Wind Energy Powered Desalination Plant

Presented by Winsal, a Partnership between Azari & GrahamTek

POWERPOINT PRESENTATION

Our Vision

- We believe in:
  - Making a real difference
  - Rethinking what has been done before
  - Taking control of our future
  - Creating something bigger than ourselves

- Water and energy are fundamental human needs
- Together we envisage a world where these needs are 100% sustainably fulfilled

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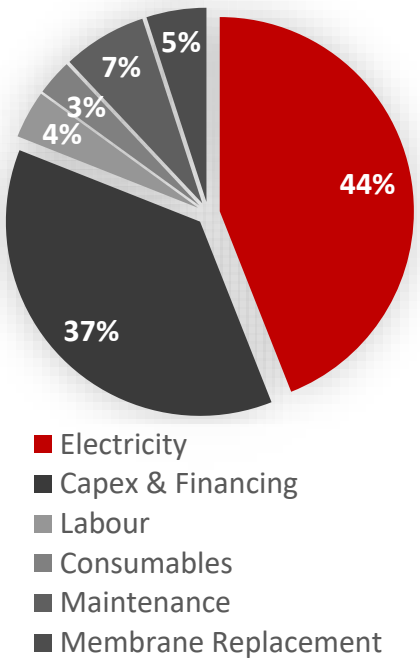
Introduction

- Winsal was conceived out of Azari Wind Energy and GrahamTek to make desalination more **environmentally attractive** and **decrease water production costs**
- Costs of produced water are largely **determined by electricity costs** - approx. 3.5 – 5.0 kWh/m^3 for modern RO plants with energy recovery
- The Winsal concept and technology is based on making **RO plants work with variable renewable energy** by incorporating **advanced controls** and **turndown capabilities** of the RO units
- **Wind energy** is converted into produced water and **stored in the produced water tanks** to be available for periods when there is less or no wind energy available
- **Energy** is therefore **stored** in the form of produced water to be **available later when there is less or no wind**



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Company Profiles

azari wind
innovation made sustainable

- Construction, operations, maintenance and repairs of wind turbines
- Project management, port and transport works, site crane and installation services
- Established in 2013
- **Successfully installed more than 400 wind turbines**

GrahamTek™

- Manufacturing, marketing and distribution of desalination water treatment systems
- Patented 16-inch RO membranes
- Chemical-free RO processes
- Established in 1994
- **Successfully completed more than 130 projects in 16 countries**

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- Wind-powered desalination developer
- Turnkey solutions
- Grid-tied & off-grid plant options
- Sustainable production of potable water using RO plants designed for renewable energy variability
- Power production using wind turbines

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Why use Wind-Powered RO Desalination?

Desalination: Reverse Osmosis (RO)

- High pressure membrane filtration method to remove salts from water, producing potable water from seawater or brackish water
- Low energy consumption (4 – 6 kWh/m^3) compared to thermal desalination (14 – 27 kWh/m^3)
- Mature technology
- 65% of the world's desalinated water is produced using RO

GrahamTek™ winsal

Why use Wind-Powered RO Desalination?

Renewable Energy: Wind

- Most arid location have high wind resources
- Sustainable technology
- Low capital cost of refurbished wind turbines
- Low land-use (0.4 ha/MW) compared to solar (2 – 4 ha/MW)
- Levelized cost of water = **2 – 3 SAR/m³ (0.5 – 0.8 USD/m³)**

Why use Wind-Powered RO Desalination?

Power Supply Alternatives

- Grid power
  - Additional load on power utility
  - Grid power is primarily produced from fossil fuels and unsustainable
- Solar PV
  - Levelized cost of water = **5 – 6 SAR/m³ (1.3 – 1.6 USD/m³)**
  - High land-use (2 – 4 ha/MW)
  - High intermittence of power (zero solar power during the night)
- Geothermal
  - High capital cost
  - Restricted to very specific locations with geothermal activity
- Wave
  - Potentially competitive with wind power
  - Technology is still at the R&D and demonstration stages

