Energy, Water and Agriculture nexus

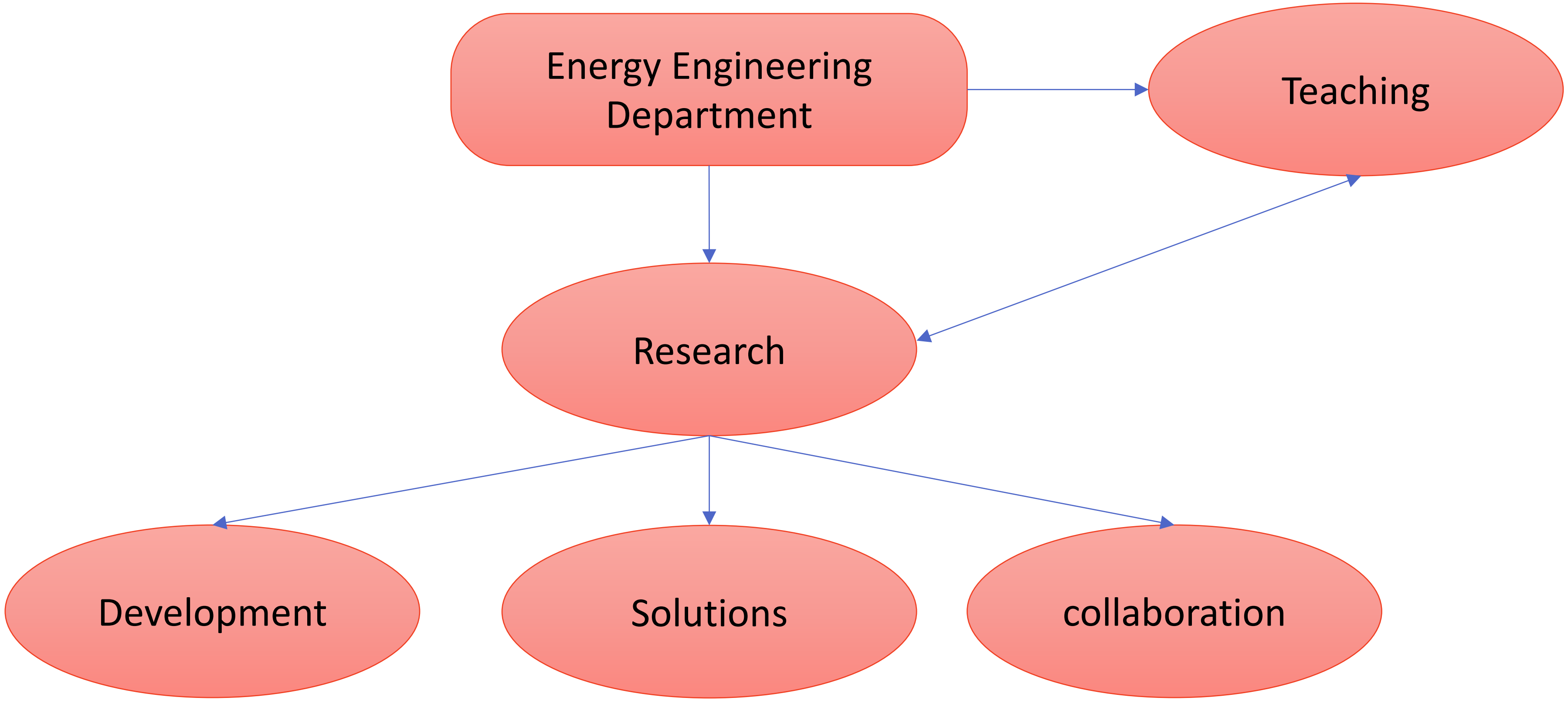
WEF – Nexus - Hashemite University | Dr.-Ing. Mathhar Bdour | 08.02.2024

German Jordanian University

- Public university established in 2005.
- Located in Madaba – Amman
- Technical oriented
- German educational model
- Energy Engineering Department is one of the main establishment cores

Introduction

Our mission


Energy Engineering Department
Teaching
Research
Development
Solutions
collaboration

SDGs in German Jordanian University

Energy, water, and agriculture share critical interdependencies that create grand challenges for sustainable resource management, especially in the current regime of population and economic growth, budgetary constraints, climatic changes, and technological shifts.

Water-Energy-agriculture Nexus: interdependence

Irrigation
Fertilizers
Harvesting
Tillage
Processing
Storage
Pumping
Treatment
Drainage
Desalination
Irrigation
Livestock
Energy
Water
AGRICULTURE
Energy
generation
Cooling
Bioenergy
production
Water quality
Return flows
Bio energy
production

Overview

- Energy and water are the main challenges in Jordan.
- Renewable energy resources integration is an important sustainable development requirement.
- Water resources can be improved by renewables exploitation.

Energy Use in the Agricultural Sector

- Energy is crucial for powering machinery and equipment used in farming operations.
- Irrigation systems rely on energy for water pumping and distribution.
- Heating and cooling systems are necessary for climate control in greenhouses, livestock buildings, and storage facilities.
- Energy is used in food processing and storage for operations like drying, refrigeration, and packaging.
- Transportation of agricultural products requires energy for vehicles used in distribution.
- Integration of renewable energy sources, such as solar and wind, is gaining traction in agriculture.
- Energy efficiency measures, like adopting efficient irrigation systems and machinery, help optimize energy use.
- Energy costs impact the financial viability of agricultural operations.

Importance of Water in Agriculture

- Essential for plant growth, photosynthesis, and crop yield.
- Facilitates the uptake and transport of nutrients to plant roots.
- Regulates plant temperature through transpiration, preventing heat stress.
- Enables irrigation to provide water when natural rainfall is insufficient.
- Affects crop quality, size, and nutritional value.
- Crucial for achieving food security and meeting the demands of a growing population.
- Contributes to sustainable agriculture practices through efficient water management.
- Ensures optimal use of water resources and minimizes environmental impacts.
- Plays a critical role in preserving natural ecosystems and biodiversity.

