

## Supplementary information (Appendix)

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### A System Dynamics Approach to Management of Water Resources in Qatar

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#### Description:

This document serves as supplementary information, providing details of the SDM-based WRM DSS simulation model developed in the aforementioned research article.

**TABLE A1: Description of model variables; MCM (Million cubic meters).**

Data source for water parameter (PSA Qatar, 2021)

Variable	Description (equation, initial value, unit)
DW Inflow	= (DW Total Capacity); [unit= MCM/Year; type = Flow]
DW Outflow	= MIN ((Domestic Water Demand (DD) * 0.9314) + (Commercial Water Demand (CD)) + (Industrial Water Demand (ID)) + (Mega Reservoir Demand) + (Wells Recharge) + (DW Loss) + (0.1 * Evaporation) + (Government Water Demand (GD)), DW Inflow); [unit = MCM/Year; type = Flow]
DW Sea Lost	= MAX (DW Inflow - DW Outflow, 0); [unit = MCM/Year; type = Flow]
GW Inflow	= (Rainfall Recharge + Wells Recharge + TSE Injection); (unit = MCM/Year; type = Flow)
GW Outflow	= (Agriculture Water Demand (AD) * 0.7) + (DD * 0.0685) + (Evaporation * 0.4) + (GW Loss) + Lost GW Sea); [unit = MCM/Year; type = Flow]
Mega Reservoir Inflow	= (Mega Reservoir Demand); [unit = MCM/Year; type = Flow]
Mega Outflow	= (Emergency Water Demand); [unit = MCM/Year; type = Flow]
Sea Lost Mega Reservoir	= MAX (Mega Inflow - Emergency Demand, 0); [unit = MCM/Year; type = Flow]
TSE Inflow	= (TSE Procesed); [unit = MCM/Year; type = Flow]
TSE Outflow	= (TSE Injection + Environmental Water Demand (ED) + (0.3 * AD) + (0.5 * Evaporation) + TSE Loss); [unit = MCM/Year; type = Flow]
TSE Sea Lost	= MAX (TSE Inflow - TSE Outflow, 0); [unit = MCM/Year; type = Flow]
CD per capita	= INIT ((CD per capita) (t - dt) + (CD per capita change rate) (dt)); [unit = MCM/Capita; type = stock; initial value = 0.0000326087]
DD per capita	= INIT ((DD per capita) (t - dt) + (DD per capita change rate) (dt)); [unit = MCM; type = stock; initial value = 0.000106884]
Desalinated Water (DW)	= INIT ((DW) (t - dt) + (DW Inflow - DW Outflow - DW Sea Lost) (dt)); [unit = MCM; type = stock; initial value = 0]
ED per capita	= INIT ((ED per capita) (t - dt) + (ED per capita change rate) (dt)); [unit = MCM/Capita; type = stock; initial value = 0.000032087]
GD per capita	= INIT ((GD per capita) (t - dt) + (GD per capita change rate) (dt)); [unit = MCM/Capita; type = stock; initial value = 0.0000213913]
Groundwater (GW)	= INIT ((GW) (t - dt) + (GW Inflow - GW Outflow) (dt)); [unit = MCM; type = stock; initial value = 0]
ID per capita	= INIT ((ID per capita) (t - dt) + (ID per capita change rate) (dt)); [unit = MCM/Capita; type = stock; initial value = 0.0000105072]