Winsal Technology

- Technology Description
- Schematic
- Deployment Options

Technology Description

- Complete turnkey solution for water and power production
- 2.0 MW wind turbines supply power to the RO plant
- GrahamTek proprietary 16-inch RO membrane vessels
- The entire RO plant is modular and containerized
  - Various module sizes producing 1000, 2000 and 4500 m^3 potable water per day
  - Containerized units (RO, MCC, substations) allow easy FAT and fast installation onsite
- Special RO plant design to handle variability in wind speed
  - Energy recovery done with a motor-driven turbocharger, power turndown of 15% per unit
  - Smart control system to balance RO production with power available from the wind turbines
  - Automated flushing procedure of RO membranes during shut down of a module – increase membrane life
  - Power management system to integrate power from wind turbines, grid and other optional sources such as solar panels
  - Storage of produced water to supply water if wind speed is too low for continuous production
- The entire plant is automated and remotely monitored with no permanent onsite staff

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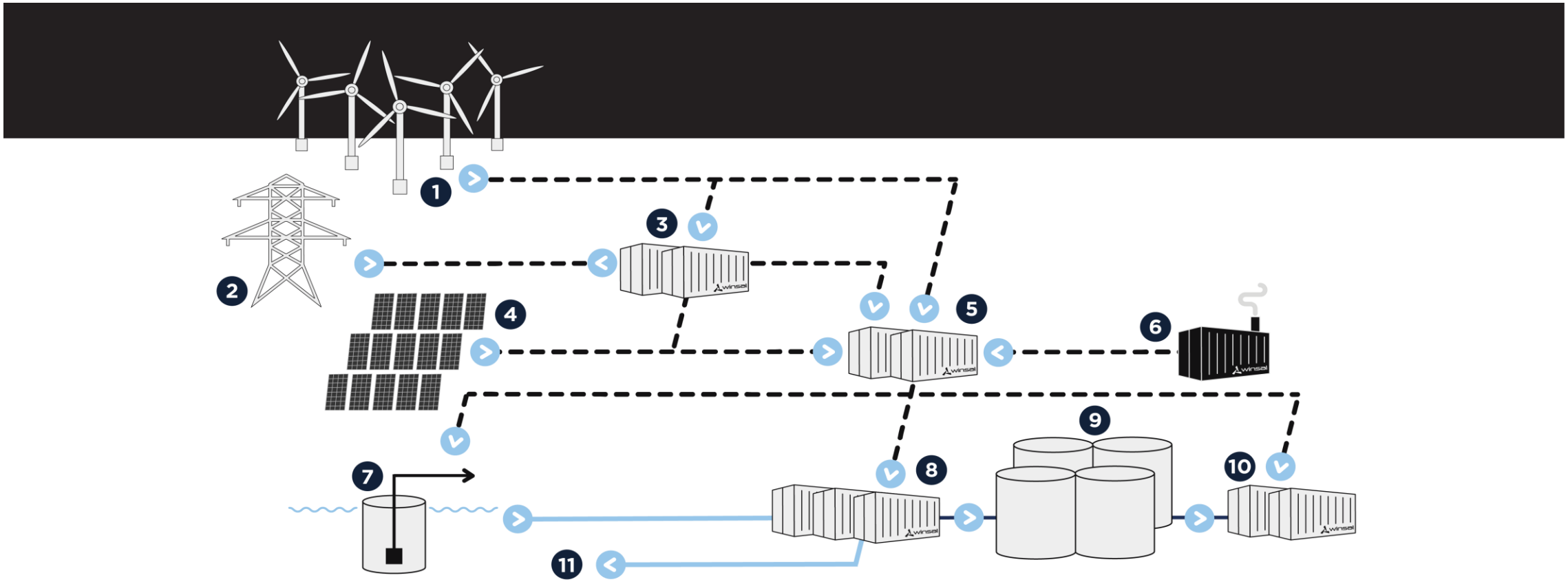
Winsal Schematic



1. WIND TURBINES
2. ELECTRICAL GRID
   (GRID-TIED OPTION ONLY)
3. METERING UNIT
   (GRID-TIED OPTION ONLY)
4. SOLAR PV PANELS (fixed and seasonally adjusted)
   (OPTIONAL ADDITION TO ACT AS SUPPLEMENTARY POWER FOR LOW WIND PERIODS)
5. POWER SUPPLY MANAGEMENT SYSTEM
6. EMERGENCY GENERATOR
   (OFF-GRID OPTION ONLY)
7. FEED WATER INTAKE
   (TRADITIONAL INTAKE METHODS OR WAVE PUMP ENERGY

8. REVERSE OSMOSIS DESALINATION PLANTS
9. PRODUCT WATER STORAGE
10. CLIENT WATER OFF TAKE MODULE
11. BRINE DISCHARGE INTO THE SEA