Renewable Energy Resources

Solar

Wind

Biomass

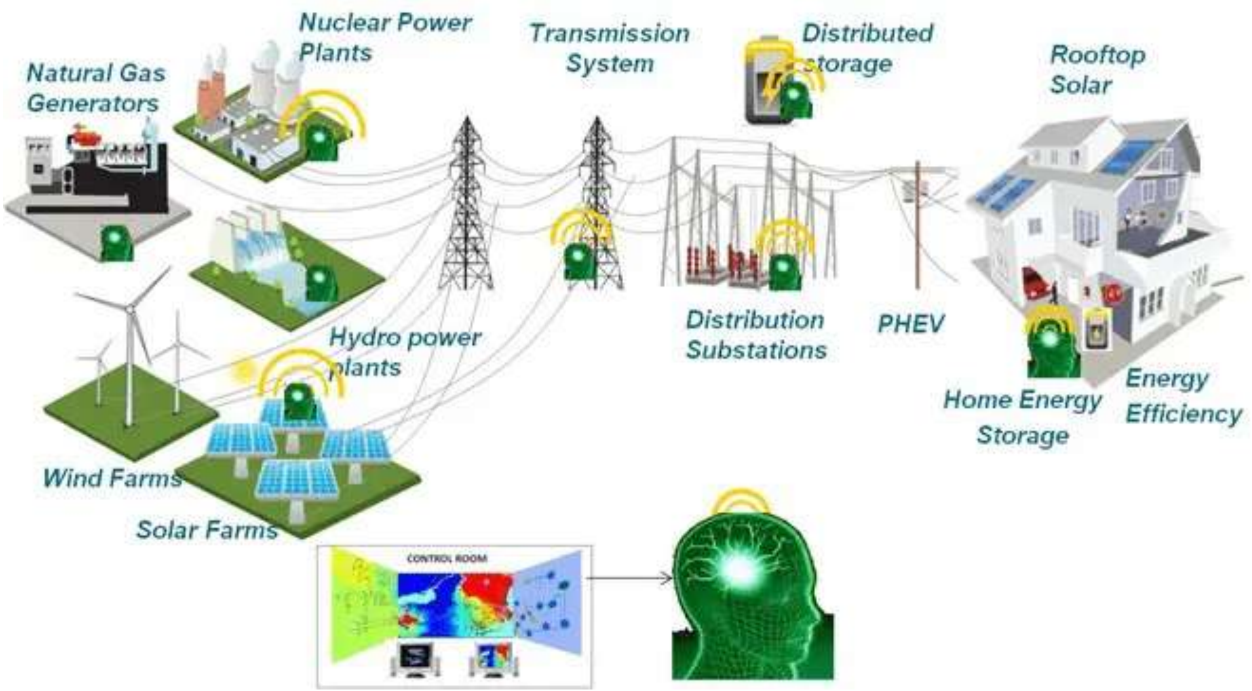
Tidal

Hydropower

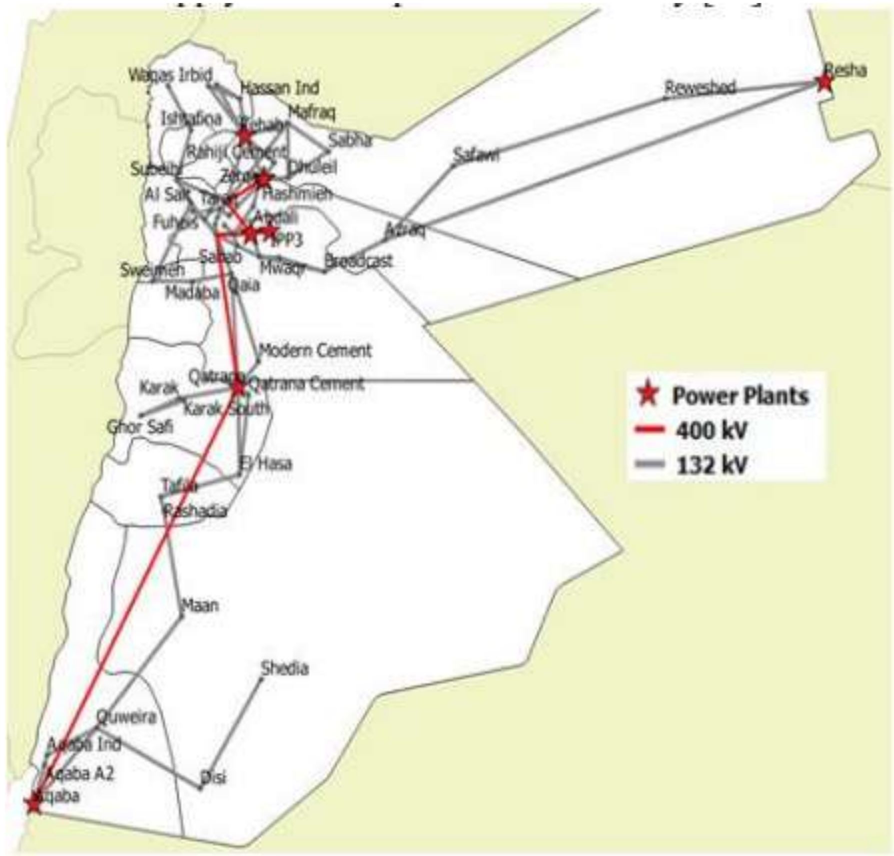
Geothermal

Electrical Energy In Jordan

Electrical Power system



https://studyelectrical.com/



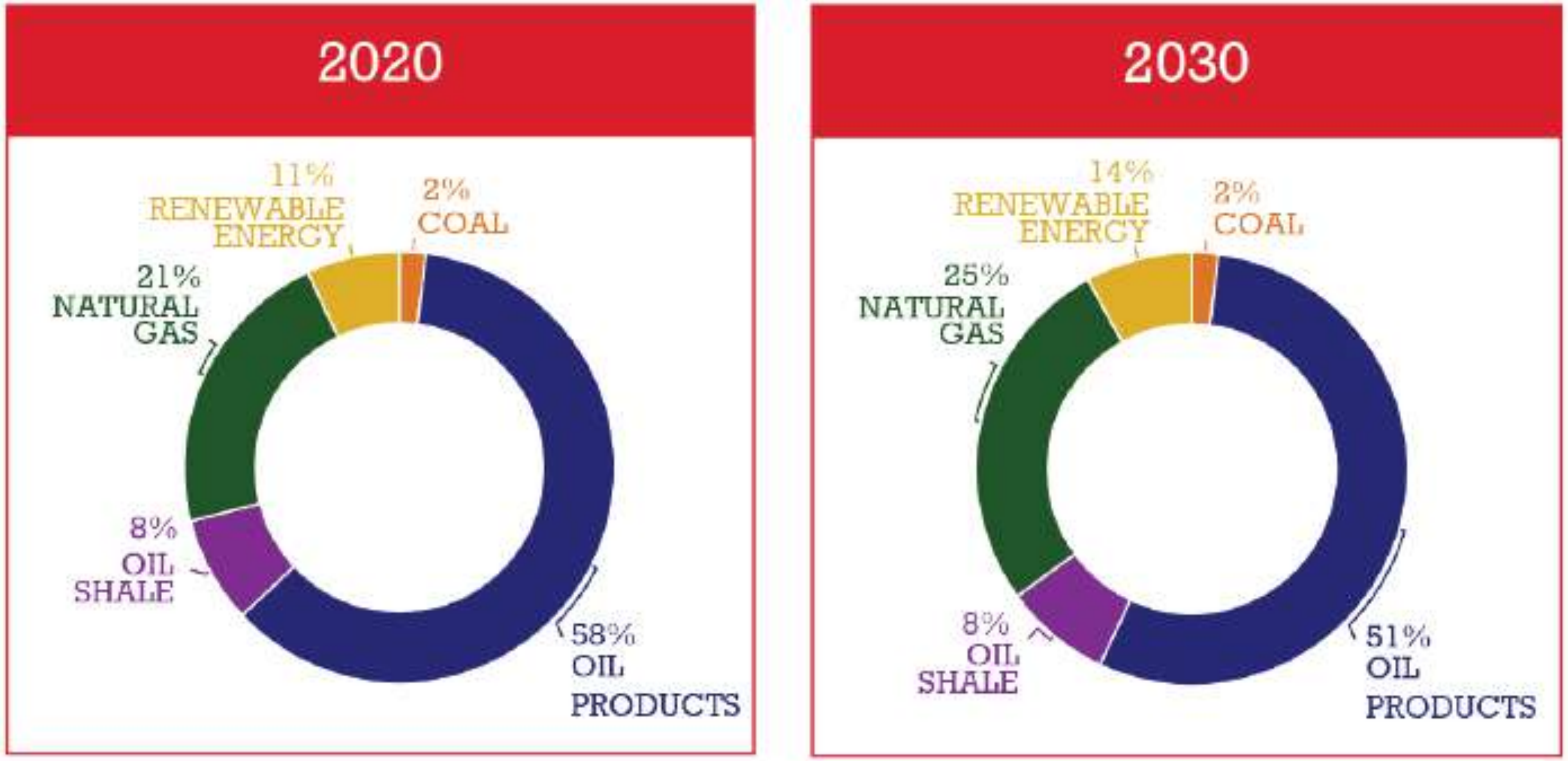
Daniel Christ*, Martin Kaltschmitt, Impact of Decentralized PV Systems Installation on Transmission Lines During Peak Load Situations – Case Study Amman, Jordan, JJMIE, 2019

