Supplementary Material ESM2, Water Resources Management

Marginal abatement cost curves for water scarcity mitigation under uncertainty

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Table 1 Estimates and assumptions for the Gotland cost curve assessment, distributions used are Log-normal LN (μ,σ) and Normal N (μ,σ)

Mitigation measure	Input variable	Unit	Estimate	Assumptions and references
Leakage detection	Potential	1000 m^3/year	LN (74,20)	Based on information on annual leakage losses (VASS, 2018) and a calculated infrastructure leakage index (ILI) (Lambert et al., 1999) for Gotland of 1.2, the theoretical potential of leakage reduction was calculated as the annual real losses minus the unavoidable annual real losses.
	Flow meters	kSEK/instrument	LN (145,20)	Cost estimates were based on Malm et al. (2015). A total of 63 district flow meters were assumed to be needed on Gotland. Useful life was set to 20 years.
	Drinking water production	SEK/m^3	LN (3.29,0.4)	Cost reduction due to lower drinking water production. Cost estimates were based on VASS (2015).
	Wastewater treatment	SEK/m^3	LN (3.54,0.4)	Lower costs for wastewater treatment due to less leakage from drinking water pipes entering wastewater pipes. 50% of the leakage was assumed to enter the wastewater pipes (Malm et al., 2015). Cost estimates were based on VASS (2018).
Desalination	Potential	1000 m^3/year	LN (1800,150)	The water availability potential was limited to approximately the 2045 forecasted demand for municipal water (County Administrative Board of Gotland, 2018).
	Treatment plant	MSEK	LN (125,10)	Cost estimates were based on expert judgement from Region Gotland. Useful life was set to 25 years.
	Technical components	MSEK	LN (60,6)	Cost estimates were based on expert judgement from Region Gotland. Useful life was set to 10 years.
	Membranes	MSEK	LN (60,6)	Cost estimates were based on expert judgement from Region Gotland. Useful life was set to 5 years.
	Pipes	MSEK	LN (190,30)	Cost estimates were based on expert judgement from Region Gotland. Useful life was set to 50 years.
	Energy costs	SEK/m^3	LN (3,0.7)	Cost estimates were based on expert judgement from Region Gotland.

Surface water extraction	Potential	1000 m^3/year	LN (378,50)	The water availability potential of increased surface water extraction was estimated based on expert judgement from Region Gotland.
	Technical components	MSEK	LN (15,3)	Cost estimates were based on expert judgement from Region Gotland. Useful life was set to 10 years.
Groundwater extraction	Potential	1000 m^3/year	LN (2000,400)	The water availability potential of increased groundwater extraction was estimated based on expert judgement from Region Gotland.
	Treatment plant	MSEK	LN (8.25,1.2)	Existing treatment plants can be used for treating some of the groundwater. Cost estimates for new treatment plants were based on expert judgement from Region Gotland. Useful life was set to 25 years.
	Technical components	MSEK	LN (8.25,1)	Cost estimates were based on expert judgement from Region Gotland. Useful life was set to 10 years.
	Pipes	SEK/m	LN (1000,300)	Cost estimates were based on expert judgement from Region Gotland. Useful life was set to 50 years.
	Groundwater wells	MSEK	LN (3,0.6)	Cost estimates were based on expert judgement from Region Gotland. Useful life was set to 50 years.
Artificial recharge	Potential	1000 m^3/year	LN (491,100)	The water availability potential of artificial recharge at 9 existing water supplies was estimated based on GIS-analysis in combination with information from Dahlqvist et al. (2017).
	Implementation	MSEK	LN (9,1)	Cost estimates were based on expert judgement from Region Gotland.
	Pipes	SEK/m	LN (1000,300)	Cost estimates were based on expert judgement from Region Gotland.
Wastewater for irrigation	Potential	1000 m^3/year	LN (600,100)	Improved wastewater treatment was assumed to be implemented in two wastewater treatment plants already connected to irrigation dams. The yearly volume treated in those plants is about 600 000 m^3.
	UV treatment etc	MSEK	LN (5,0.8)	Cost estimates were based on expert judgement from Region Gotland. Useful life was set to 10 years.
	Geotextile	SEK/m^2	LN (50,7)	The 7 current irrigation dams need new geotextiles, assumed need was 5 ha per dam. Cost estimates were based on Hidås and Malm (2010).
	Waste disposal	SEK/1000 kg	LN (450,50)	About 420 000 kg sludge was assumed to have accumulated on the old geotextile. Cost estimates for waste disposal was based on expert judgement from Region Gotland.
Rainwater harvesting	Potential	m^3/house & year	LN (35,4)	The average annual precipitation was assumed to be 550 mm (Region Gotland, 2017), the average roof area 100 m^2, and the run-off coefficient 0.8 (Environment Agency, 2010). Water availability potential was calculated according to methods described in Abdulla and Al-Shareef (2009). The potential was then adjusted based on estimates in Herbert and Erikson (2009).
	Number of vacation houses	# Houses	N (7000,800)	Investments in rainwater harvesting systems were assumed to be carried out in all houses with private water supply. All vacation houses were here assumed to have private water supply. Gotland has about 17,200 single family resident houses (Region Gotland, 2017), of which about 40% are vacation houses (Region Gotland, 2015).
	Number of permanent houses	# Houses	N (8000,800)	Investments in rainwater harvesting systems were assumed to be carried out in all single houses with private water supply. About 20,000 permanent residents on Gotland are supplied with water from their own well (County Administrative Board of Gotland, 2018). About 2.5 persons live in each house (Statistics Sweden, 2018).

