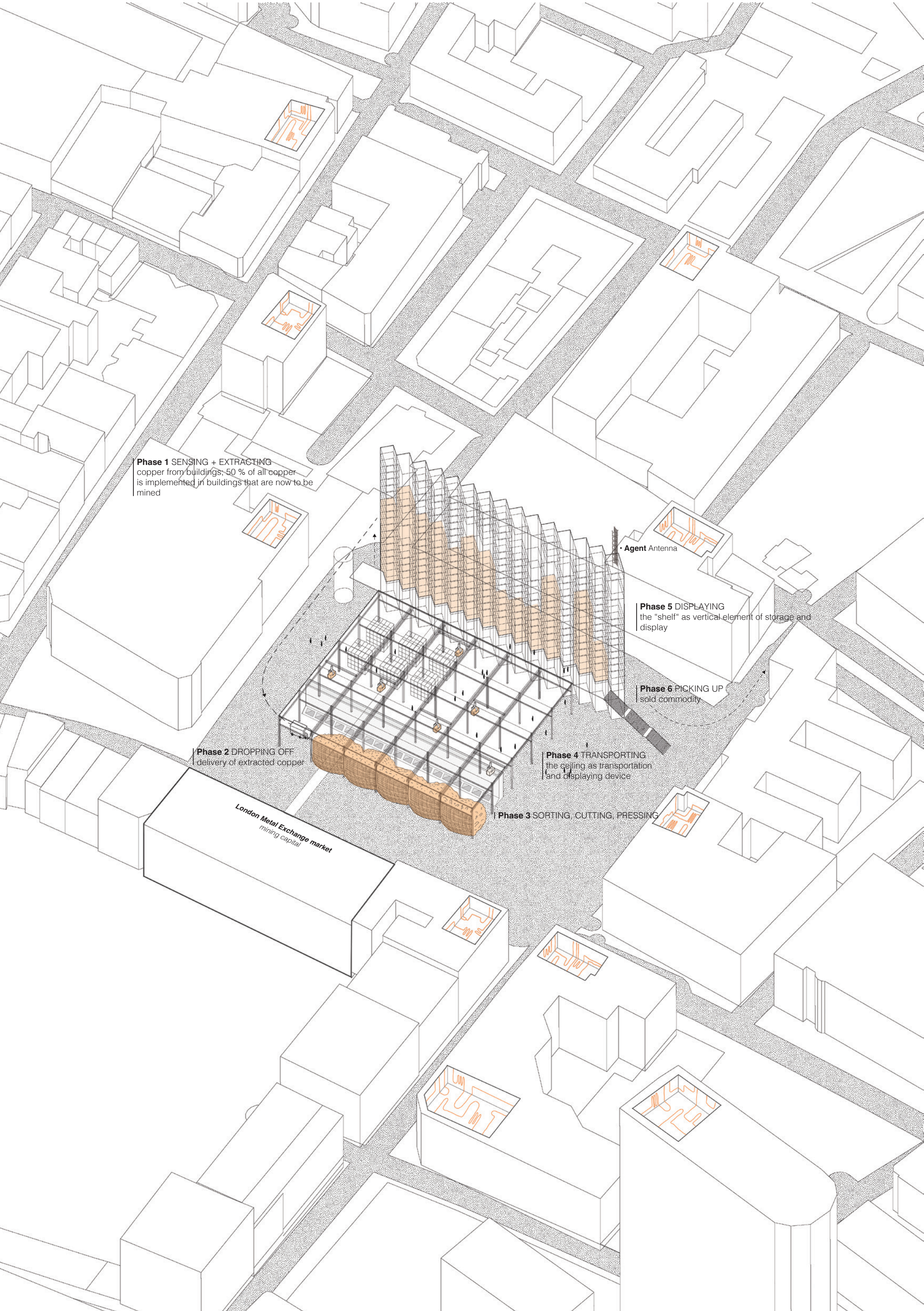
London Mine

London Mine
overview

Problem
// increasing depletion of natural copper deposits
// increasing copper demand