Available Capacity of Generating Plants / Transmission Network (MW)

Year	Steam	Gas Tur-bines	Combined Cycle	Diesel*	Renewable Energy			Total	
					Hydro	Wind	Solar	Renewable	Traditional
2018	605	83	2740	814	6	280	449	735	4242
2019	605	83	2740	814	6	369	637	1012	4242
2020	363	83	2740	814	6	518	887	1411	4000
2021	363	60	2740	814	3.6	622	938	1564	3977
2022	598	60	2740	814	3.6	622	958	1584	4212

NEPCO, Annual Report, 2022

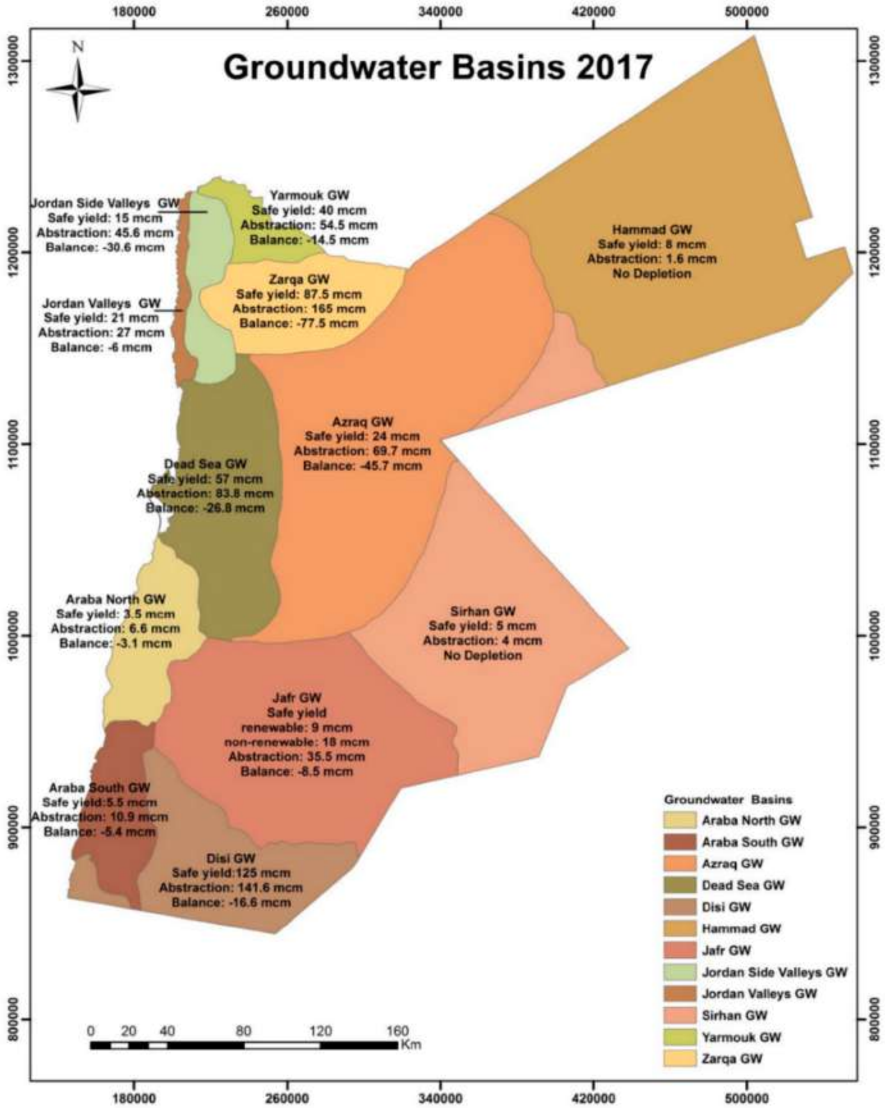
Energy generation by source in Jordan



Ministry of Energy & Mineral Resources – Annual Report 2020

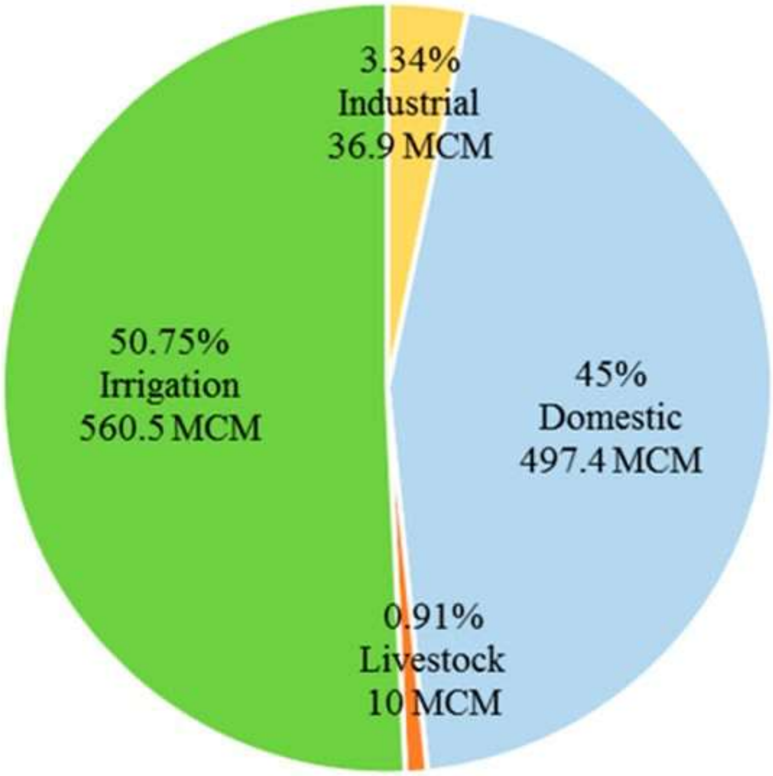
Water situation in Jordan

- Estimated annual water availability is 1,054 MCM
  - Surface water: 288 MCM
  - Ground water: 619 MCM
  - Non-conventional: 147 MCM

