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A water scarcity and water quality footprint on the example of two Lithium mines

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GEFÖRDERT VOM

Bundesministerium für Bildung und Forschung

WANDEL Wasserressourcen Energiewende als bedeutsame Faktoren der auf lokaler und globaler Ebene

GRoW GLOBALE RESSOURCE WASSER

Key Global Sustainability Challenges

Water & Energy

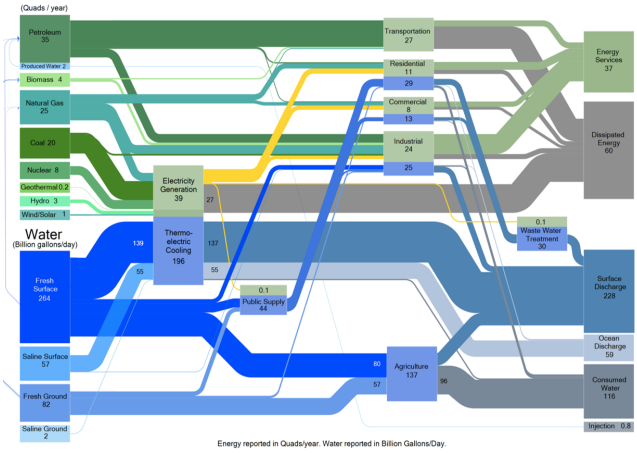


FIGURE 2: Water-Energy-Nexus according to Bauer (2015). Annual water withdrawals for cooling purposes in electricity generation according to Flörke et al. (2013).

Water & Energy

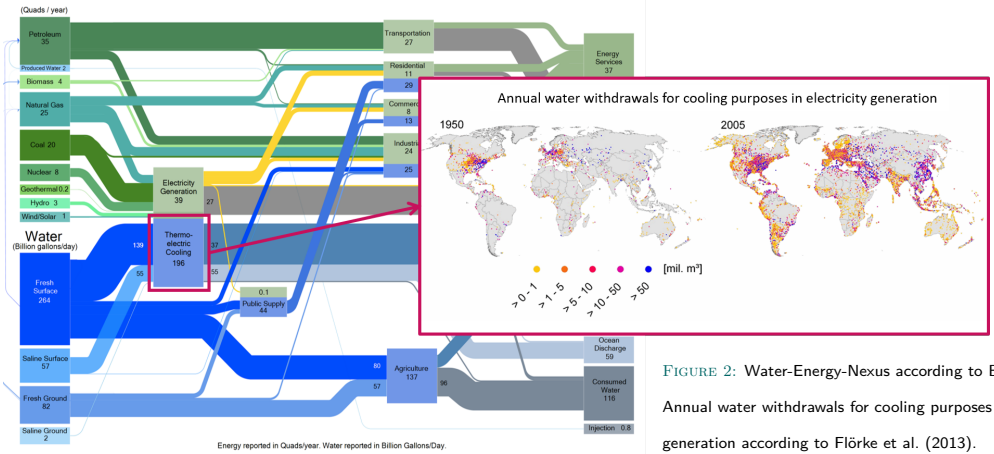
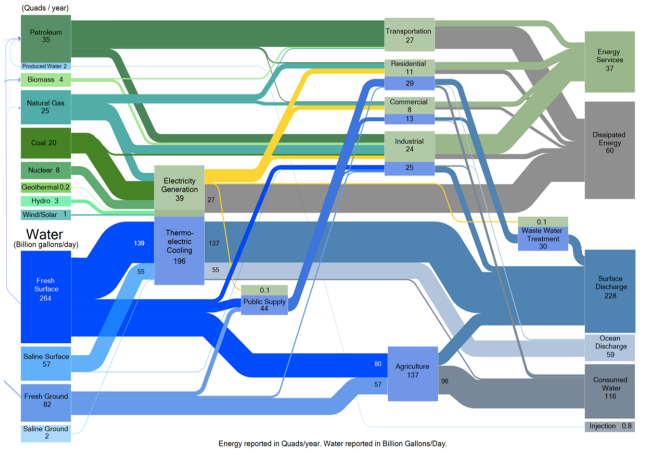


FIGURE 2: Water-Energy-Nexus according to Bauer (2015). Annual water withdrawals for cooling purposes in electricity generation according to Flörke et al. (2013).