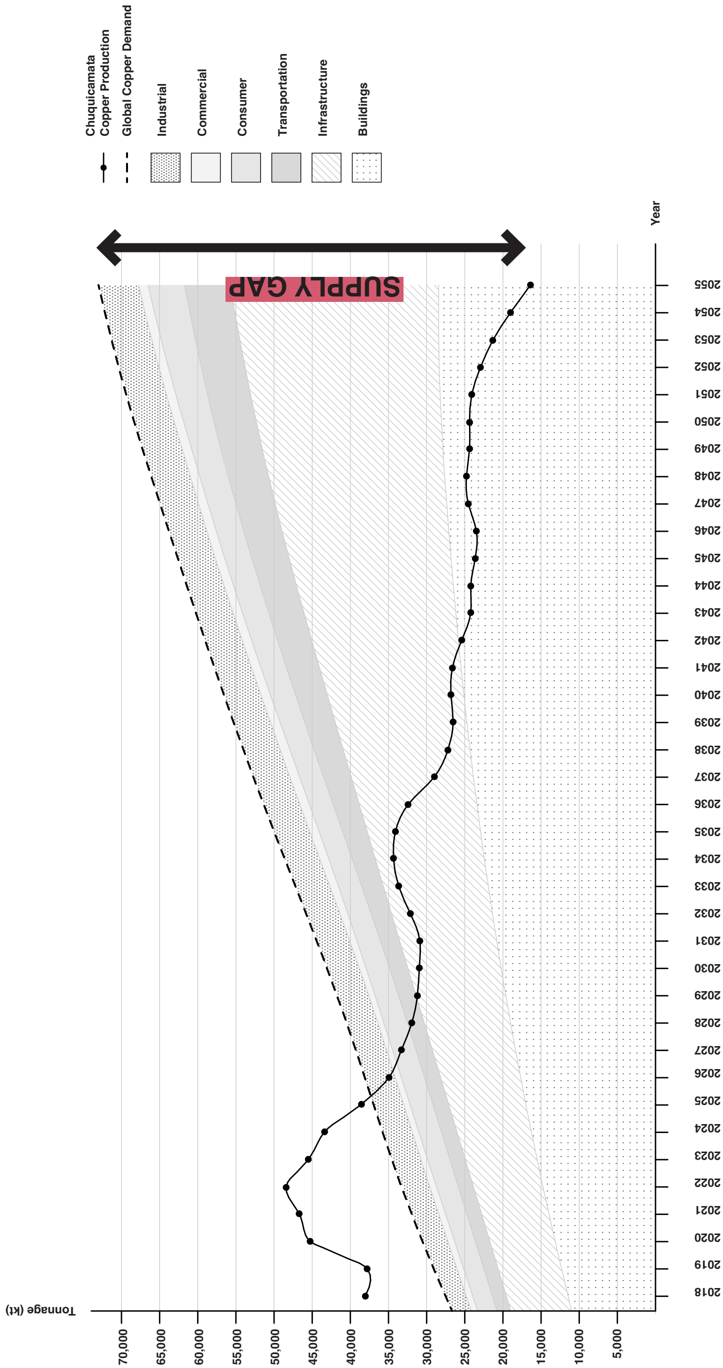
Design
// taps into the city as a copper deposit
// recycles copper scrap
// shifts around economic dependencies

The design turns the city itself into a site of copper extraction: Mining the buildings, the London Mine can keep up with an increasing demand for copper, while turning the existing economic and material dependencies of two continents around.



Phase 1 SENSING + EXTRACTING
copper from buildings; 50 % of all copper is implemented in buildings that are now to be mined
Agent Antenna
Phase 5 DISPLAYING
the "shelf" as vertical element of storage and display
Phase 6 PICKING UP
sold commodity
Phase 2 DROPPING OFF
delivery of extracted copper
Phase 4 TRANSPORTING
the ceiling as transportation and displaying device
Phase 3 SORTING, CUTTING, PRESSING
London Metal Exchange market
mining capital

The Problem
increasing copper demand



// 1 Development of Chuquicamata Copper Production and Global Copper Demand

Applications of Copper
non-electroconductive applications in the house

Plumbing tubes
Fittings
Roofing
Door hardware
Doorknobs
Chimney Caps
Valves
Furniture
Decoration
Cladding
Kitchenware
Electrical springs
Heat exchangers
Air conditioning
Refrigerators
Freezers
Heat sinks
Electronic packaging
Heat exchangers
Vacuum tubes
Cathode ray tubes
Magnetrons
Electrical contacts
Waveguides
Welding electrodes
Downpipes
Spires
Weathervanes
Keys
Tools
Heat Pump
Dishwasher
Dehumidifier
Clothes Washer
Clothes Dryer (1)

Applications of Copper
current and emerging conductive uses

High conductivity wires
Data/Signal Transmission
Electric product manufacturing
Transportation
Building construction
Infrastructure
Power generation
Terminals and connectors.
Springs for relay contacts and switchgear
Integrated circuit lead frames
Busbars
Rotor bars
Armatures
Commutators
Spot welding electrodes, seam welding wheels
Heavy electrical switchgear
Power transmission lines
Spark plugs

Electrodes
Heat exchangers
Refrigeration tubing
Water-cooled copper crucibles
Air Conditioning, Heating and Refrigeration Systems
Automotive Wiring
Gas Combustion
Electric Energy Transmission
Electronic Interconnection
Electronic Thermal Management
Motor-Driven Systems
Renewable Energy
Automotive Electrical Propulsion
Seismic Energy Dissipation
Thermal Energy Storage
Induction Coils
Electronic connectors
Circuitry wiring and contacts
Printed circuit boards
Micro-chips
Semi-conductors
Magnetrons in microwaves
Electromagnets
Vacuum tubes
Commutators
Welding electrodes
Fire sprinkler systems
Heat sinks
Heat exchanger tubes for condensers
Irrigation and agricultural sprinkler systems
Piping at distillation plants
Seawater feed lines
Cement pumps for drill water supply
Tubes for distribution of natural and liquefied petroleum
Fuel gas distribution piping ② ③

Application of Copper importance of conductive material in emerging technologies

“There is speculation that copper consumption is entering a new growth phase driven by a society that is increasingly becoming ‘electrified’. With the electrification of energy, it is an expectation that demand for electricity will outpace the growth in total primary energy demand in the future.

The production, distribution and transmission will require a substantial amount of copper. Specifically, the future of electronic transportation may be a mega-trend for the increase in demand for copper. This is because copper is an excellent conductor of electricity and lacks price-competitive substitutes. Currently, around 72% of copper consumption is in the power and utilities sector, and in electrical products.

With sales of electric and hybrid-electric vehicles on the rise, up 65.7% in 2017 globally, the future demand for copper and copper products is set to increase dramatically. This is further facilitated by governments around the globe who encourage the use of electric vehicles through various schemes.” (4)

“Demand for the metal is increasing and the demand-supply gap widening. Media reports indicate a wide gap of 8.2m metric tons by 2030 as the metal is used in applications powering the energy transition. We also expect demand to be driven by the recommissioning of infrastructure and manufacturing projects. Supply, on the other hand, has been under pressure for several years and is likely to remain so.