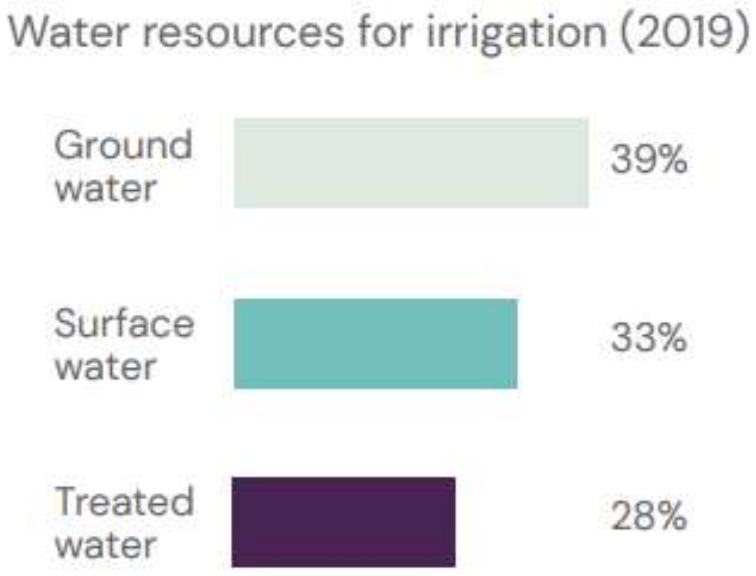


MWI. *Jordan Water Sector Facts and Figures 2017*

Water consumption

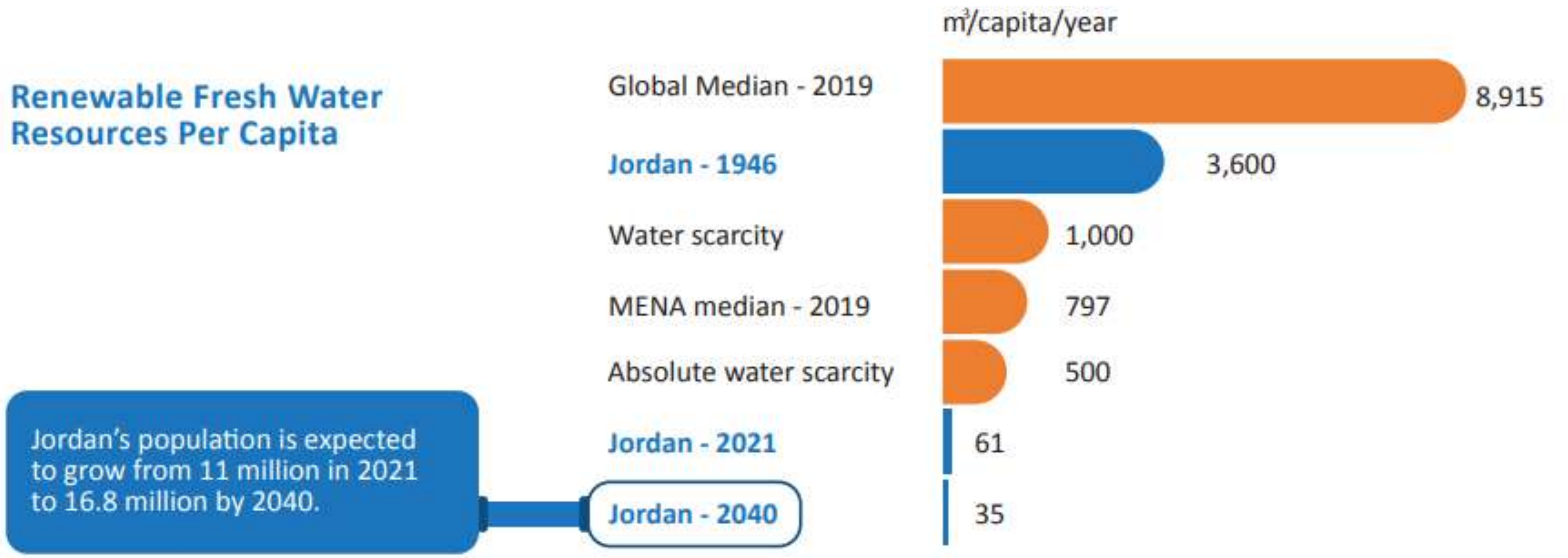


MWI. Jordan Water Utilities Monitoring Report 2019



Ministry of Water and Irrigation (2019), Water Budget 2019

