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Concentrate Management Toolbox

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MSSC - 2/28/19

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Toolbox

Why is it important?

Evaluate existing technologies

- Catalog of available technologies
- Open platform
- Identify technologies and research gaps

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Toolbox

What is it?

Subjective assessment

- Many choices in CM Technologies
  - No existing comparison
- Existing technologies
  - Not sustainable
  - Expensive
  - Difficult to implement

Planning level tool

"Apples to Apples" Comparison of Concentrate Treating Technologies

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Toolbox Overview

- Assessment Sheets
  - Constraints
  - Criteria
  - Peer reviewed
- Toolbox
  - Compilation of assessment sheets
  - Guidance or planning level
  - Excel based

Toolbox Overview

- Technology Description and Comparison
  - Subjective
  - Literature Based
  - Open Platform
- Not an assessment of proprietary technology
  - Literature not available
  - Limited data, expertise and knowledge
  - Proprietary technology will be added to technology assessment

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Assessment Sheet

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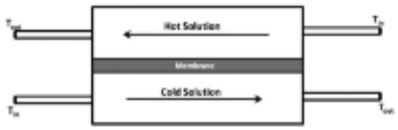
U.S. Department of the Interior
Bureau of Reclamation

Direct Contact Membrane Distillation (DCMD)

Membrane distillation utilizes membranes and a vapor pressure driving force to produce distillate. Membrane distillation provides improved distillate production (more water production with a lower energy input) compared to traditional thermal distillation. Membrane distillation can be used as a primary desalination method, however, because distillate production is less dependent on feed water salinity than conventional membrane desalination, it may be best suited to secondary desalination specifically tailored to concentrate desalination.

1.0 Technology Description

Condensation of water vapor on the permeate side of the membrane is required for membrane distillation. There are various configurations that condense this vapor and in the DCMD configuration, a cooler liquid is in direct contact with the membrane on the permeate side of the membrane. This results in water vapor going through the membrane and condensing in the cooler liquid.