- ELECTRICAL SUPPLY
- SEAWATER/BRINE
- FRESH WATER FLOW

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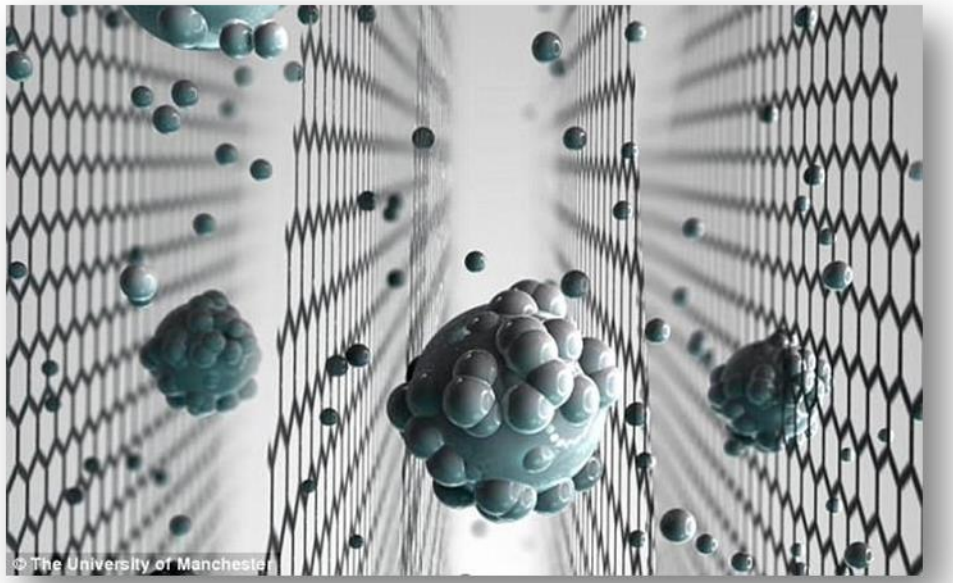
Deployment Options

Demonstration plant

- Water priority
  - Typical size: 2000 – 9000 m^3/day + 2 – 8 MW wind
    - Grid-tied with electricity export
    - Off-grid standalone – Water supply only
- Water and power
  - Typical size: 2000 – 9000 m^3/day + 20 MW wind
    - Grid-tied with electricity export