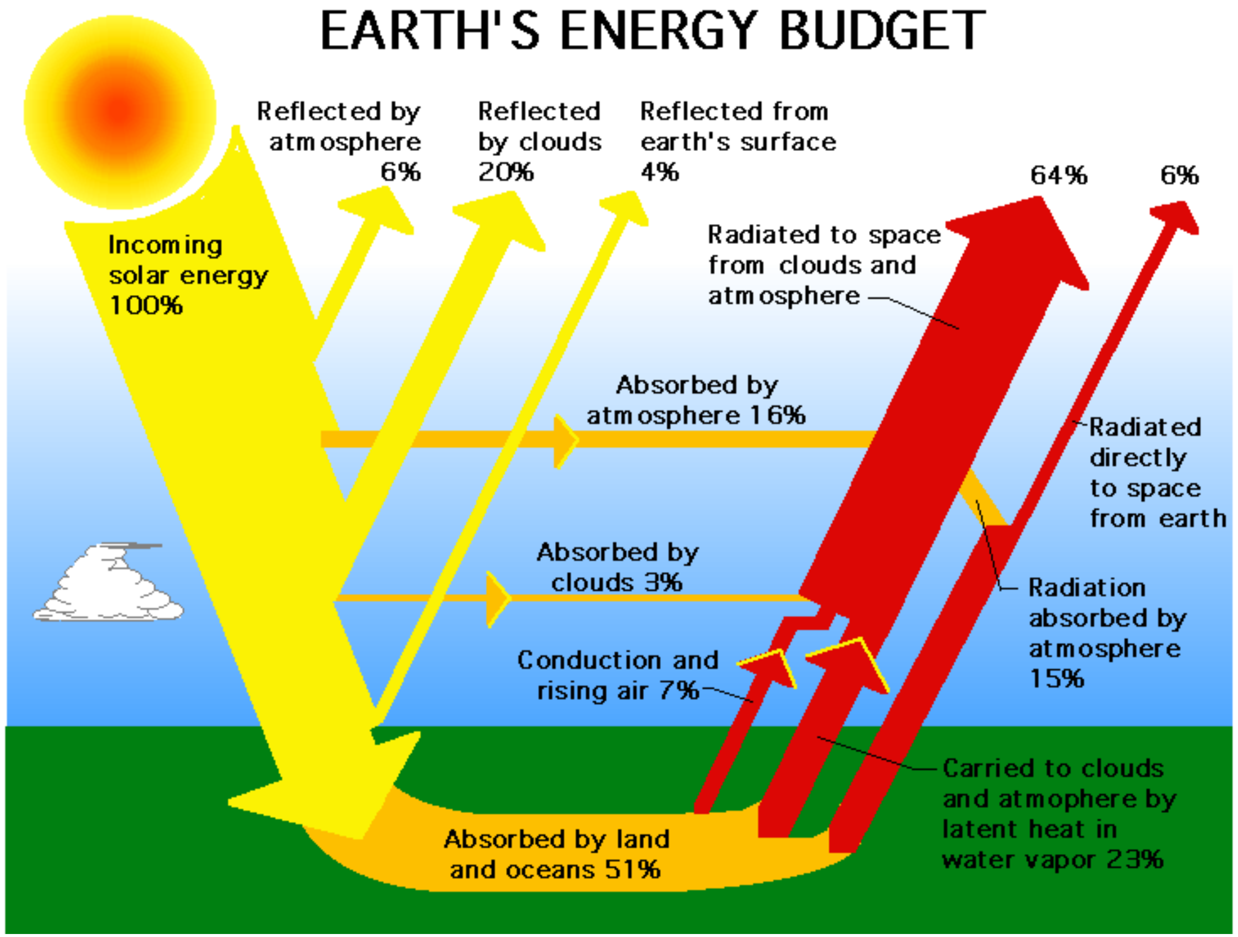
Per capita share of water



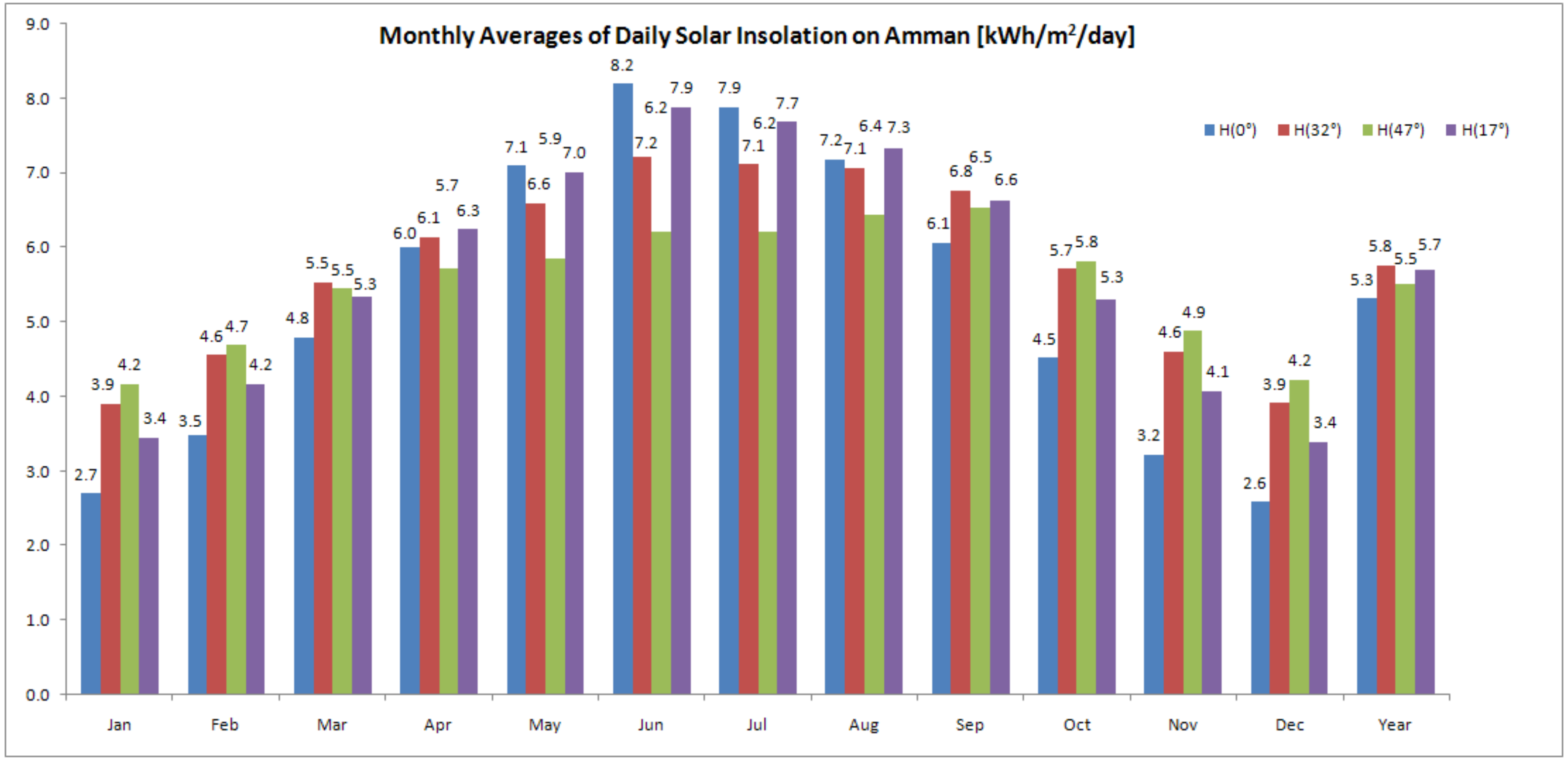
Ministry of Water and Irrigation, 2021

Solar Energy

Global solar irradiation



Solar Radiation at Site

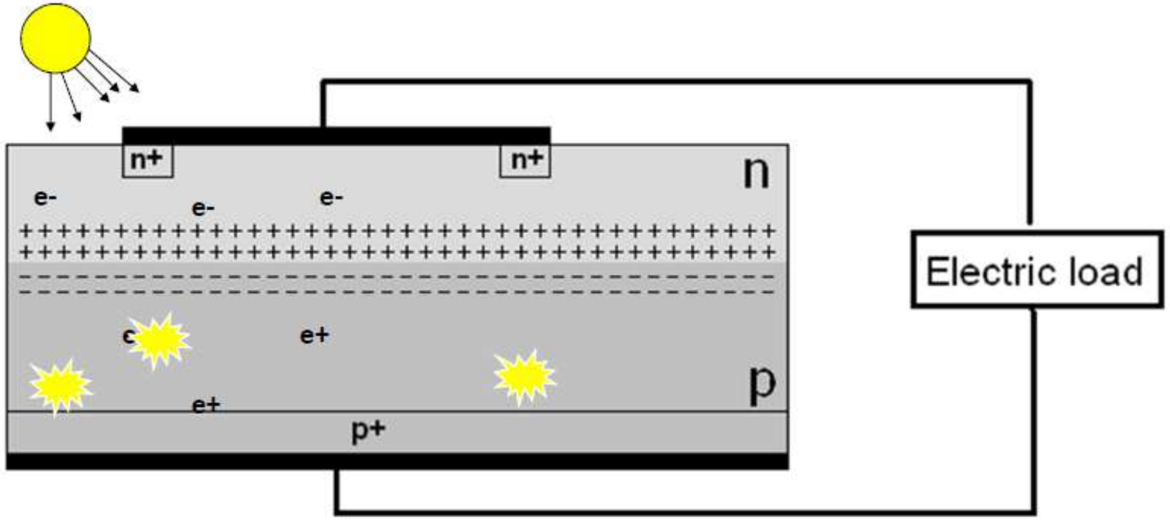