Digitalisation increases demand for computers, mobile phones and networks and, therefore, for components for these devices and systems. It also increases demand for technological infrastructure. Copper wire is used in all electrical and electronic devices. Some estimates forecast that an additional 5.3m metric tons of copper will be required to cover demand created by 42 emerging technologies by 2035.

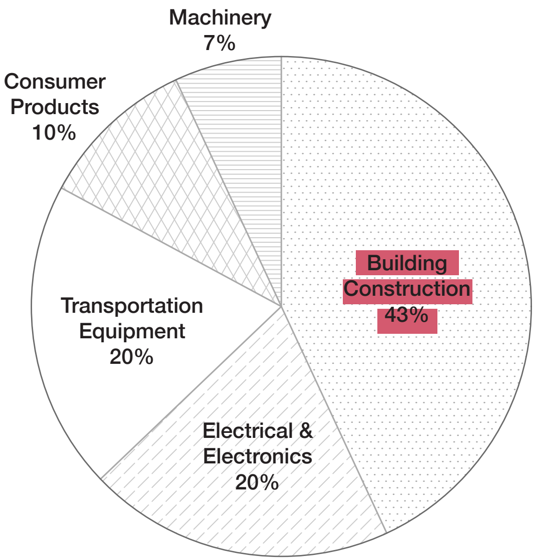
Cutting carbon emissions is another global priority. China has pledged to neutralise its carbon emissions by 2060. US President Biden has committed USD2tn to help cut emissions, and the EU targets zero emissions by 2050. To achieve such goals, governments would need to shift to sustainable energy sources, requiring additional copper for constructing the infrastructure

Electric vehicles (EVs) and renewable energy from solar and wind farms are projected to reduce carbon footprints. EVs also drive copper demand. It is estimated that EVs will generate additional copper demand of 1.5m metric tons in 2025 and 3.3m metric tons (forecast to be 10% of total demand) by 2030 versus less than 500 kilotons in 2020. The world’s biggest auto market, China, expects EVs to account for c.60% of vehicle sales by 2035. The US expects them to account for 50% of vehicle sales by 2030. The number of EVs is forecast to reach 7m by 2025, requiring c.5m charging ports to support them.” ⑤

The City As New Deposit current uses of copper

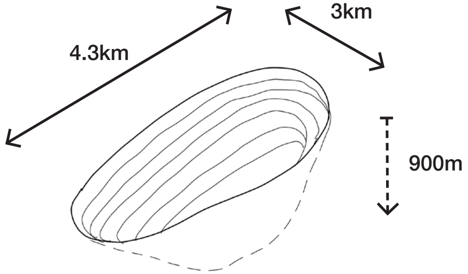
Building construction accounts for 43% of all copper use. (6)

Residential construction makes up about two-thirds of the building construction market. (7)



// 2 Diagram Depicting Current Uses of Copper

The City As New Deposit deposit volume comparison

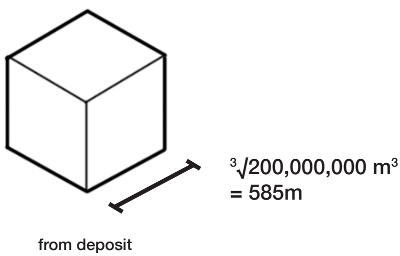


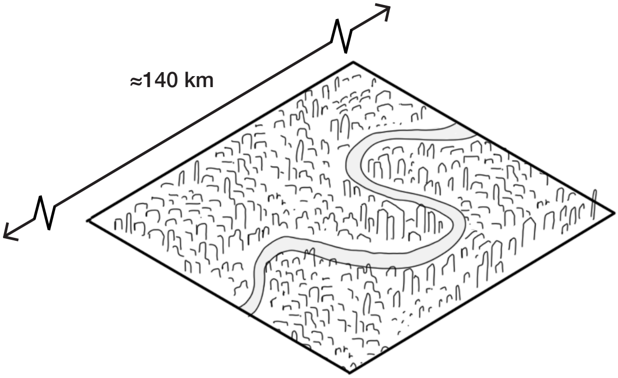
The copper ore reserves of the Chuquicamata underground mine are estimated to be 1,760 billion kg of Copper. (8)

Density (ρ) of Copper = $8.96g/cm^3 = 8960kg/m^3$

-

$$v = \frac{m}{\rho} = \frac{1,760,000,000,000}{8960} \approx 200,000,000\ m^3 \text{ of Copper}$$





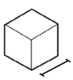
An average dwelling contains ≈ 160kg of Copper [9]

- 73kg building wire
- 53 kg - plumbing tube, fittings, valves
- 10 kg - plumbers‘ brass goods
- 19 kg - built-in appliances
- 4 kg - builders hardware
- 4 kg - other wire and tube

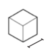
There are an estimated 3.6 million dwellings in London. [10]
3,600,000 x 160kg
≈ 576 million kg of Copper

-

$$v = \frac{m}{\rho} = \frac{576,000,000}{8960} \approx 64,000\ m^3 \text{ of Copper}$$