Water & Energy

WANDEL
Wasserressourcen als Indikatoren/Faktoren der Energiewende auf lokaler und globaler Ebene



Energy
needs
Water
needs
Energy

FIGURE 2: Water-Energy-Nexus according to Bauer (2015). Annual water withdrawals for cooling purposes in electricity generation according to Flörke et al. (2013).

Energy & Mining

	Lithium-ion LFP	Lithium-ion NCA	Lithium-ion NMC	Lead-acid battery	Vanadium Redox Flow Battery	CAES & flywheel	2030 total metal extra need (ton)	2050 total metal extra need (ton)
Market share (100% in total)	25%	25%	25%	8%	5%	12%		
Al	30	7.5	16.5	0	0	No metal	449 500	1 147 500
Ce/La	0	0	0	7	0	demand	5 000	13 000
Co	0	3	6	0	0	modelled	83 250	191 250
Li	1.25	1.2	1.2	0	0		36 075	82 875
Mn	0	0	6	0	0		55 500	127 500
Ni	0	24	6	0	0		277 500	637 500
Pb	0	0	0	72	0		213 120	489 600
V	0	0	0	0	9		16 650	38 250

[kg/ MW]

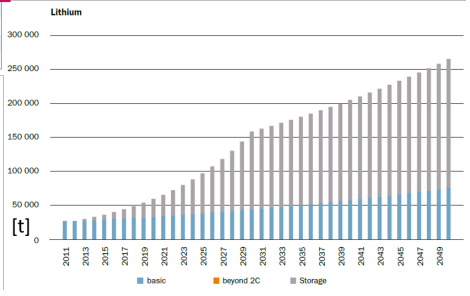


FIGURE 3: Metal demands for battery technologies and required lithium growth according to Rietveld et al. (2018).

Water Use in Mining

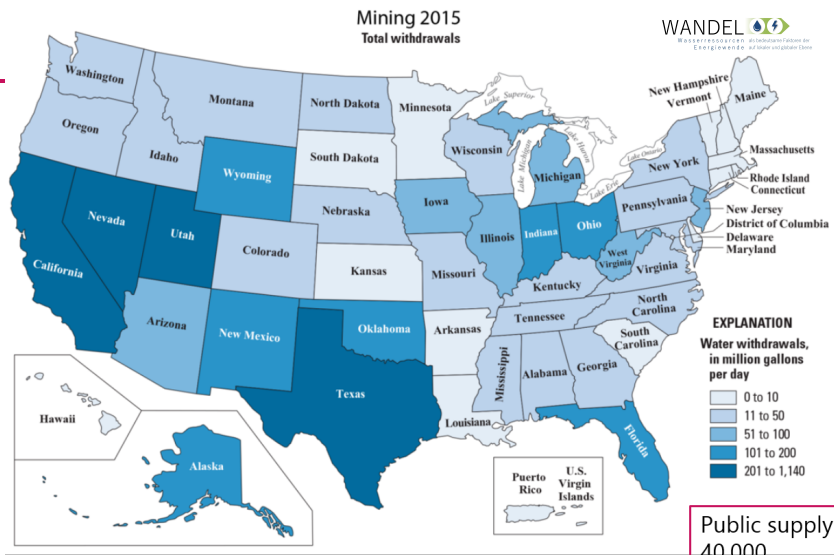


FIGURE 4: Water use for mining purposes in the U.S. 2015 according to Maupin et al. (2014).