Solar insolation (kWh/m^2) varies from one day to another during the year.

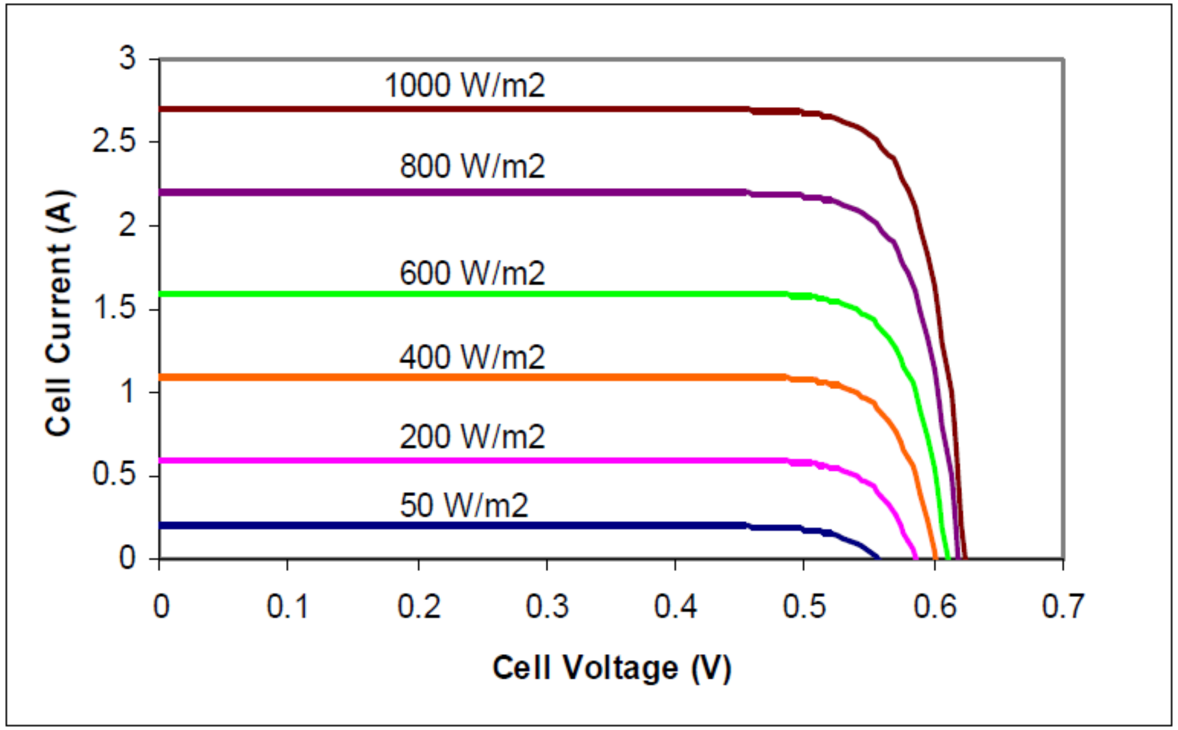
What is the design solar insolation month? Insolation at latitude tilt ± 15°

Note: insolation = **in**put **sol**ar radi**ation** = daily solar radiation sums