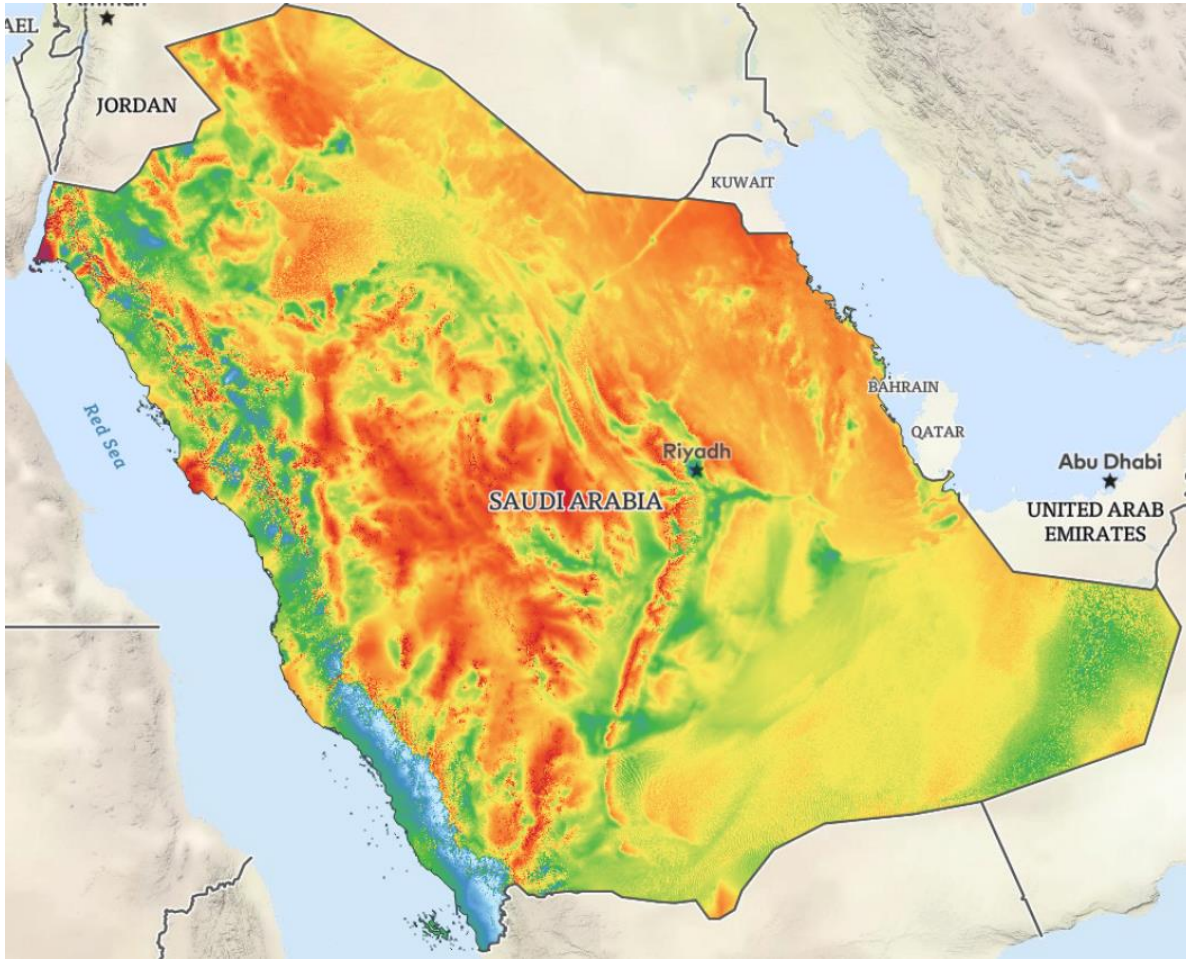
Large scale plant

- Typical size: 150 000 m^3 /day + 150 MW wind
  - Grid-tied with electricity export
  - Off-grid standalone possible
  - Benefits from economies of scale – lower produced water & power cost

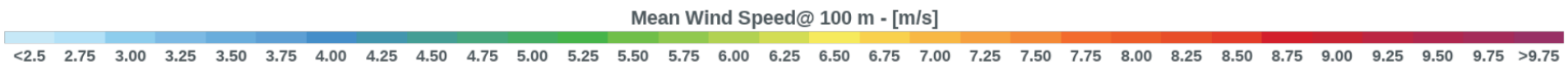
Winsal Solutions for Saudi Arabia

- Wind Resources
- Financial and Project Assumptions
- Indicative Economics

Wind Resources of Saudi Arabia



- Modelled wind data from Global Wind Atlas
- Modeling done by combination of reanalysis, mesoscale, generalization and microscale modeling
- Resolution is a 250m x 250m grid
- Wind speed has modelled at various heights of 10m, 50m, 100m, 150m and 200m
- Average seasonal and hourly wind speed variability has also been modelled