$\sqrt[3]{64,000\ m^3}$
= 40m



$\sqrt[3]{31,000\ m^3}$
= 30m

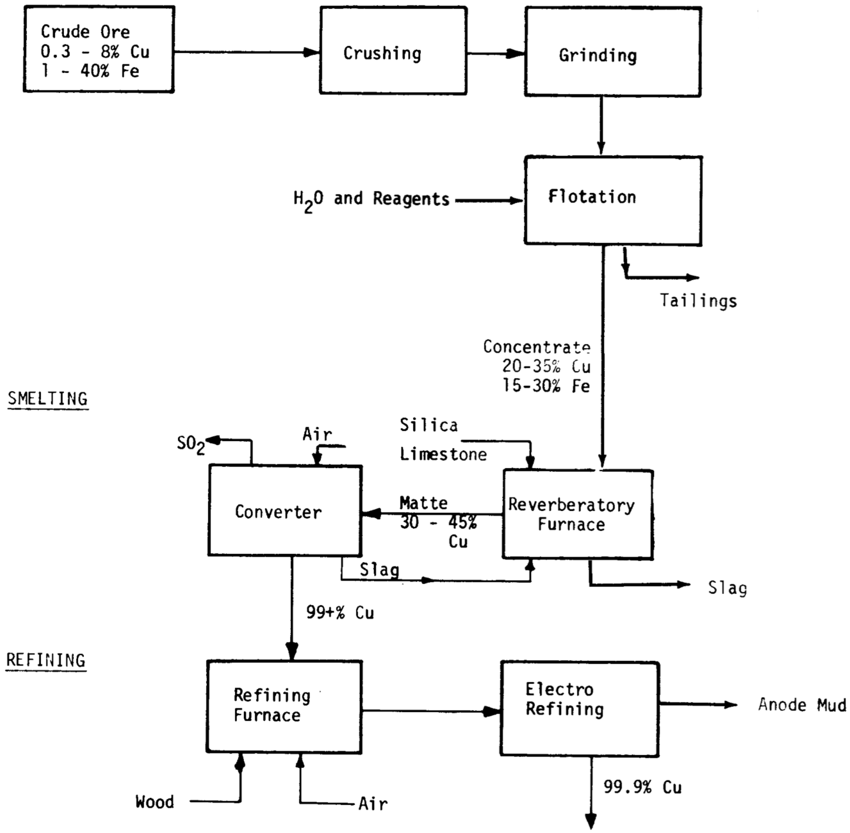
from dwellings
(29%)

from other buildings/
infrastructure
(14%)

Energy Expenditures

mining vs. recycling
energy comparison

images : htt

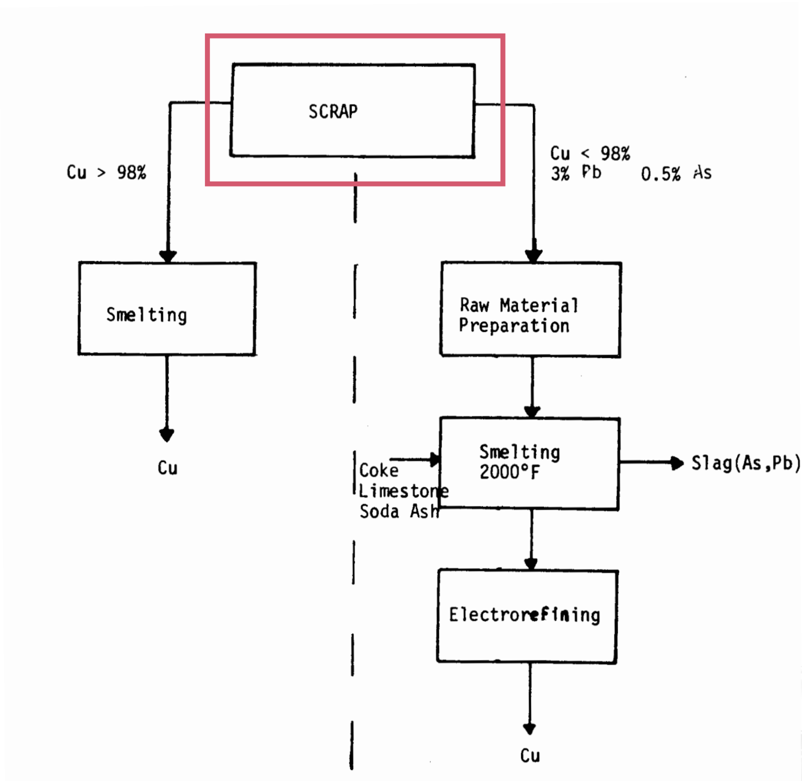


// 3 Mining Process Diagram

Energy Expenditure of Reclaiming Copper from Raw Sulfide Ores
=12,000 kWh/ton
= £ 226,800 /ton (11) (12)

The London intervention will elaborate
specifically on this part of the recycling process