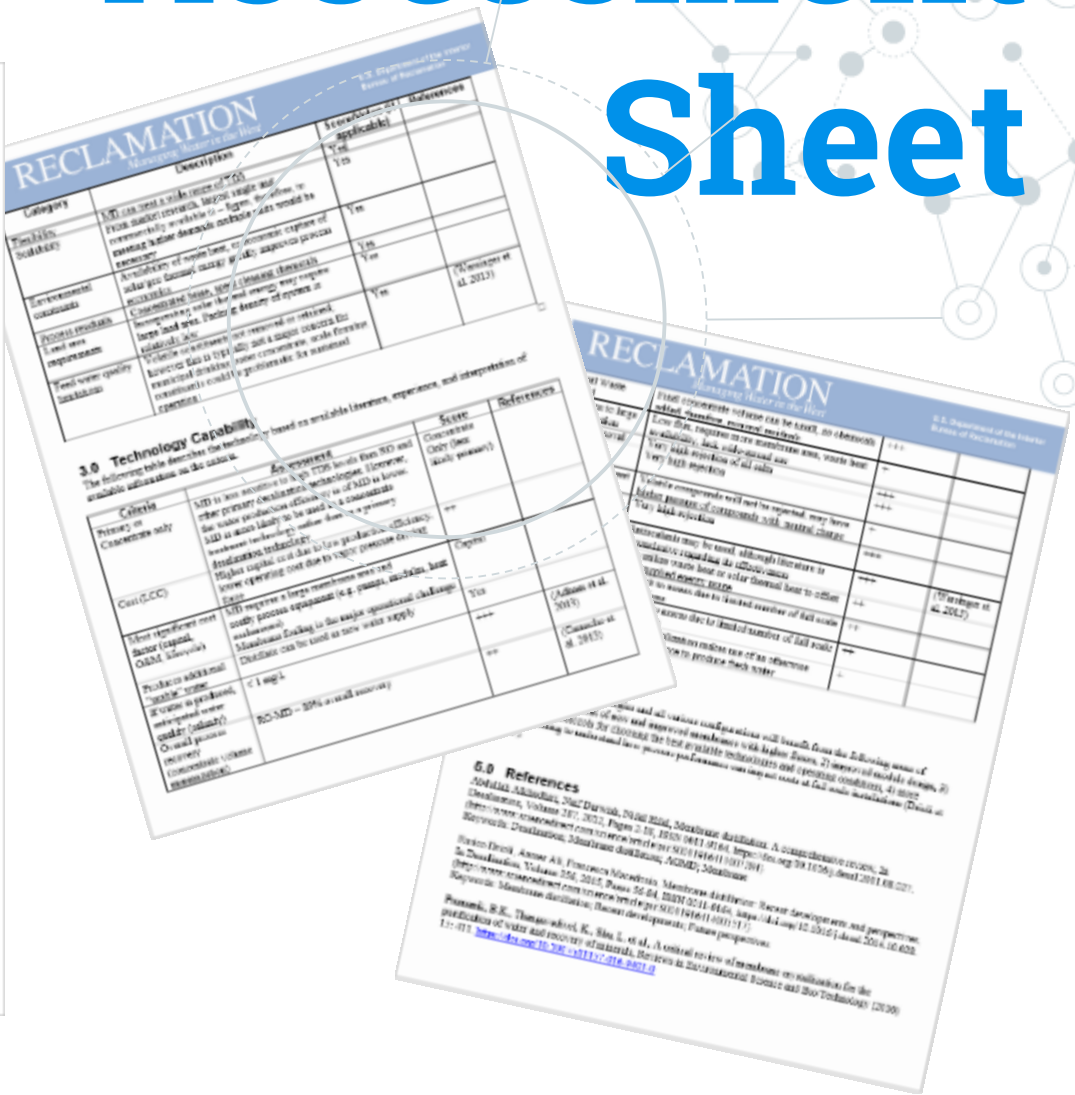


DCMD Configuration - A. Alkhudhiri et al. / Desalination 287 (2012) 2–18

2.0 Technology Constraints

The following table describes some of the usage constraints that may limit the applicability of the technology to certain applications. The answers to these questions are used to eliminate technologies from future consideration.

Category	Description	Score/Value (if applicable)	References
Greenfield or bolt-on Integrated into primary desal facility?	When used as a concentrate treatment process, MD does not need to be integrate during initial design.	Bolt-On	
Technology maturity	DCMD is the most mature configuration of MD currently.	7	Alkhudhiri et al 2012 Thomas, N et al 2017 Mickley 2018



Assessment Sheets

- Describes the technology
  - Literature
  - Experience
  - Interpretation of available information

- Sections
  - Description
  - Constraints
  - Capability
  - Research Needs
  - References

Technology Constraints

Reduce potential viable technologies

- Use input

Constraints
Greenfield or bolt-on?
Technology maturity
Flexibility
Scalability
Environmental constraints
Process residuals
Land Area Availability

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Constraints
Greenfield or bolt-on?
Technology maturity
Flexibility
Scalability
Environmental constraints
Process residuals
Land Area Availability

Technology Constraints

Technology Maturity

Eliminate based on user need

TRL Status Groupings

- 1-4, Concept development, bench scale
- 5-7, Pilot and demonstration
- 8-9, Full scale

TRL 1 Basic principles observed and reported (idea d … cteristics and behaviors of systems and architectures. Descriptive tools are mat
TRL 2 Technology concept and/or application formul … are focused on specific application area to define the concept. Characteristi … analysis of the application.
TRL 3 Analytical and experimental critical function and/or characteristic proof-of concept (bench scale): Proof of concept validation. Active Research and Development (R&D) is initiated with analytical and laboratory studies.
TRL 4 Component/subsystem validation in laboratory environment (bench scale): Standalone prototyping implementation and test. Integration of technology elements. Experiments with full-scale problems or data sets.
TRL 5 System/subsystem/component validation in relevant environment (pilot testing): Thorough testing of prototyping in representative environment; pilot testing. Basic technology elements integrated with reasonably realistic supporting elements. Prototyping implementations conform to target environment and interfaces.
TRL 6 System/subsystem model or prototyping demonstration in a relevant end-to-end environment (pilot testing): Prototyping implementations on full-scale realistic problems. Partially integrated with existing systems. Limited documentation available. Engineering feasibility fully demonstrated in actual system application.
TRL 7 System prototyping demonstration in an operational environment (demonstration testing): System prototyping demonstration in operational environment. System is at or near scale of the operational system, with most functions available for demonstration and test. Well integrated with collateral and ancillary systems. Limited documentation available.
TRL 8 Actual system evaluated through test and demonstration in an operational environment: End of system development. Fully integrated with operational hardware and software systems. Most user documentation, training documentation, and maintenance documentation completed. All functionality tested in simulated and operational scenarios. Verification and Validation (V&V) completed.
TRL 9 Technology has been used successfully at full-scale use: Fully integrated with operational hardware/software systems. Actual system has been thoroughly demonstrated and tested in its operational environment. All documentation completed. Successful operational experience.
TRL Status Groupings:
Concept development Bench Scale Testing: 1-4
Pilot and Demonstration Testing: 5-7
Full Scale: 8-9