	Installation	kSEK/house	LN (34,6)	Cost estimates for storage tank and installation was based on expert judgement. Useful life was set to 25 years.
	Treatment system	kSEK/system	LN (12,2)	Cost estimates for particle separation, carbon and UV treatment systems were based on information from technique providers.
	Pump	SEK/house	LN (5000,800)	Useful life was set to 25 years.
	UV reinvestment	MSEK/every 2 years	LN (24,2)	UV lamps were assumed to be replaced every other year, to a cost of 1600 SEK each.
	Particle & carbon reinvestment	MSEK/year	LN (14,1)	Particle and carbon filters were assumed to be replaced every year, to a cost of 150 and 790 SEK each.
Small scale desalination	Number of vacation houses	# Houses	N (550,200)	Investment in desalination was assumed to be carried out in all single houses on Gotland's west coast within 300 meters from the Baltic sea. The number of houses was estimated based on GIS analysis. The water consumption in vacation houses was assumed to be 157 liters per person per day (Statistics Sweden, 2017).
	Vacation house usage	person days/year	N (180,25)	The utilization of vacation houses was estimated to be on an average three persons over 60 days per year (Statistics Sweden, 2017).
	Number of permanent houses	# Houses	N (825,300)	Investment in desalination was assumed to be carried out in all single houses on Gotland's west coast within 300 meters from the Baltic sea. The east coast was considered too shallow for feasible raw water intake. The number of houses was estimated based on GIS analysis. About 2.5 persons live in each house (Statistics Sweden, 2018). The water consumption in permanent houses was assumed to be 140 liters per person per day (SWWA, 2018). The total water availability potential for small scale desalination was calculated by the input variables number of houses (permanent and vacation) times the estimated annual consumption in vacation and permanent houses respectively as described above.
	Raw water intake pipes	SEK/m	LN (1000,200)	300 meter pipes per house was assumed to be needed. Cost estimates was based on information from consultants. Useful life was set to 50 years.
	Pipes on land	SEK/m	LN (400,50)	On average 150 meter land based pipes per house was assumed to be needed. Cost estimates was based on information from consultants. Useful life was set to 50 years.
	Treatment system vacation houses	kSEK/house	LN (97,15)	Cost estimates for reversed osmosis treatment systems were based on information from technique providers. Cost for annual filter change was assumed to be 1600 SEK/system. Energy consumption was assumed to 15 SEK/m^3.
	Treatment system permanent houses	kSEK/house	LN (137,15)	Cost estimates for reversed osmosis treatment systems were based on information from technique providers. Cost for annual filter change was assumed to be 2500 SEK/system. Energy consumption was assumed to 7.5 SEK/m^3.
	RO reinvestment vacation house	kSEK/house	LN (14,2)	Pump and RO membrane were assumed to make up about 15% of investment cost. They were assumed to be replaced every 10 years in vacation houses.
	RO reinvestment permanent house	kSEK/house	LN (20,3)	Pump and RO membrane were assumed to make up about 15% of investment cost. They were assumed to be replaced every 7 years in permanent houses.
Vacuum toilets	Potential	m^3/capita & day	LN (0.3,0.01)	About 30 liters per capita and day was assumed to be used for toilet flushing (SWWA, 2018).
	Number of permanent residents	residents (thousands)	LN (25.7,2)	Investments in vacuum toilets were assumed to be carried out in all single houses. Gotland has about 17,200 single family resident houses (Region Gotland, 2015), of which about 60% are