tps://www.osti.gov/servlets/purl/7351678



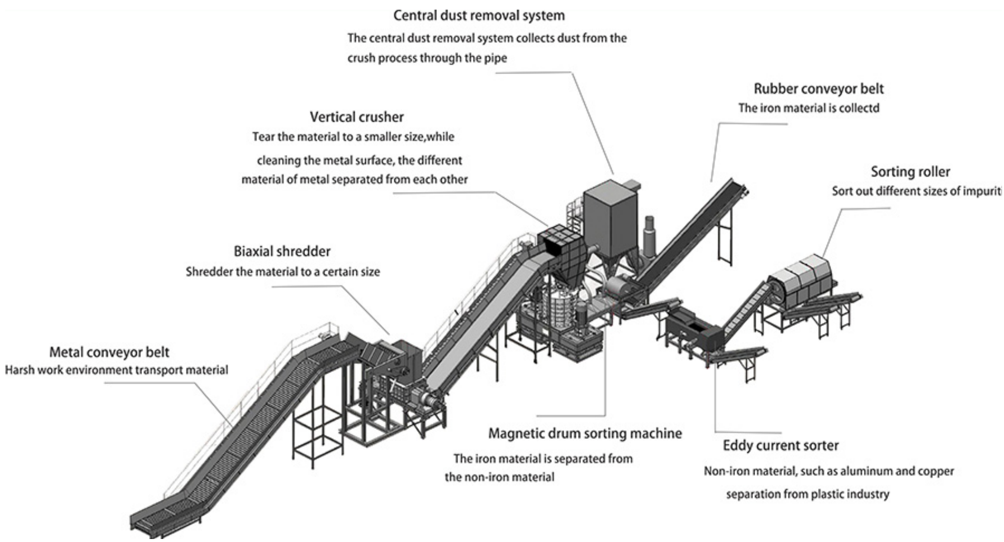
// 4 Recycling Process Diagram

Energy Expenditure of Recycling Copper from Scrap
= 1,560 kWh/ton
= £ 29,484 /ton (11) (12)

Energy Expenditures
scrapping machinery

Energy Expenditure of First Machine
=500 kWh/ton
£ 9,450 /ton (11) (12)

Collected copper items + unwanted scrap → Cleaning/ crushing/ sorting

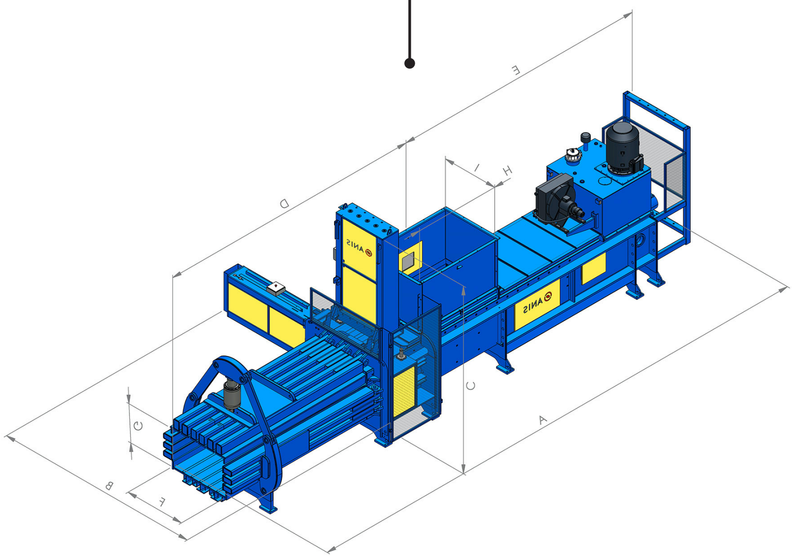


// 5 First Scrap Machine

Energy Expenditure of Second Machine
= 250 kWh/ton
£ 4,725 /ton (11) (12)

Baling

Scrap Copper Bale



// 6 First Scrap Machine

Copper Extraction London Mine

properties of scrap copper bale

// 7 Scrap Bale

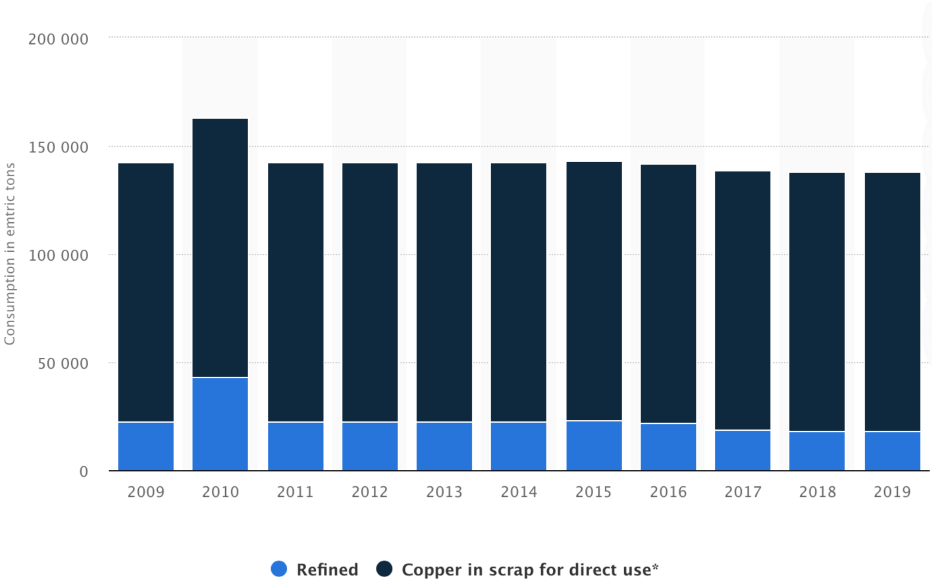
Bale dimensions (L×W×H)	600×600×300mm
Weight	≈ 300 kg (estimation depending on contents)
Selling Price	£ 8.45 per kg (Based on Copper stats at time of writing)
Density (ρ)	3,000 kg/m³ (13)

∴

If as previously stated, the Recycled Copper yield of 1 household ≈ 160kg

1 scrap bale ≈ Copper Yield of 2 households

Copper Extraction London Mine scrap bale production rates



// 8 Copper Scrap Consumption UK

In 2019, approximately 120,000 metric tons of copper in scrap were consumed for direct use in the United Kingdom, while around 18,000 metric tons of refined copper were consumed in the UK in the same year.