Technology Constraints

Scalability

Process redesign/modification based on change in flowrate

Constraints
Greenfield or bolt-on?
Technology maturity
Flexibility
Scalability
Environmental constraints
Process residuals
Land Area Availability

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Technology Capability

Scores used for ranking

Evaluated by reviewer

- -/+/++/+++

Weighted by user

Capability	
Technology Readiness Level	Heavy metals removal
Cost (LCC)	Organic contaminant removal
Produces additional “usable” water	Radionuclide removal
If water is produced, anticipated water quality (salinity)	Low chemical demand
Overall process recovery (concentrate volume minimization)	Energy demand
Residual Waste Disposal	Labor requirements
Limitations to large scale utilization	Reliability
Hardness removal	Value added

Technology Capability

Produces Additional “usable" water

- +++ Additional water produced
- - Concentrate volume reduced; no water produced

Capability	
Technology Readiness Level	Heavy metals removal
Cost (LCC)	Organic contaminant removal
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Technology Capability

If water is produced, anticipated water quality (salinity)

Anticipated product water salinity

- +++ Less than 500 mg/L
- ++ 500 to 1000 mg/L
- + 1000 to 2000 mg/L
- - more than 2000 mg/L

Capability	
Technology Readiness Level	Heavy metals removal
Cost (LCC)	Organic contaminant removal
Produces additional “usable” water	Radionuclide removal
If water is produced, anticipated water quality (salinity)	Low chemical demand
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Residual Waste Disposal	Labor requirements
Limitations to large scale utilization	Reliability
Hardness removal	Value added

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Technology Capability

Labor requirements

Operator oversight needed

- +++ Little or no operator oversight
- ++ Trained operator onsite at all times
- + Level (A) operator to be onsite at all times
- - System complexity is considered prohibitive, 24x7x365 top level (A) dedicated operator

Capability	
Technology Readiness Level	Heavy metals removal
Cost (LCC)	Organic contaminant removal
Produces additional “usable” water	Radionuclide removal
If water is produced, anticipated water quality (salinity)	Low chemical demand
Overall process recovery (concentrate volume minimization)	Energy demand
Residual Waste Disposal	**Labor requirements**
Limitations to large scale utilization	Reliability
Hardness removal	Value added