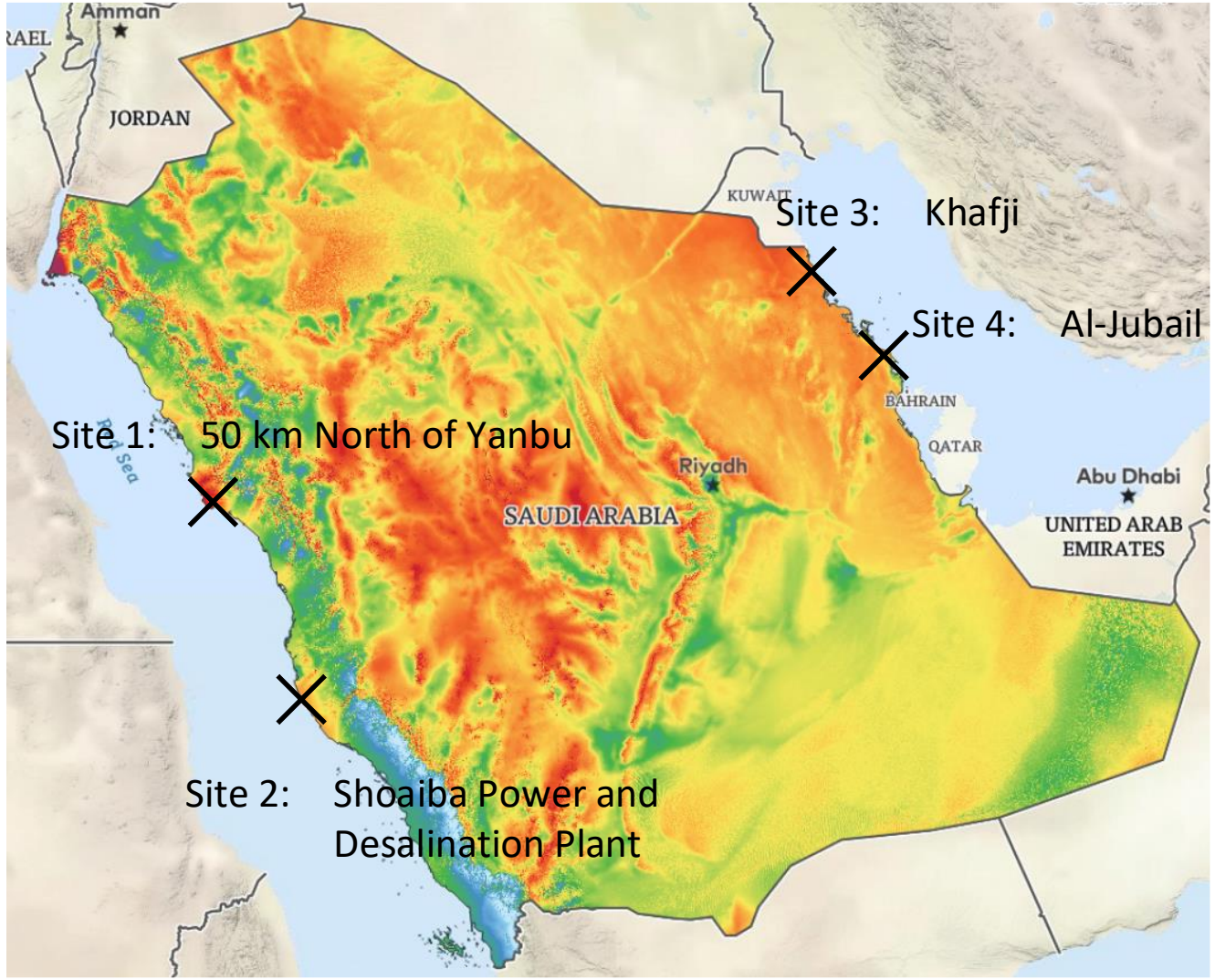


Reference: https://globalwindatlas.info/

Potential Wind-Powered RO Sites

Site	Site Description	Mean Wind Speed at 100m [m/s]
1	50km North of Yanbu	8.94
2	Shoaiba Power and Desalination Plant	7.27
3	Khafji	7.82
4	Al-Jubail	7.32

- There is also the potential of brackish water desalination with inland boreholes around Riyadh