Due to missing information, we can assume that the yearly Consumption of scrap Copper specifically in London is 50,000 metric tons per year.

Assuming that the entire amount of London's scrap copper is processed through the London Mine, what are the yearly/daily/hourly rates of processing and baling required to keep up with the city's demand?

50,000 tons ≈ 50,000,000 kg

How many scrap bales would 50,000,000kg be?

$\frac{50{,}000{,}000 \text{ bales}}{300 \text{ days}}$ ≈ 166,666 bales per year

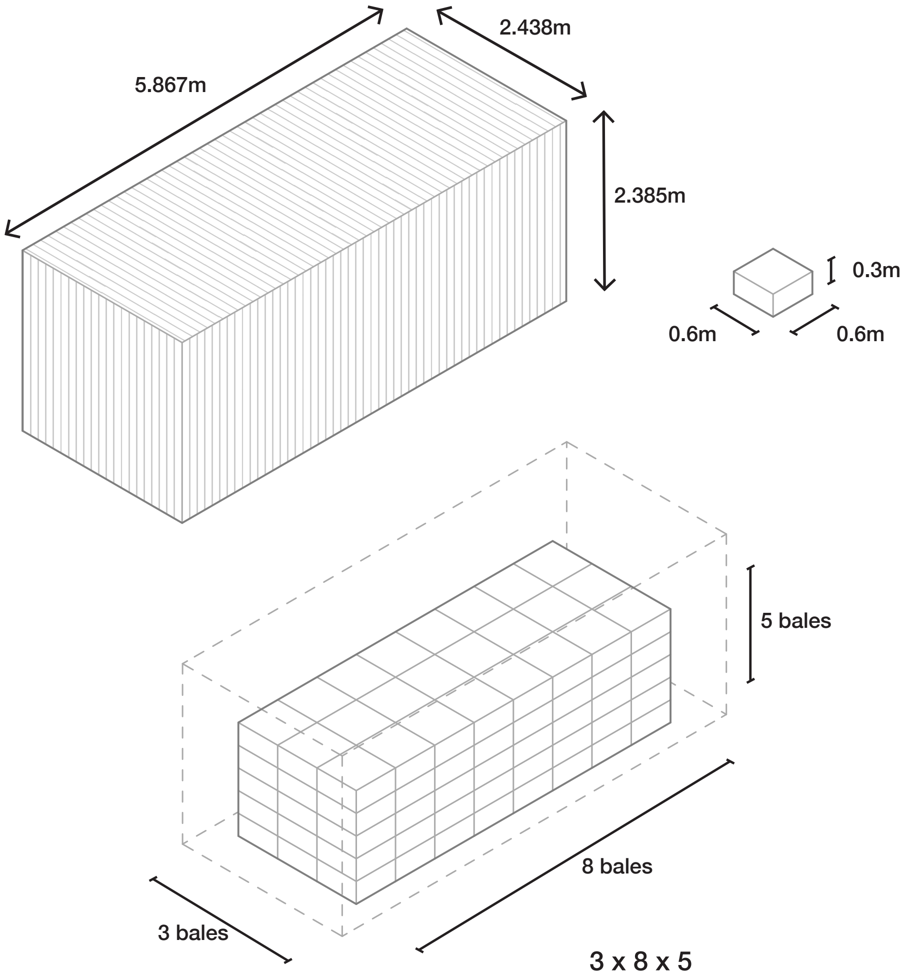
-

$\frac{166{,}666 \text{ bales}}{365 \text{ days}}$ ≈ 456 bales per day

-

$\frac{456 \text{ bales}}{24 \text{ hours}}$ ≈ 19 bales per hour

Architectural Application
east facade



3 x 8 x 5
=120 bales per container

In the North facade, the bales are to be stored and stacked reaching the dimensions of ISO containers.

It is assumed that each copper scrap bale remains a maximum of 1 month 'on the shelf', waiting to be sold. Consequently, the maximum storage capacity of the North facade can be calculated.

Maximum storage capacity = daily prod. rate x shelf-time
= 456 (bales/day) x 30 days
= 13,680 bales

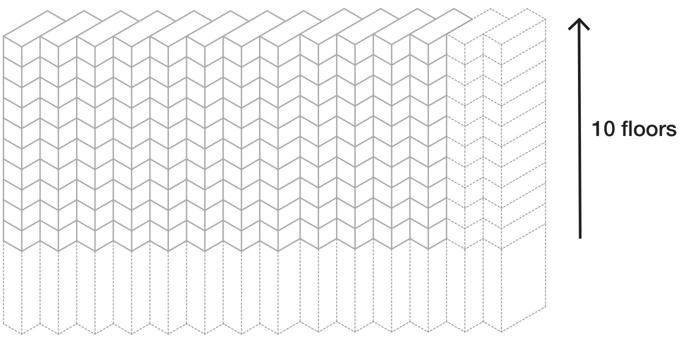
Assuming there are 12 units of storage per floor in the East facade, the maximum scrap bale storage capacity per floor can be calculated.

Max. bale capacity per floor = capacity of 1 container x 12
= 120 x 12
= 1,440 bales

With both of the above-calculated amounts, we can conclude how many floors are required to accommodate the scrap bale quantity at times of maximum capacity.