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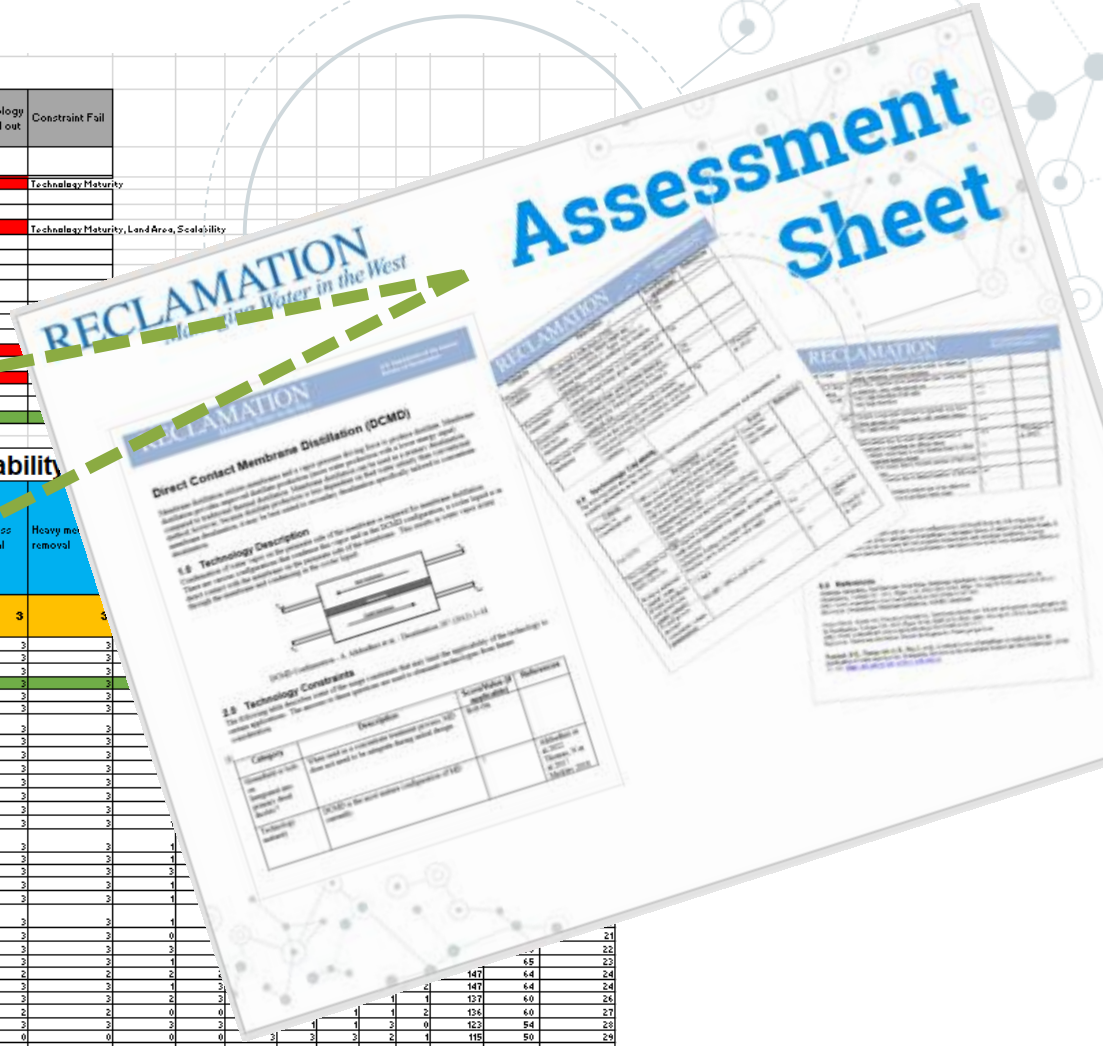
Toolbox

Technology Constraints

Technology	Greenfield or bolt-on? Integrated into primary desal facility?	Technology maturity	Flexibility	Scalability	Environmental constraints	Process residuals	Land Area Requirements	Feed water quality limitations	Technology filtered out	Constraint Fail
NTMWD Requirement (as described in 'User input -	Primary or Bolt on	6 or above	No	Yes	Yes	Yes	No	No		
AgueSol	Bolt-on	5	Yes	Yes	Yes	Yes	Yes	No	Yes	Technology Maturity
Brine Cryztallizer	Bolt-On	9	Yes	Yes	Yes	Yes	Yes	Yes		
CDI	Bolt-on	7	Yes	Yes	Yes	Yes	Yes	Yes		
Direct Solar Vapor	Bolt-On	3	Yes	No	No	Yes	No	Yes	Yes	Technology Maturity, Land Area, Scalability
Removal	Bolt-On	7	Yes	Yes	Yes	Yes	Yes	Yes		
Dual RO with Pellet Reactor	Bolt-On	7	Yes	Yes	Yes	Yes	Yes	Yes		
Dual RO with SPARRO	Bolt-On	7	Yes	Yes	Yes	Yes	Yes	Yes		
Dual RO with precipitation	Bolt-On	6	Yes	Yes	Yes	Yes	Yes	Yes		
DWI	Bolt-On	9	Yes	Yes	Yes	Yes	Yes	Yes		
ED	Bolt-on	9	Yes	Yes	Yes	Yes	Yes	Yes		
ED with SPARRO	Bolt-On	7	Yes	Yes	Yes	Yes	Yes	Yes		
EDM	Bolt-on	5	Yes	Yes	Yes	Yes	No	Yes	Yes	
ED with gypsum precipitation	Bolt-On	6	Yes	Yes	Yes	Yes	Yes	Yes		
FO	Bolt-On	8	Yes	Yes	No	Yes	Yes	No	Yes	
HDH	Bolt-On	5	Yes	Yes	Yes	Yes	Yes	Yes		
HEED	Bolt-on	7	Yes	Yes	Yes	Yes	Yes	Yes		
MD	Bolt-On	7	Yes	Yes	Yes	Yes	Yes	Yes		