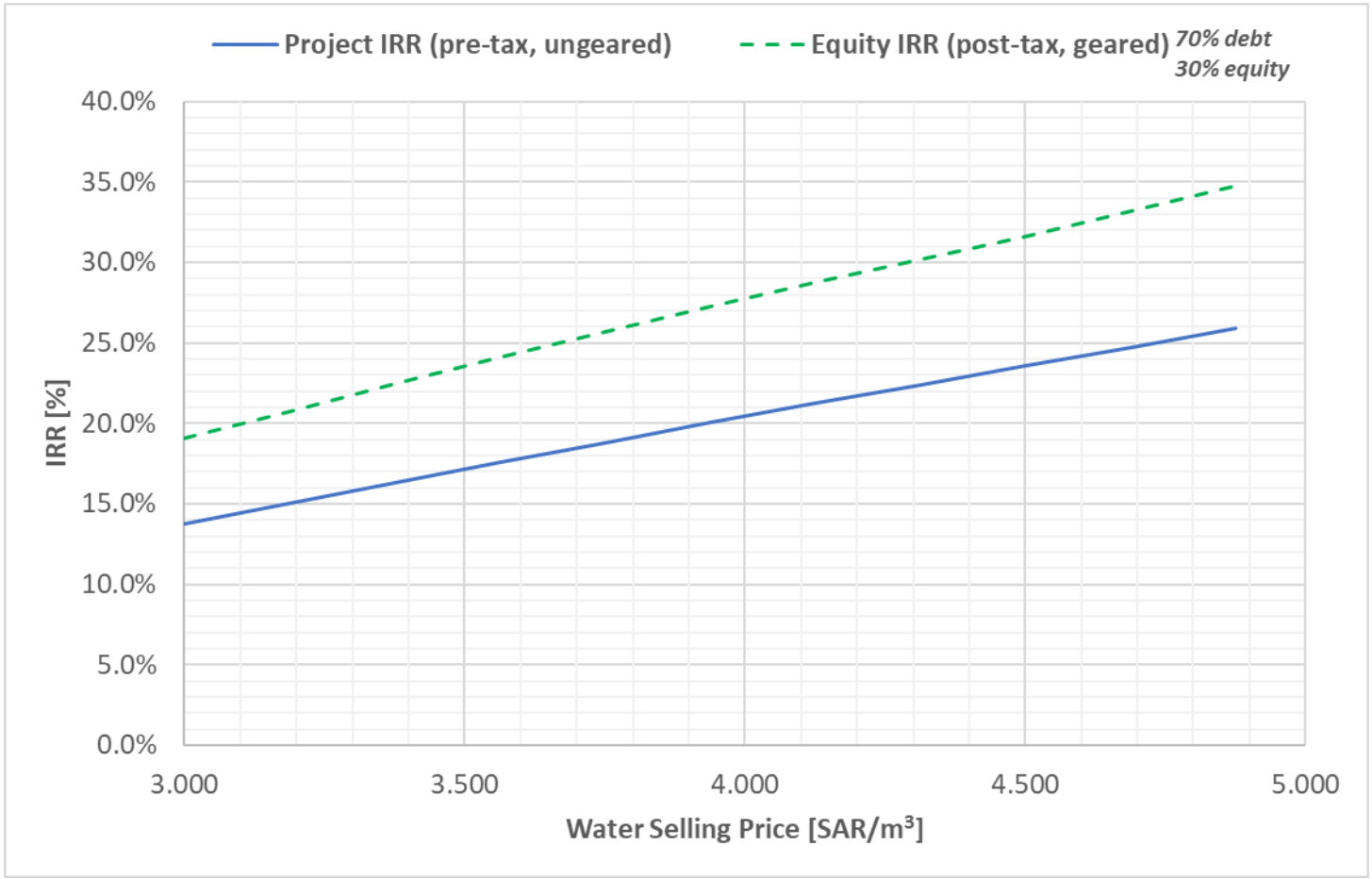
Financial and Project Assumptions

- Tax rate = 20%
- Lending rate = 3.0%
- Inflation = 0%
- Diesel price = 0.525 SAR/L (0.14 USD/L)
- Evaluation period = 10 years
- Project start date = January 2021