Solar – PV

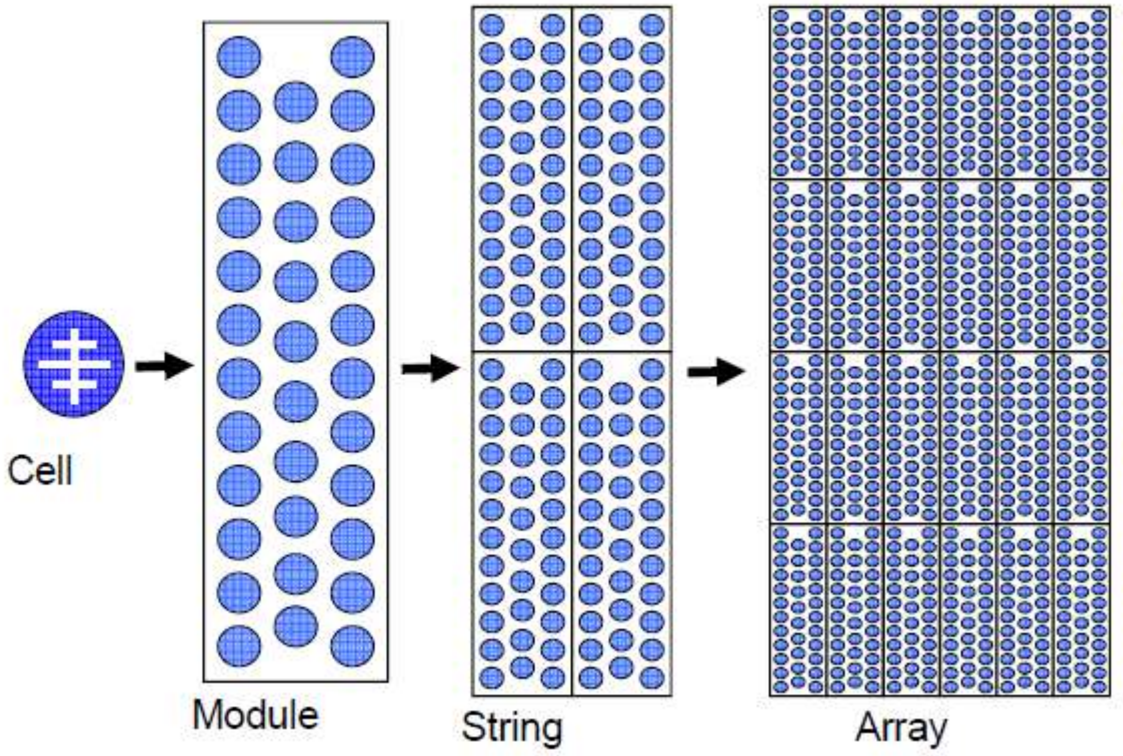


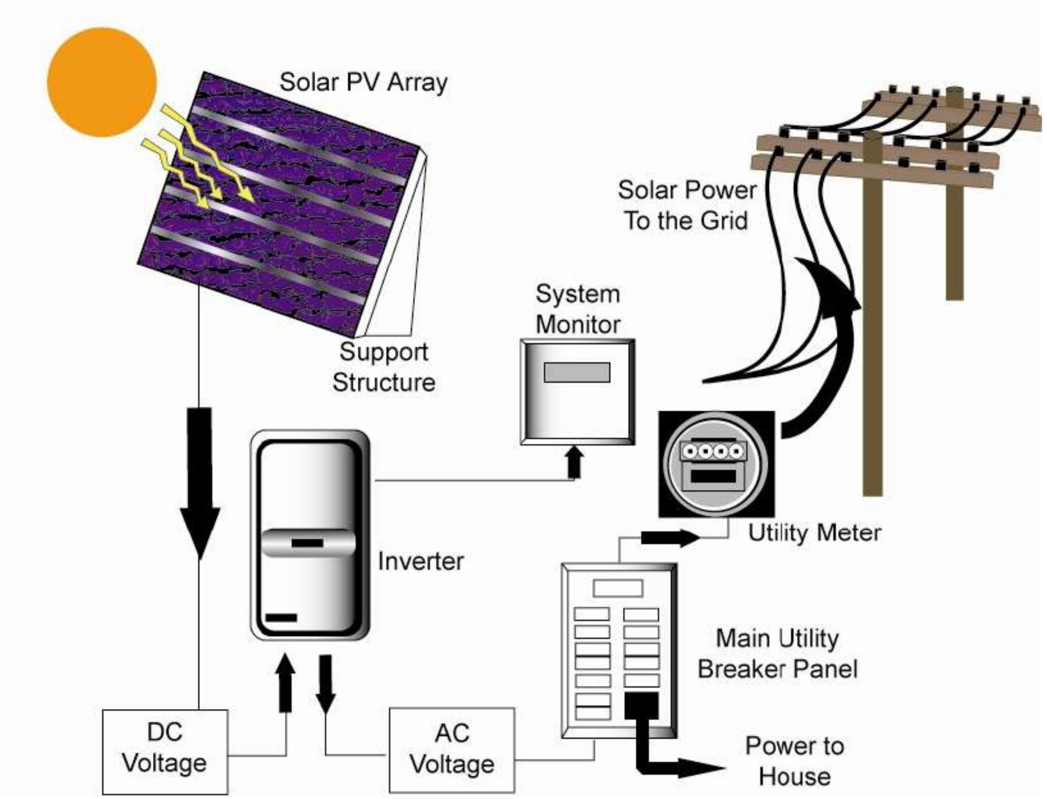
n+
n+
n
e-
e-
e-
p
e+
e+
p+
Electric load



1000 W/m2
800 W/m2
600 W/m2
400 W/m2
200 W/m2
50 W/m2
Cell Current (A)
Cell Voltage (V)
0
0.5
1
1.5
2
2.5
3
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

PV system and connection



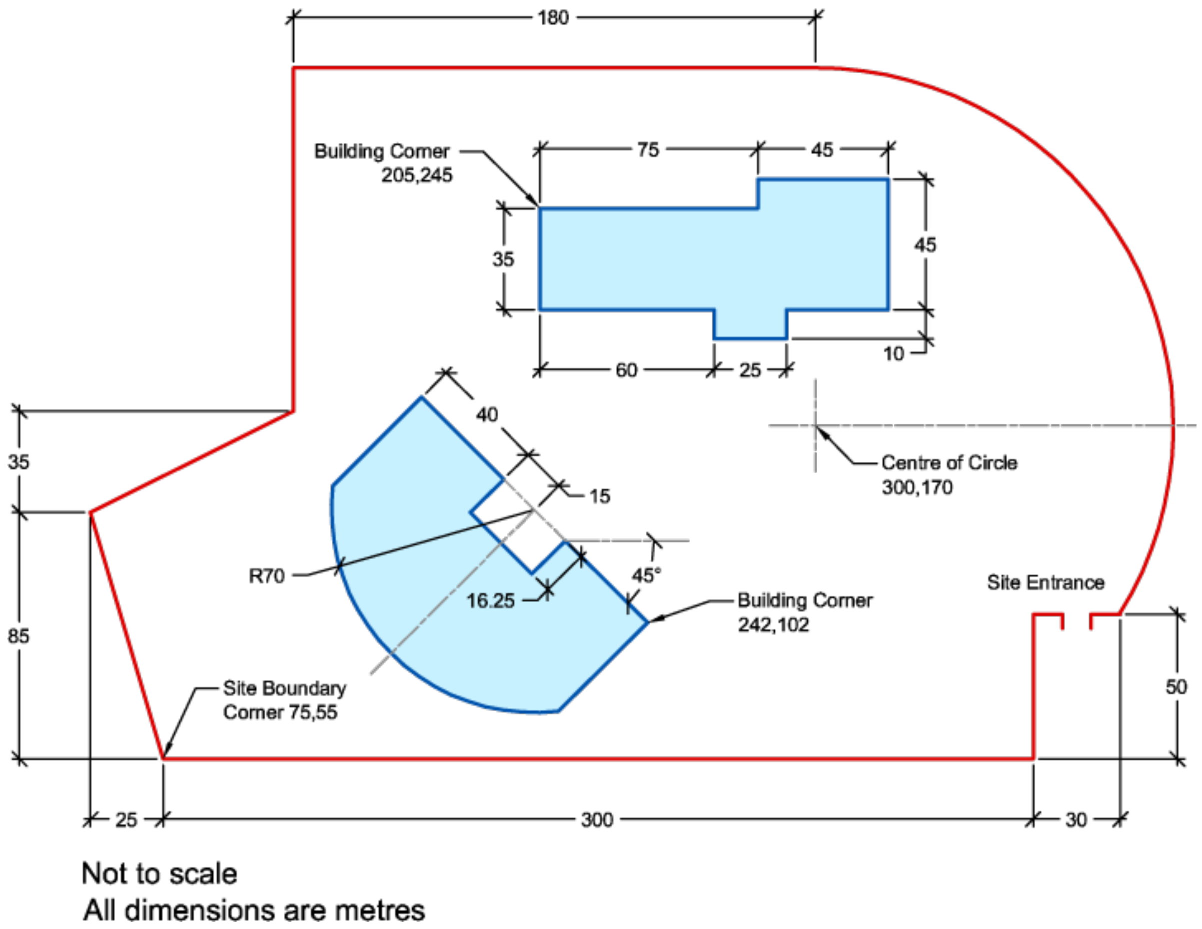


Project preparation

- **Site Visit:**
  - **Draw site layout (coordinates, directions and dimensions).**
  - **Check where to place PV array, batteries, charge controller and inverter.**
  - **Perform shading analysis to check monthly and annual solar access.**
  - **Count the loads (power and energy/electricity consumption).**
- **Solar Radiation at Site:**
  - **Get monthly averages of daily solar radiation sums (kWh/m^2/day) from available local and/or international data sources.**
  - **Calculate Average Peak Sun Hours (PSH) for each month.**
  - **Determine design PSH**
- **Start Sizing System Components:**
  - **PV Array Sizing**
  - **Battery Sizing**
  - **Solar Charge Controller Sizing**
  - **Inverter Sizing**