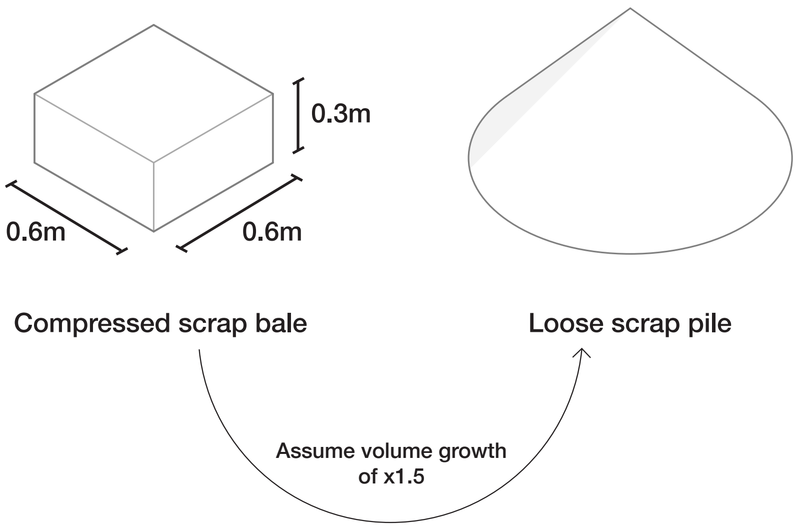
$$\text{Required floors} = \frac{\text{maximum storage capacity}}{\text{max capacity per floor}} = \frac{13{,}680}{1{,}440} = 9.5 \text{ floors}$$

= 10 floors



Architectual Application
west facade

The West facade is to serve as a showcase and storage of the retrieved raw copper objects, before they are processed and later sold. It is to be composed of a 10m high horizontal net that holds up the large scrap pile.
To calculate the volume of the scrap pile to be stored at the West Facade, we will assume that the copper in the loose, uncompressed state has a volume that is 1.5x larger than the previously calculated, processed scrap bale.



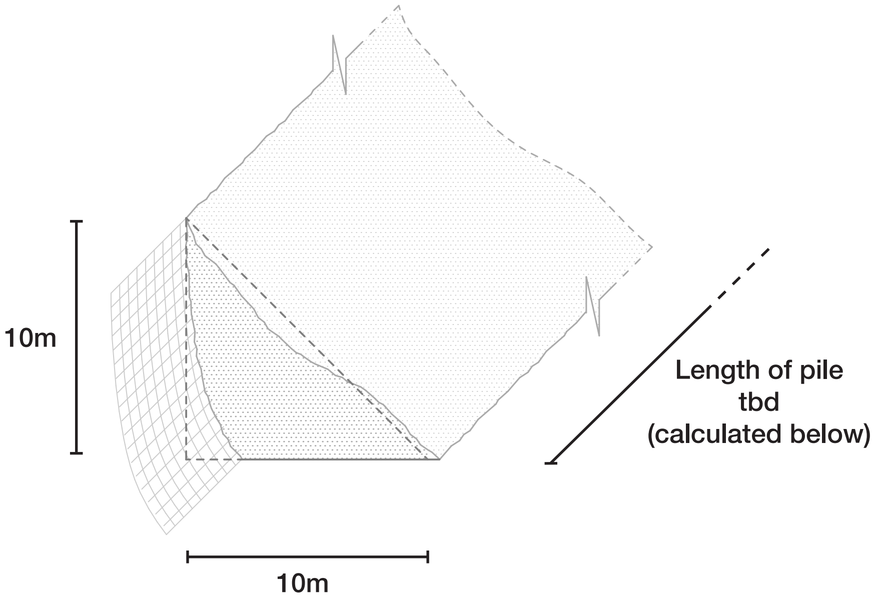
Volume of single scrap pile = Volume of compressed bale x 1.5 factor
= (0.6 x 0.6 x 0.3) x 1.5
= 0.162m^3

Since the same logic applies for the maximum capacity of Copper as in the North facade‘s calculations, the capacity for the South Facade is yet again estimated to be 13,680 bales.

Volume capacity at South Facade = 13,680 x Volume of single scrap pile
= 13,680 x 0.162m^3
≈ 2,216m^3

Knowing the maximum volume capacity of loose copper that should be contained by the South Facade, we can now calculate the span of the entire net required to hold the loose scrap pile. The height of the net is fixed at 10m, and it is assumed that the pile will slide and slack at a horizontal distance of 10m, as illustrated below.

To calculate the required length of the net...

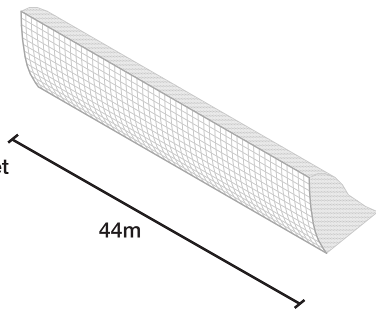


To make the calculation simpler, the copper pile's cross section is assumed to take the form of a triangle

-

Volume of pile = Cross Section Area x Length of Pile/Net

$$\text{Length of Pile/Net} = \frac{\text{Volume of Pile}}{\text{Cross Section Area}} = \frac{2{,}216}{(10*10)/2_{\text{ [Area of Triangle]}}}$$