Technology Capability

Technology	Primary desalination or concentrate only	Cost (LCC)	Most significant cost factor (capital, O&M, lifecycle)	Produces additional "usable" water	If water is produced, anticipated water quality (salinity)	Overall process recovery (concentrate volume minimization)	Residual Waste Disposal	Limitations to large scale utilization	Hardness removal	Heavy metal removal
Weight (as described in 'User input - NTMWD' worksheet)	NA	2	NA	7	5	3	5	9	3	3
MD - Crystallization	Concentrate Only	1	Capital	3	3	3	3	1	3	3
Vapor Compression	Primary or	1	Capital	3	3	3	2	1	3	3
MD	Concentrate Only	2	Capital	3	3	2	3	1	3	3
MD-Direct Contact	Concentrate Only	2	Capital	3	3	2	3	1	3	3
RO - CCD	Concentrate Only	2	Capital	3	3	3	3	2	3	3
HEED	Primary or	2	Capital	3	3	3	1	2	3	3
ED with gypsum precipitation	Concentrate Only	1	Capital	3	3	2	2	2	3	3
Brine Cryztallizer	Primary or	0	Capital	3	3	3	2	2	3	3
ED with SPARRO	Concentrate Only	1	Capital	3	3	2	2	2	3	3
MED	Concentrate	1	Capital	3	3	1	2	2	3	3
AgueSol	Concentrate Only	1	Capital	3	3	3	2	1	3	3
Parapertation	Concentrate	2	Capital	3	3	1	2	1	3	3
RO-ED	Concentrate Only	1	Capital	3	3	2	2	2	3	3
MD - Vacuum	Concentrate Only	1	Capital	3	3	2	3	1	3	3
MD-Air Gap	Concentrate Only	1	Capital	3	3	2	3	1	3	3
MD-Sweep Gas	Concentrate Only	1	Capital	3	3	2	3	1	3	3
MSF	Primary or	1	Capital	3	3	2	2	1	3	3
Dual RO with Pellet Reactor	Concentrate Only	1	Capital	3	3	2	3	2	3	3
Dual RO with SPARRO	Concentrate Only	1	Capital	3	3	2	3	2	3	3
RO of Intermediate Biological Reduction of Sulfate	Concentrate Only	1	Capital	3	3	2	3	2	3	3
ED	Concentrate	1	Capital	3	2	2	2	2	3	3
HDH	Concentrate Only	2	O&M	2	3	2	2	1	3	3
Dual RO with precipitation	Concentrate Only	1	Capital	3	3	2	2	2	3	3
WAIV - Membrane Cryztallizer	Concentrate Only	2	Capital	2	2	2	2	1	2	2
Dual RO with IX for Silica	Concentrate Only	1	Capital	3	3	2	2	1	3	3
FO	Concentrate Only	1	Capital	3	3	3	2	0	3	3
EDM	Concentrate Only	2	Lifecycle	3	1	3	1	3	2	2
DWI	Concentrate Only	2	Capital	0	0	0	3	2	3	3
WAIV	Concentrate Only	3	Capital	0	0	2	2	1	0	0
CDI	Concentrate	1	Capital	1	3	1	2	1	2	1
Solvent Extraction	Concentrate Only	1	LCC	1	2	2	1	1	3	2
Direct Solar Vapor	Concentrate	0	LCC	1	3	0	1	0	3	3