				permanet houses (Region Gotland, 2015). About 2.5 persons live in each house (Statistics Sweden, 2018).
	Number of vacation houses	# Houses	N (7000,800)	Gotland has about 17,200 single family resident houses (Region Gotland, 2015), of which about 40% are vacation houses (Region Gotland, 2015).
	Vacation house usage	person days/year	N (180,25)	The utilization of vacation houses was estimated to be on an average three persons over 60 days per year (Statistics Sweden, 2017).
	Installation vacation houses	kSEK/house	LN (70,10)	Cost estimates were based on SwAM (2016). Useful life was set to 25 years.
	Installation permanent houses	kSEK/house	LN (89,10)	Cost estimates were based on SwAM (2016). Useful life was set to 25 years.
	Running costs	MSEK/year	LN (30,3)	Annual energy costs were assumed to be 20 SEK/house, waste collection was assumed to cost 1150 SEK/collection with an average 1.5 collections per year and house (SwAM, 2016).
Greywater reuse	Potential	m^3/capita & day	LN (1.2,0.01)	Estimates of produced greywater per capita and day was based on SwAM (2016).
	Number vacation houses	# Houses	N (7000,800)	Investments in greywater reuse systems were assumed to be carried out in all single houses with private water supply. All vacation houses were assumed to have private water. Gotland has about 17,200 single family resident houses (Region Gotland, 2017), of which about 40% are vacation houses (Region Gotland, 2015).
	Vacation house usage	Person days/year	N (180,25)	The utilization of vacation houses was estimated to be on an average three persons over 60 days per year (Statistics Sweden, 2017).
	Number permanent residents	Residents (thousands)	N (20,1.5)	About 20,000 permanent residents on Gotland are supplied with water from their own well (County Administrative Board of Gotland, 2018). About 2.5 persons live in each house (Statistics Sweden, 2018).
	Greywater system	kSEK/system	LN (39,4)	Cost estimates were based on information from technique providers. Useful life was set to 25 years.
	Installation	kSEK/system	LN (10,2)	Cost estimates were based on information from consultants.
	Storage tank	kSEK/tank	LN (14,2)	Cost estimates were based on information from consultants. Useful life was set to 25 years.
Sub irrigation (large scale)	Sub irrigated area	ha	N (30,6)	Estimates of sub irrigated area were based on GIS analysis of soil layers, elevation, water courses and land use. The water availability potential was calculated as the product of the input variables subirrigated area and irrigation demand.
	Implementation cost	kSEK/implementation	LN (500,100)	Based on the GIS analysis, 2 agricultural areas were judged as feasible for large scale sub irrigation One regulating construction per area was assumed to be needed. Cost estimates were based on expert judgement from The Federation of Swedish Farmers (LRF) on Gotland. Useful life of regulating constructions was set to 50 years.
	Permit	kSEK/permit	LN (500,60)	Estimates were based on expert judgement from LRF Gotland.
	Maintenance	SEK/regulated drain outlet & year	LN (500,100)	Estimates were based on expert judgement from LRF Gotland.
	Irrigation demand	m^3/year & ha	N (1250,200)	Estimates were based on expert judgement from LRF Gotland.
Sub irrigation (small scale)	Sub irrigated area	ha	N (1430,300)	Estimates of sub irrigated area was based on GIS analysis of soil layers, elevation, water courses and land use. The water availability potential was calculated as the product of the input variables subirrigated area and irrigation demand.