Public supply 40,000

Distribution and future expansion

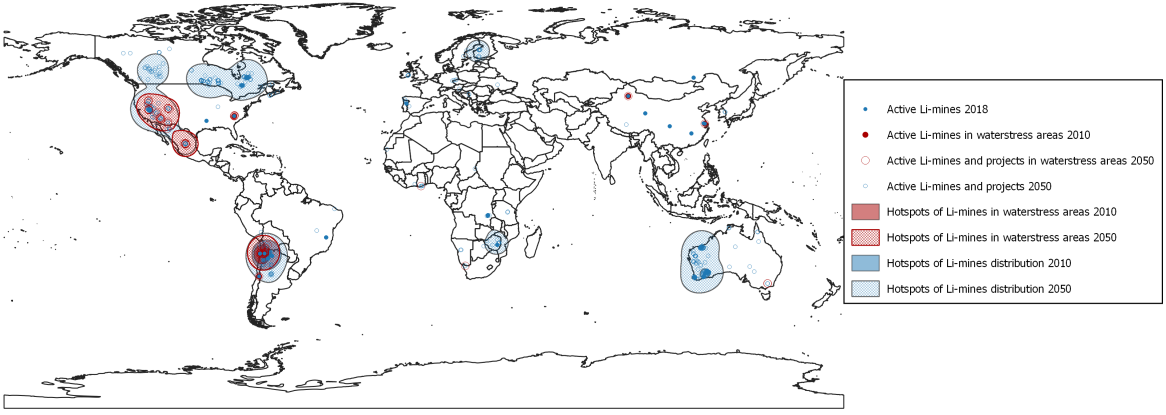


FIGURE 6: Distribution and future expansion of Lithium mines as reported in the MiningIntelligence provided by InfoMine according to Schomberg & Bringezu 2019 [Unpublished]. Water stress 2010 and 2050 derived from the hydrological modelling framwork WaterGAP3.

Lithium mine types

- refinery product: Lithium carbonate equivalent (LCE)
- geological Lithium sources
  - hard rock: petalite, spodumen, lepidolithe, eucryptit, hectorit (mostly magmatic)
  - brines: shallow groundwater with enriched concentrations (extraction so far only from salars)
- world resources (in ranking order): Bolivia, Chile, Argentina, USA, China

refinery product LCE = functional unit in LCA

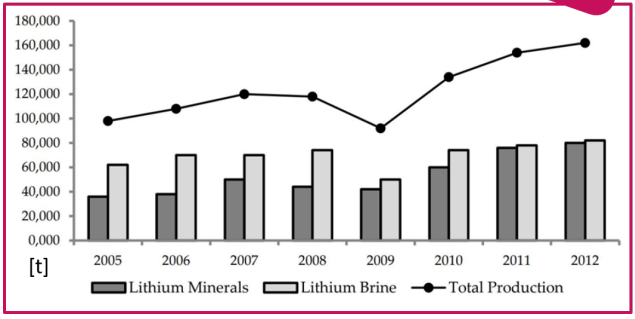


FIGURE 7: Share of hard rock and brine mining in global Lithium production according to Braga et al. (2014).

Lithium mine types

Definition

WANDEL Wasserressourcen als limitierender Faktor der Energiewende auf lokaler und globaler Ebene

Assessment of the on-site and remote impacts on water availability for human and nature caused by human water usage for Lithium mining (Lithium-ion battery production) in a spatially explicit way with the means of Life Cycle Assessment

Flows & Assessment

current LCA consensus for assessment: AWaRe (Boulay et al. 2017)

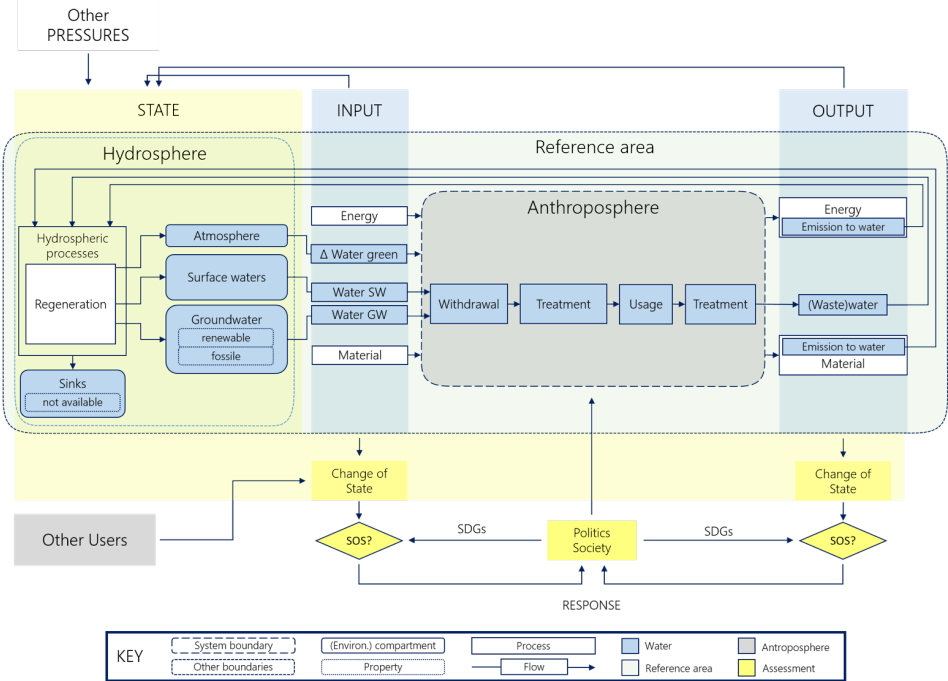


FIGURE 8: Water Footprint Assessment Framework according to Schomberg & Bringezu 2019 [Unpublished]. SOS = Safe Operating Space.