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	Technology Constraints									
7	Technology	Greenfield or bolt-on? Integrated into primary desal facility?	Technology maturity	Flexibility	Scalability	Environmental constraints	Process residuals	Land Area Requirements	Feed water quality limitations	Technology filtered out	Constraint Fail
8	NTMWD Requirement (as described in 'User input - NTMWD' worksheet)	Primary or Bolt on	6 or above	No	Yes	Yes	Yes	No	No		
9	AquaSel	Bolt-on	5	Yes	Yes	Yes	Yes	Yes	No	Yes	Technology Maturity
10	Brine Crystallizer	Bolt-On	9	Yes	Yes	Yes	Yes	Yes	Yes		
11	CDI	Bolt-on	7	Yes	Yes	Yes	Yes	Yes	Yes		
12	Direct Solar Vapor	Bolt-On	3	Yes	No	No	Yes	No	Yes	Yes	Technology Maturity, Lan
13	Dual RO with IX for Silica Removal	Bolt-On	7	Yes	Yes	Yes	Yes	Yes	Yes		
14	Dual RO with Pellet Reactor	Bolt-On	7	Yes	Yes	Yes	Yes	Yes	Yes		
15	Dual RO with SPARRO	Bolt-On	7	Yes	Yes	Yes	Yes	Yes	Yes		
16	Dual RO with precipitation	Bolt-On	8	Yes	Yes	Yes	Yes	Yes	Yes		
17	DWI	Bolt-On	9	Yes	Yes	Yes	Yes	Yes	Yes		
18	ED	Bolt-on	9	Yes	Yes	Yes	Yes	Yes	Yes		
19	ED with SPARRO	Bolt-On	7	Yes	Yes	Yes	Yes	Yes	Yes		
20	EDM	Bolt-on	5	Yes	Yes	Yes	Yes	No	Yes	Yes	Technology Maturity
21	ED with gypsum precipitation	Bolt-On	8	Yes	Yes	Yes	Yes	Yes	Yes		
22	FO	Bolt-On	8	Yes	Yes	No	Yes	Yes	No	Yes	Environmental Contraints
23	HDH	Bolt-On	5	Yes	Yes	Yes	Yes	Yes	Yes		
24	HEED	Bolt-on	7	Yes	Yes	Yes	Yes	Yes	Yes		
25	MD	Bolt-On	7	Yes	Yes	Yes	Yes	Yes	Yes		
26	MD - Crystallization	Bolt-On		Yes	Yes	Yes	Yes	Yes	Yes		
27	MD - Vacuum	Bolt-On		Yes	Yes	Yes	Yes	Yes	Yes		