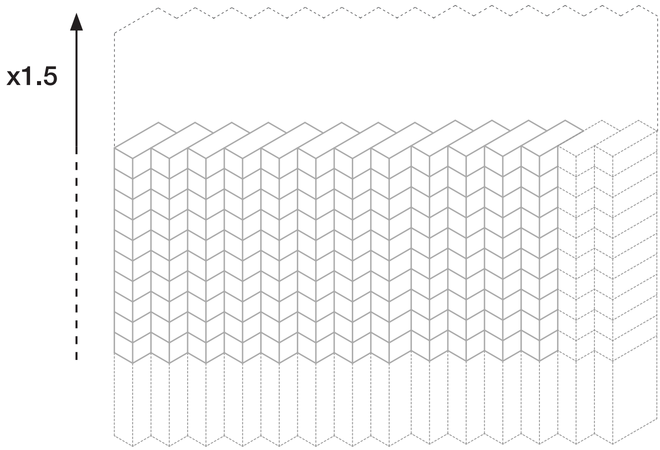


Length of Pile/Net = 44m

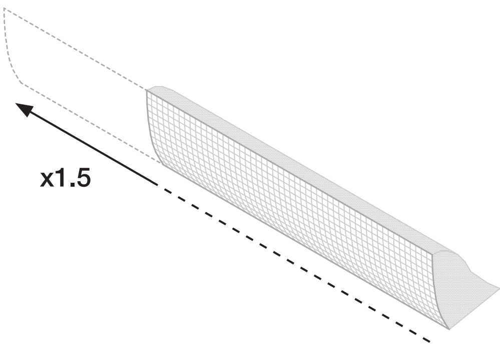
Architectural Application factoring for increasing demand

As discussed previously, the demand for copper in all states is expected to rise significantly in the coming years. Considering the imminent depletion of geological copper deposits in mines, the dependence on scrap will increase substantially.

To address this, a factor of 1.5x is applied to the size of the storage facilities in the building, since over the years, a larger copper volume is expected to be stored at both the facades.

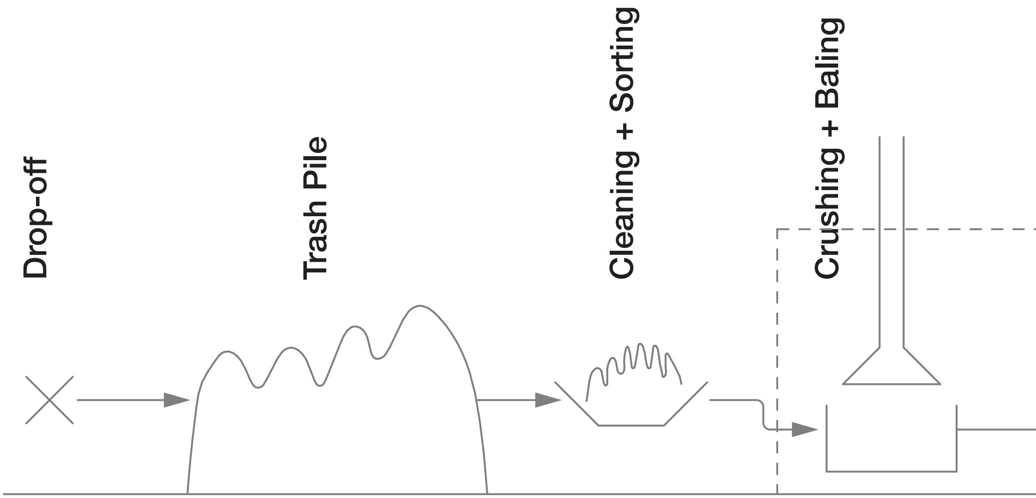


New amount of floors = pre-calculated number x factor
= 10 floors x 1.5
= 15 floors

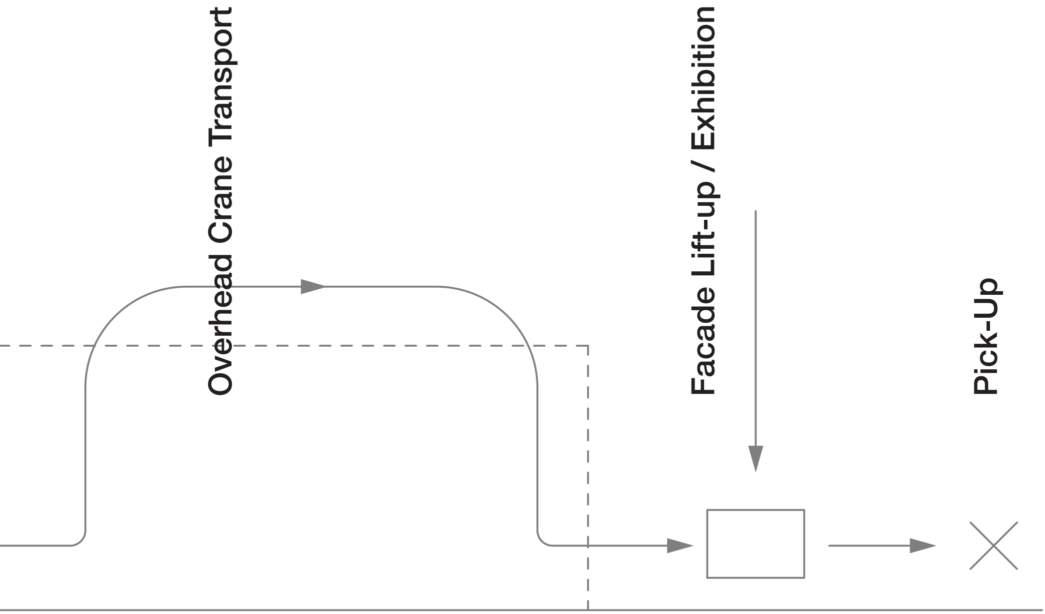


New storage net length = pre-calculated length x factor
= 44mx 1.5
= 66m

Complete Process
overview



// Process Diagram


Overhead Crane Transport
Facade Lift-up / Exhibition
Pick-Up

The London Mine
footnotes

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Appendix I
figures

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