Indicators

Nomenclature after Hoekstra et al. 2011

1) Withdrawal surface water
2) Withdrawal groundwater
3) Evaporation from dams

→ Blue

4) Virtual dilution volume
5) Potential for AMD

→ Grey

6) Δ Evapotranspiration

→ Green

Spatially explicit

WANDEL Wasserressourcen als bestimmender Faktor der Energiewende auf lokaler und globaler Ebene

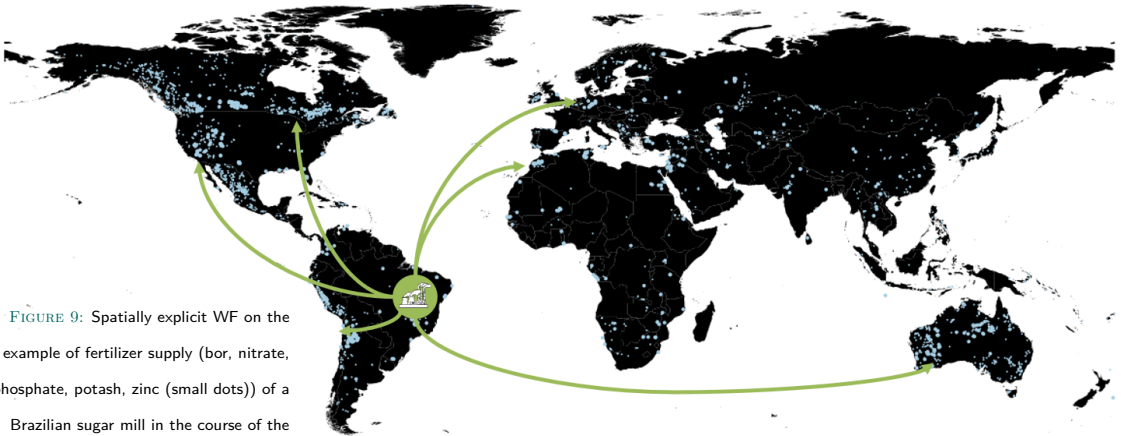


FIGURE 9: Spatially explicit WF on the example of fertilizer supply (bor, nitrate, phosphate, potash, zinc (small dots)) of a Brazilian sugar mill in the course of the BMBF project WANDEL.

Inventory: Hard rock mining

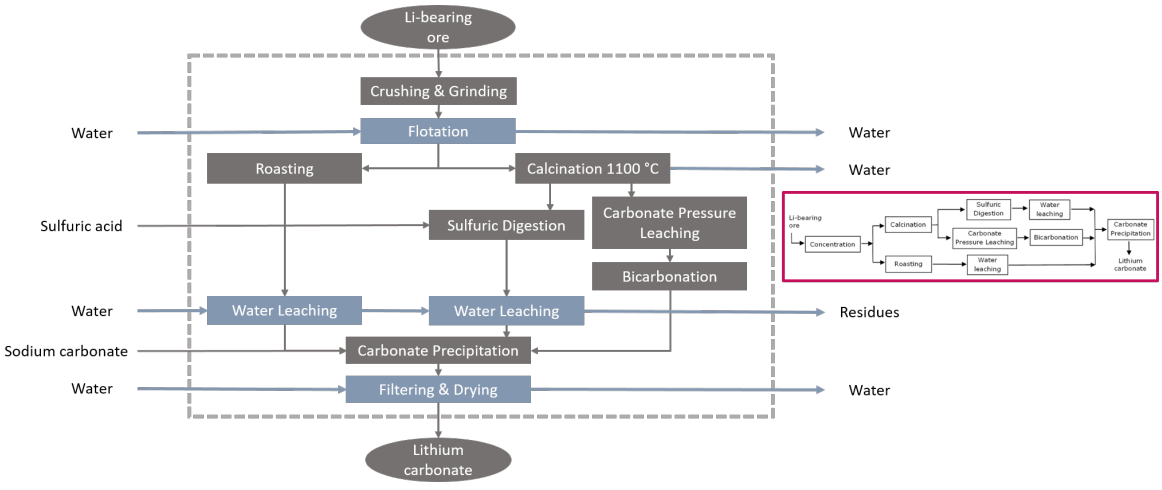


FIGURE 10: Flow chart modified according to Margarido et al. 2014 (red box).