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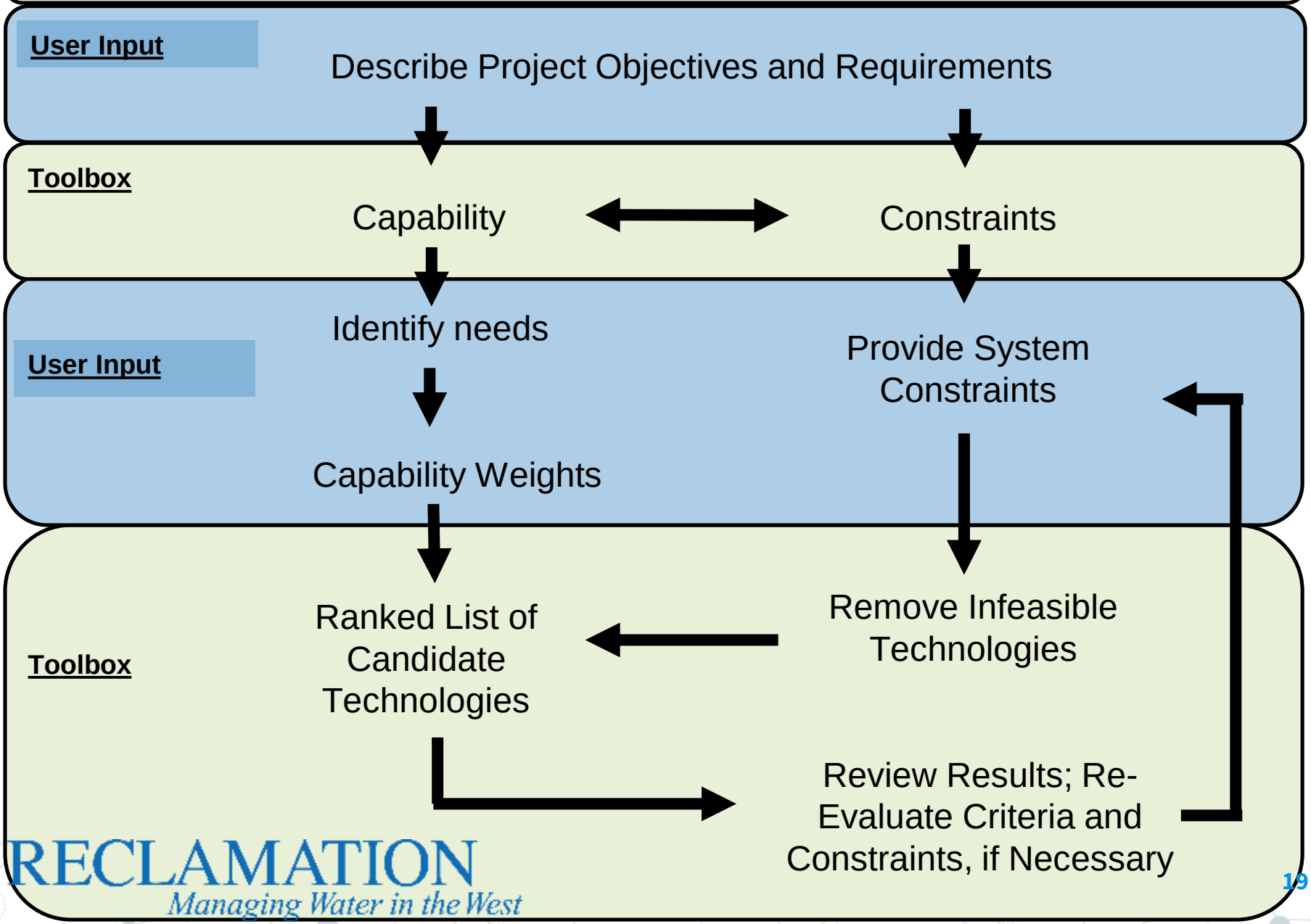
Technology Capability							
Technology	Technology Readiness Level	Cost (LCC)	Produces additional "usable" water	If water is produced, anticipated water quality (salinity)	Technology Score	Technology Score (normalized to 100)	Technology Rank for being a solution for NTMWD
Weight (as described and changed in 'User Input' worksheet)	**10**	**1**	**7**	**5**	**210**	**100**	**Rank**
Vapor Compression	7	1	3	3	185	88	1
MED	9	1	3	3	185	88	2
Brine Crystallizer	9	0	3	3	184	88	3
ED with gypsum precipitation	8	1	3	3	183	87	4
RO - CCD	7	2	3	3	182	87	5
MD	7	2	3	3	177	84	6
MD-Direct Contact	7	2	3	3	177	84	6
ED with SPARRO	7	1	3	3	176	84	8
MSF	9	1	3	3	176	84	9
Dual RO with precipitation	8	1	3	3	171	81	10
HEED	7	2	3	3	169	81	11
ED	9	1	3	2	168	80	12
MD - Vacuum	6	1	3	3	166	79	13
MD-Air Gap	6	1	3	3	166	79	13
MD-Sweep Gas	6	1	3	3	166	79	13
Pervaporation	4	2	3	3	162	77	16

Concentrate Toolbox Data Flow Diagram



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Toolbox output

Technology assessment sheets

Recommended list of technologies based on end-user input

Verification of end-user selection(s)

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Beyond Toolbox

Desktop study on toolbox recommended technology

Piloting of recommended technologies

- Performance testing
- Cost estimation


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