Indicative Economics - Notes

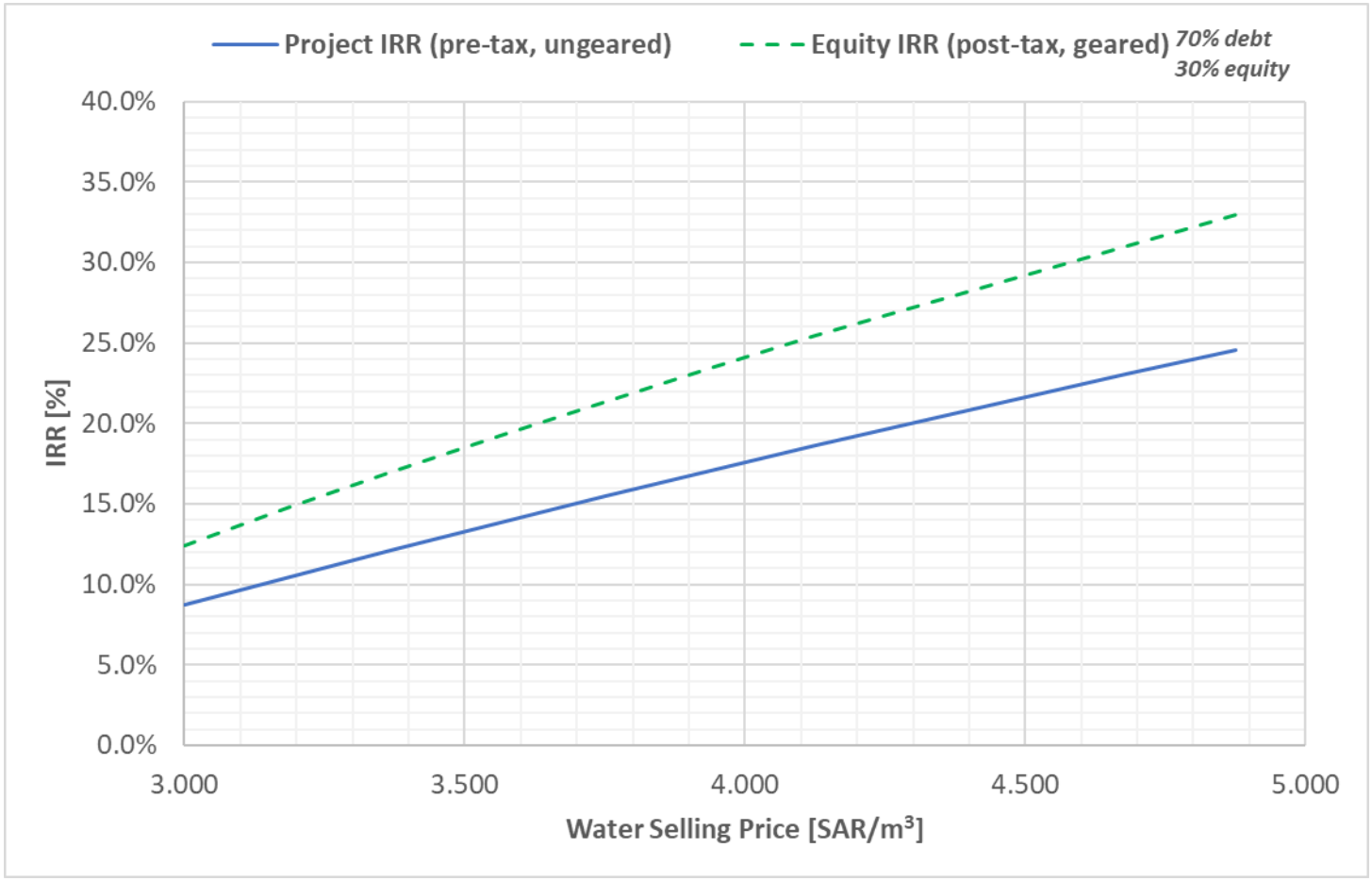
- The plant's water production can be scaled up or down by selecting different number of modules and sizes
- Smaller plants will result in high water selling prices due to economy-of- scale
- There is the option to increase the size of the wind farm if power exports is also a major part of the business model.
- Increasing the wind power component will also increase the overall utilization of the wind power for RO and thus less reliance on fossil fuels.
- The following power configurations were considered for Saudi Arabia:
  - Off-grid with wind only
  - Off-grid with wind and diesel generator assistance
  - Grid-tied (export) with wind only
  - Grid-tied (export) with wind and diesel generator assistance

Indicative Economics – Site 1 (Yanbu)



- Grid-tied (export) with wind only
- Site located at 50 km Northwest of Yanbu
- 7 000 m^3/day water production
- 8 MW wind farm
- Total installed cost = 50 million SAR (13 million USD)
- Carbon savings = 6 200 tons CO_2 equivalent greenhouse gas emissions per year prevented
- 100% wind power
- Negligible fossil fuel use
- 5 MW power export capacity
- Annual energy production = 22 000 MWh
- Assumed power selling price = 0.15 SAR/kWh (0.04 USD/kWh)