Mega Reservoir	= INIT ((Mega Reservoir) (t - dt) + (Mega Reservoir Inflow - Mega Reservoir Outflow - Sea Lost of Mega Reservoir) (dt)); [unit = MCM; type = stock; initial value = 0]
Population	= INIT ((Population) (t - dt) + (Population change rate) (dt)); [unit = People; type = stock; initial value = 2760000]
Population change	= (Population * NORMAL (Population Growth Rate, Population Growth Rate/2), estimated); [unit = People/Year; type = Flow]
Surface Water (SW)	= INIT ((SW) (t - dt) + (SW Inflow - SW Outflow)(dt)) [unit = MCM; type = stock; initial value = 0]
Treated Sewage Effluent (TSE)	= INIT ((TSE) (t - dt) + (TSE Inflow - TSE Outflow - TSE Sea Lost) (dt)); [unit = MCM; type = stock; initial value = 0]
Agriculture Water Demand (AD) <i>change</i>	= 1 (note: 1 meant "as is", no change in BAU policy "A") [unit = Dimensionless; type = converter; initial value = 1]
Additional DW capacity	= (DW change * DW Plant Capacity); [unit = MCM/Year; type = converter]
Additional TSE capacity	= (TSE Capacity * TSE change); [unit = MCM/Year; type = converter]
Agriculture Demand (AD)	= (AD change * (311)); [unit = MCM/Year; type = converter]
Baseline population	= (2760000 (PSA Population, 2021)); [unit = People; type = converter; initial value = 2760000]
Commercial Water Demand (CD)	= (CD per capita * Population) + (CD per capita * Tourists); [unit = MCM/Year; type = converter]
Domestic Water Demand (DD)	= (DD per capita * Population); [unit = MCM/Year; type = converter]
DW Loss	= ((DD + ID + CD) * 0.06); [unit = MCM/Year; type = converter]
DW Plant Capacity	= (671); [unit = MCM/Year; type=converter; initial value = 671]
DW Total Capacity	= (DW Plant Capacity + STEP (Additional DW capacity, "time of inflow of DW additional capacity")); [unit = MCM/Year; type = converter]
Emergency Water Demand	= 0; [unit = MCM/Year; type = converter; initial value = 0]
Environmental Water Demand (ED)	= ((ED per capita * Population) + (ED per capita * Tourists)); [unit = MCM/Year; type = converter]
Evaporation	(25.5 (Bilal et al., 2021)); [unit = MCM/Year; type = converter; initial value = 25.5]
GDP increase	= (0.027 (International Monetary Fund, 2022) ) [unit = Dimensionless; type = converter; initial value = 0.027]
Government Water Demand (GD)	= (GD per capita * Population); [unit = MCM/Year; type = converter]

GW Loss	= (0.06 * AD); [unit = MCM/Year; type = converter]
Industrial Water Demand (ID)	= (ID per capita * Population); [unit = MCM/Year; type = converter]
Lost GW Sea	= (18 (Abbas et al., 2023; PSA Qatar, 2021)); [unit = MCM/Year; type = converter; initial value = 18]
Mega Reservoir Demand	= (14 (Saleem et al., 2023)); [unit = MCM/Year; type = converter; initial value = 14]
Population Growth Rate	= ((Increase Rate Population - Decrease Rate Population) + Residential Utility); [unit = Dimensionless; type = converter]
Decrease Rate Population	= (average value of 0.0013); [unit = Dimensionless; type = converter; initial value = 0.0013]
Increase Rate Population	= (average value of 0.012); [unit = Dimensionless; type = converter; initial value = 0.012]
Rainfall Recharge	= (46); [unit = MCM/Year; type = converter; initial value = 46]
Runoff Rainfall	= (1.15 (Bilal et al., 2021)); [unit = MCM/Year; type = converter; initial value = 1.15]
Total TSE Plant Capacity	= (TSE capacity + STEP (Additional TSE capacity, "inflow time of TSE additional capacity")); [unit = MCM/Year; type = converter]
Total Water Consumption	= (TSE Outflow + GW Outflow + DW Outflow); [unit = MCM/Year; type = converter]
Total Water Demand	= (DD + GD + ED + CD + ID + AD); [unit = MCM/Year; type = converter]
Total Water Supply	= ((TSE Inflow) + (GW Inflow) + (DW Inflow)); [unit = MCM/Year; type = converter]
Tourists	= (178334 (Qatar Tourism, 2022)); [unit = People; type = converter; initial value = 178334]
TSE capacity change	= 1 (note: 1 meant "as is", no change in BAU policy "A") [unit = Dimensionless; type = converter; initial value = 1]
TSE treatment capacity	= (360); [unit = MCM/Year; type = converter; initial value = 360]
TSE collected	= NORMAL ((GD + DD + ID + CD) * 0.60), (GD + DD + ID + CD) * 0.02), estimated); [unit = MCM/Year; type = converter]
TSE injection	= (78); [unit = MCM/Year; type = converter; initial value = 78]
TSE processed	= MIN (TSE Collected * 0.997, Total TSE Capacity * 0.997); [unit = MCM/Year; type = converter]
Wells Recharge	= (80); [unit = MCM/Year; type = converter; initial value = 80]
Water Sustainability Index (WSI)	= (Total Water Supply / Total Water Demand, (Li et al., 2019)); [unit = Dimensionless; type = converter]

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