Inventory: Brine mining

Withdrawal of brine calculated from evaporation considering concentration

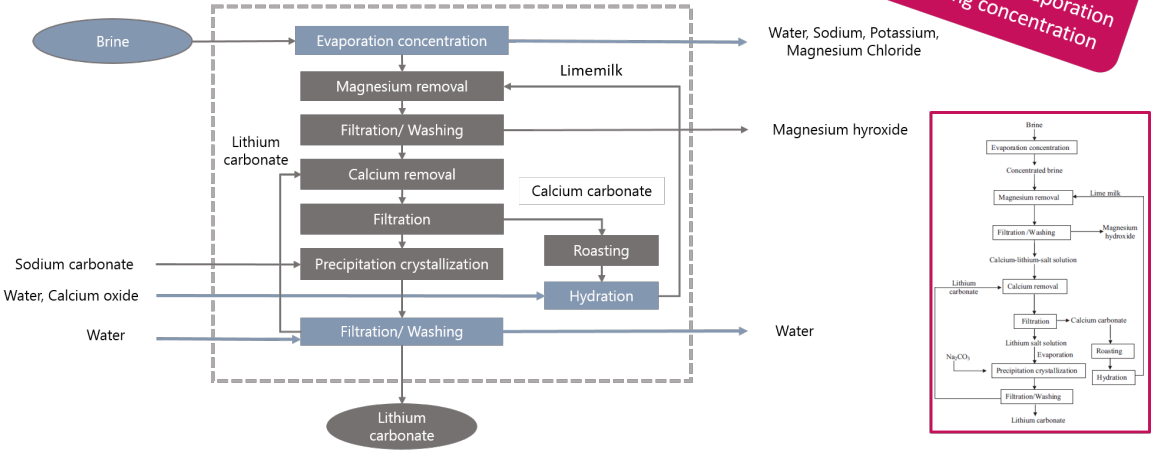


FIGURE 11: Flow chart modified according to Meshram et al. (2014) (red box).

Water Quality: VDV

$$VDV = \frac{Substance_i\ [mg]}{c_1\left[\frac{mg}{L}\right] - c_0\ [\frac{mg}{L}]}$$

	process output	threshold WHO	background concentration	VDV
	[mg/ kg LCE]	[mg/L]	[mg/L]	[L]
Carbonate	35143	500	no data	70
Sodium, ion	26943	200	no data	135
Sulfate	56117	250	no data	224

Emission to water from the process „Leaching of spodumene with sulfuric acid“ according to ecoinvent 3.1, localisation: Greenbushes Lithium mine

Water Quality: Potential for AMD

- AMD = Acid Mine Drainage
- caused by weathering of rock that is exposed to water and oxygen if sulfide minerals react to sulfuric acid
- common sufide minerals: pyrite (FeS_2), markasite (FeS_2), chalkopyrite ($CuFeS_2$), galena (PbS)...
- can be extremely accelerated under microbial activity
- impacts: lowering of pH value, leaching of heavy metals

Water Quality: Potential for AMD

Assumptions
microbial acivity not considered,
number of rainy days considered
as proxy for reaction conditions

$$FeS_2 + \frac{7}{2}O_2 + H_2O \rightarrow Fe^{2+} + 2SO_4^{2-} + 2H^+$$

Water Quality: Potential for AMD

Data
0,001 wt % sulfide minerals in granite, FeAsS at Greenbushes, production data from 1983 on, data gaps were filled continously, share of overburden calculated from production data

$$1\ kg\ FeS_2 \rightarrow\ 1{,}6\ kg\ SO_4^{2-}$$

$$FeS_2 + \frac{7}{2}O_2 + H_2O \ \rightarrow\ Fe^{2+} + 2SO_4^{2-} + 2H^+$$

→ number of rainy days/ year to weight

$rd\ [\%]$

volume of overburden
volume of cumulated production
kind of sulfide mineral
sulfide mineral content in rock
surface-volume ratio