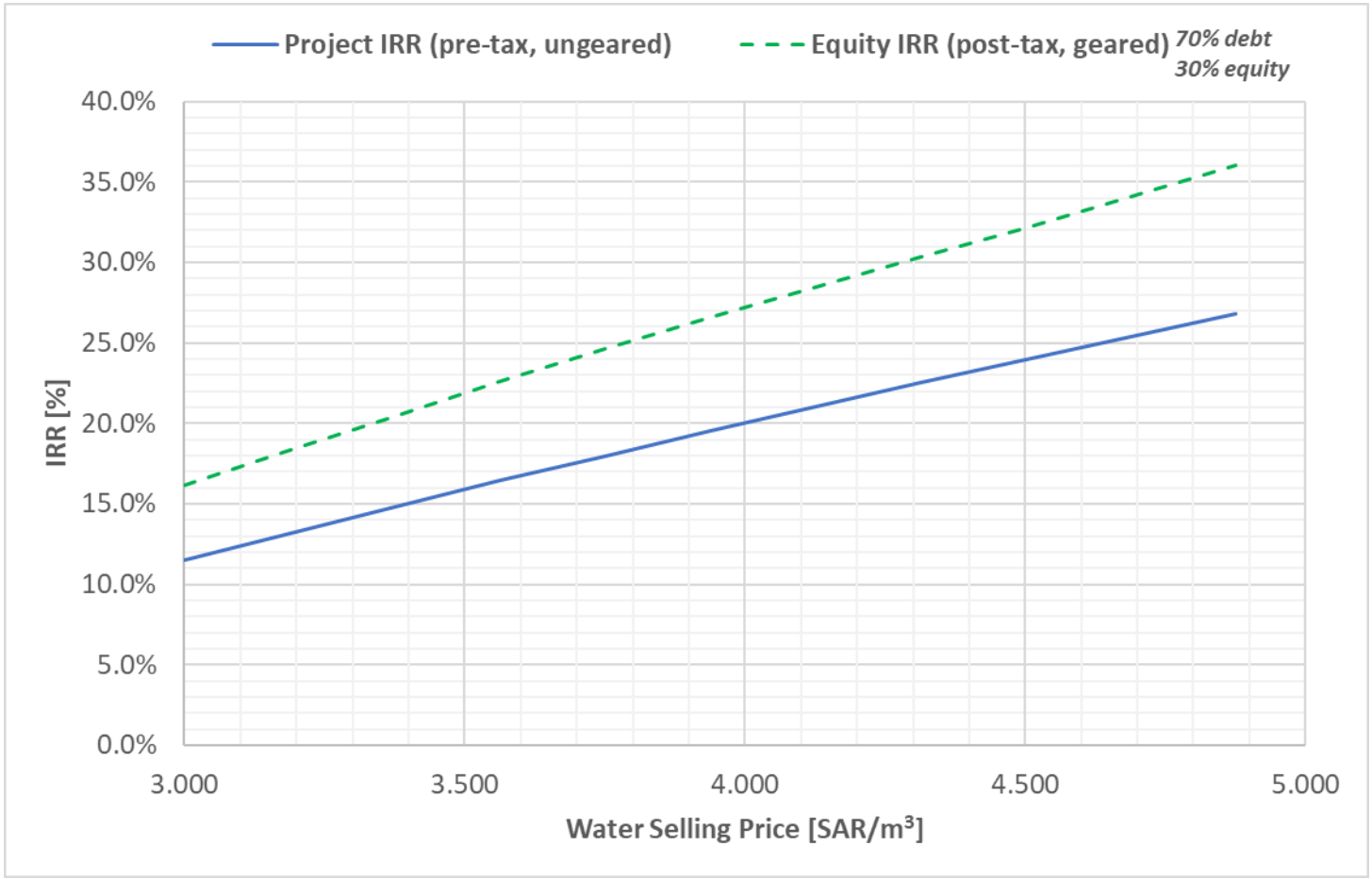
Indicative Economics – Site 2 (Shoaiba)



- Off-grid with wind and diesel generator assistance
- Site located at Shoaiba Power and Desalination Plant
- 9 000 m^3/day water production
- 8 MW wind farm
- Total installed cost = 50 million SAR (13 million USD)
- Carbon savings = 6 500 tons CO_2 equivalent greenhouse gas emissions per year prevented
- Diesel generator used for emergency production
- 86% wind power, 14% diesel power

- Note: IRR lower at site 2 due to lower wind resources

Indicative Economics – Site 2 (Shoaiba)



- Grid-tied (export) with wind and diesel generator assistance
- Site located at Shoaiba Power and Desalination Plant
- 9 000 m^3/day water production
- 8 MW wind farm
- Total installed cost = 50 million SAR (13 million USD)
- Carbon savings = 6 500 tons CO_2 equivalent greenhouse gas emissions per year prevented
- Diesel generator used for emergency production
- 86% wind power, 14% diesel power
- 2.5 MW power export capacity
- Annual energy production = 6 600 MWh
- Assumed power selling price = 0.15 SAR/kWh (0.04 USD/kWh)

- Note: IRR lower at site 2 due to lower wind resources

Next Steps

- Next steps to realize these opportunities

Next Steps

- Identify key role players and get buy-in and commitment
- Assemble a task team
- Obtain better siting data
- Commence with pre-feasibility study to define/test/refine concepts presented in this presentation
- Identify key agreements, guarantees and approvals that need to be in place for this concept to work

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