	Implementation cost	kSEK/implementation	LN (60,10)	Based on the GIS analysis, 28 agricultural areas were judged as feasible for small scale sub irrigation. Two regulating constructions per area was assumed to be needed. Cost estimates were based on expert judgement from LRF Gotland. Useful life of regulating constructions was set to 50 years.
	Application	SEK/application	LN (1350,100)	Cost of application to the County administrative board.
	Maintenance	SEK/regulated drain outlet & year	LN (500,100)	Estimates were based on expert judgement from LRF Gotland.
	Irrigation demand	m^3/year & ha	N (1250,200)	Estimates were based on expert judgement from LRF Gotland.
Irrigation dams	Potential	Mm3/year	LN (5,1)	The water availability potential was limited to the 2045 forecasted demand for irrigation water (County Administrative Board of Gotland, 2018).
	Excavation cost	SEK/m^3	LN (25,4)	Estimates were based on Hidås and Malm (2010) and expert judgement from LRF Gotland. To cover losses from evaporation, the total dam volume needed was increased with 20%. Excavation material was assumed to amount to 2/3 of dam volume. The average dam volume was assumed to be 70,000 m^3. Useful life of irrigation dams was set to 40 years.
	Consulting cost	kSEK/dam	LN (40,10)	Estimates were based on Hidås and Malm (2010).
	Irrigation assets	kSEK/asset	LN (700,100)	Estimates of pumps, machines and pipes were based on (SMHI, 2017). Useful life 10 years.
	Agricultural land value	kSEK/ha	LN (113,20)	Irrigation dams are often placed on arable land. Estimates of reduced land value was based on price statistics for arable land on Gotland for 2017 (Helin, 2018).
	Irrigation cost	SEK/ha	LN (360,50)	Estimates were based on Hansson (2012). The average land was assumed to be irrigated five times per year.
Ramp irrigation	Potential	1000 m^3/year	LN (625,100)	Water efficiency was assumed to increase from 70 to 82.5% when switching from traditional to ramp irrigation techniques on the current irrigated land. Estimates were based on Rosenqvist (2006).
	Investment	kSEK/machine	LN (210,40)	Estimates were based on Rosenqvist (2006). Useful life 10 years.
	Maintenance	kSEK/machine & year	LN (4, 0.5)	Increased maintenance cost estimates were based on Rosenqvist (2006).
	Moving cost	SEK/ha & year	LN (568,50)	Increased moving cost estimates were based on Rosenqvist (2006).
	Irrigation demand	m^3/year & ha	N (1250,200)	Estimates were based on expert judgement from LRF Gotland.
Reuse of mining drainage water	Potential	1000 m^3/year	LN (700,100)	Water availability potential was limited to the approximate amount of good quality drainage water currently being transported from one of the mines to the Baltic sea.
	Treatment plant	MSEK	LN (25,3)	Cost estimates were based on expert judgement from Region Gotland. Useful life was set to 25 years.
	Membrane	MSEK	LN (12,1)	Cost estimates were based on expert judgement from Region Gotland. Useful life was set to 7 years.
	Technical components	MSEK	LN (12,1)	Cost estimates were based on expert judgement from Region Gotland. Useful life was set to 10 years.
	Pipes	MSEK	LN (1,0.2)	About 1000 meter raw water pipes was assumed needed. Cost estimates were based on expert judgement from Region Gotland. Useful life was set to 50 years.
	Operating costs	MSEK/year	LN (2.4,0.2)	Operating costs were assumed to be about the same as regular surface water treatment, approximated to 3.5 SEK/m^3 based on VASS (2015).

Saltwater pools and toilets at campsites	Potential pools	m^3/campsite	LN (1000,150)	Gotland has 16 campsites, of which half are assumed to have pools. Water availability potential was based on from one of the local campsites.
	Installation pools	kSEK/campsite	LN (227,40)	Cost estimates was based on from one of the local campsites. Useful life was set to 25 years.
	Potential toilets	m^3/campsite	LN (1400,200)	Water availability potential was based on from one of the local campsites.
	Installation toilets	kSEK/campsite	LN (264,40)	Cost estimates was based on from one of the local campsites. Useful life was set to 25 years.
Retrofit showers and taps at hotels	Potential	m^3/room & year	LN (9,1)	Investments in water saving showerheads and taps were assumed to be carried out in all hotels on Gotland. There are in total 1,846 hotel rooms on Gotland (Statistics Sweden, 2018). The hotels connected to The Nordic Swan Ecolabel, with in total 469 hotel rooms, was excluded as they already had installed water saving devices. Water availability potential was based on water savings made in one of the local hotels.
	Installation	SEK/room	LN (363,50)	Cost estimates were based on information from one of the local hotels. Useful life was set to 25 years.
	Energy saving	SEK/room & year	LN (1200,150)	Energy saving estimates were based on information from one of the local hotels.

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