$SO_4^{2-}\ [mg]$ sf

$$SO_4^{2-} \times\ sf\ \times rd\ = AMD_{pot}\ [mg]$$

$$\frac{AMD_{pot}}{c_1 - c_0} = VDV\ [L]$$

Water Quality: Potential for AMD

Data
0,001 wt % sulfide minerals in granite, FeAsS at Greenbushes, production data from 1983 on, data gaps were filled continously, share of overburden calculated from production data (a)

$$1\ kg\ FeS_2 \rightarrow\ 1{,}6\ kg\ SO_4^{2-}$$

$$FeS_2 + \frac{7}{2}O_2 + H_2O \ \rightarrow\ Fe^{2+} + 2SO_4^{2-} + 2H^+$$

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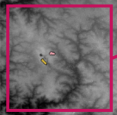
$SO_4^{2-}\ [mg]$ sf

$$SO_4^{2-} \times\ sf\ \times rd\ = AMD_{pot}\ [mg]$$

$$\frac{AMD_{pot}}{c_1 - c_0} = VDV$$

3
L/ kg LCE

Water Quality: Potential for AMD



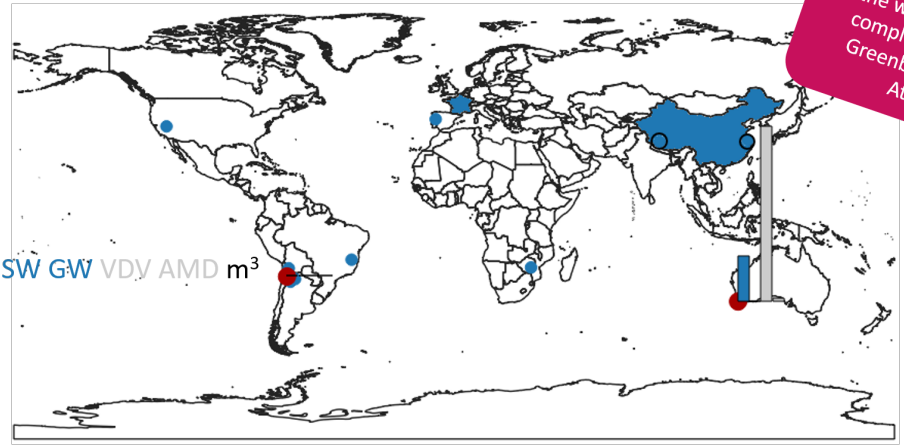
Digital Elevation Model
Aster Global DEM
used to calculate volume of overburden *(b)*

Water Quality: Potential for AMD

Digital Elevation Model
Aster Global DEM
used to calculate volume of overburden *(b)*

7
L/ kg LCE

WF of Li-ion battery



Australia's and Chile's share of the world production were completely assigned to the Greenbushes and Salar de Atacama mine

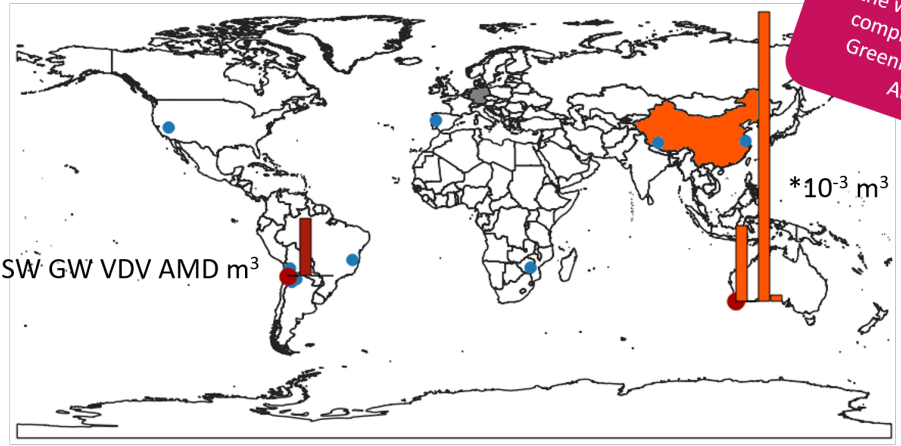
1 LiI-B 2,5 MWh

Mostert et al. 2018

60361 m^3

SW + GW, assessed with AWARE

WF of Li-ion battery



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