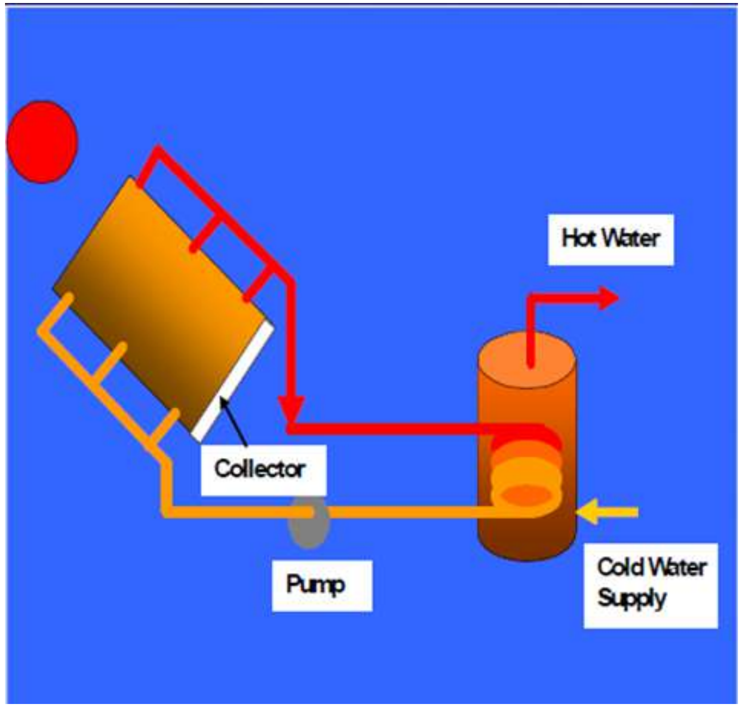
Site layout

Draw site layout (coordinates, directions and dimensions). Check where to place PV array, batteries, charge controller and inverter.



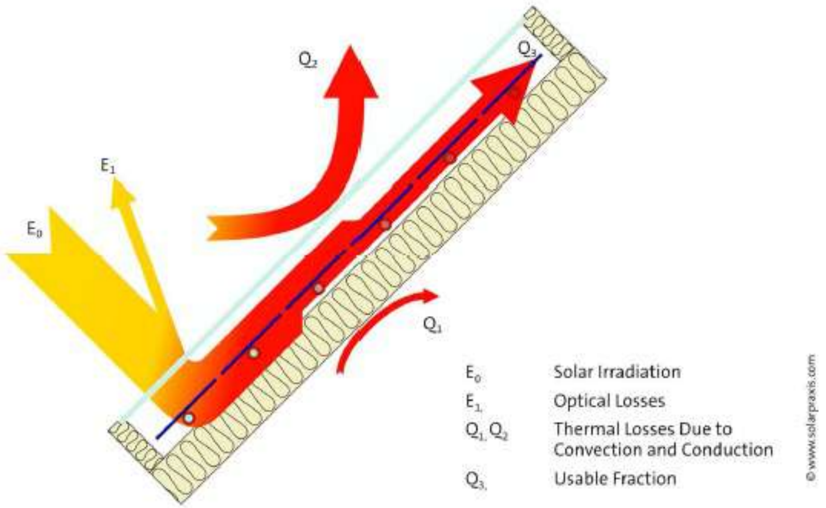
Solar Thermal System

- Types of Application:
  - Pool heating
  - Domestic hot water
  - Space heating
  - Solar cooling / Air conditioning

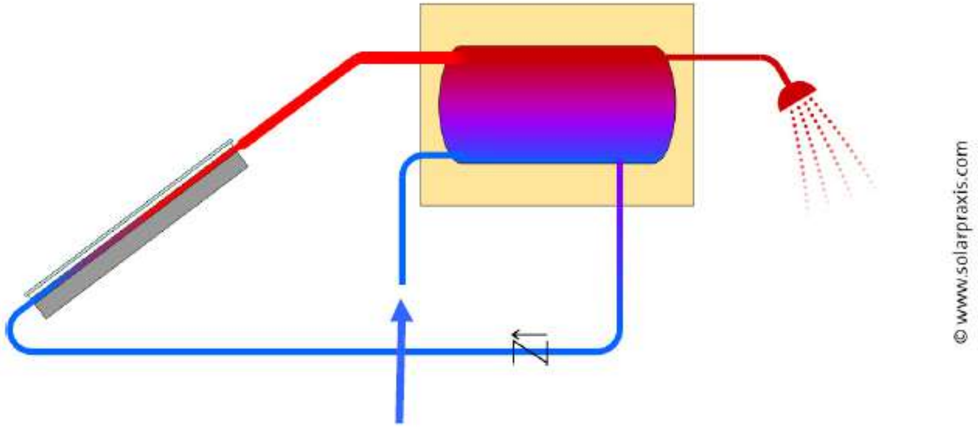


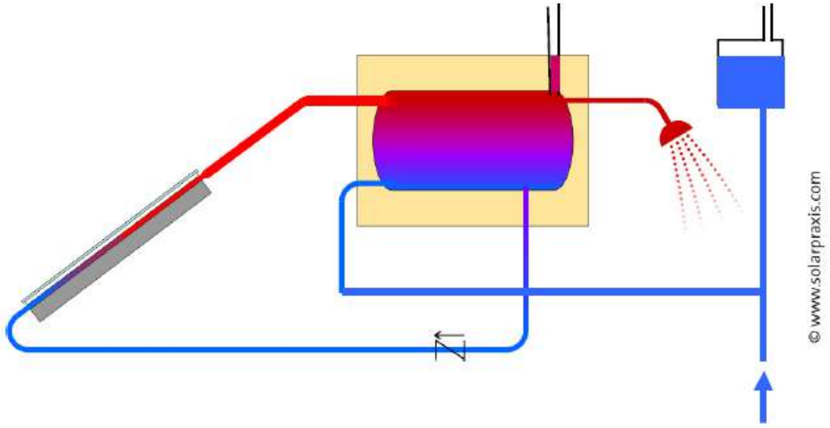
- Types of Systems:
  - Open systems
  - Closed systems
  - Sealed Pressurized
  - Direct systems
  - Indirect systems
  - Natural flow / thermo siphon / gravity flow
  - Forced circulation

Principle of Solar Thermal Collection



Domestic systems





Closed System
Direct Circuit
Gravity Flow (Thermo siphon)

Open System
Direct Circuit
Gravity Flow (Thermo siphon)

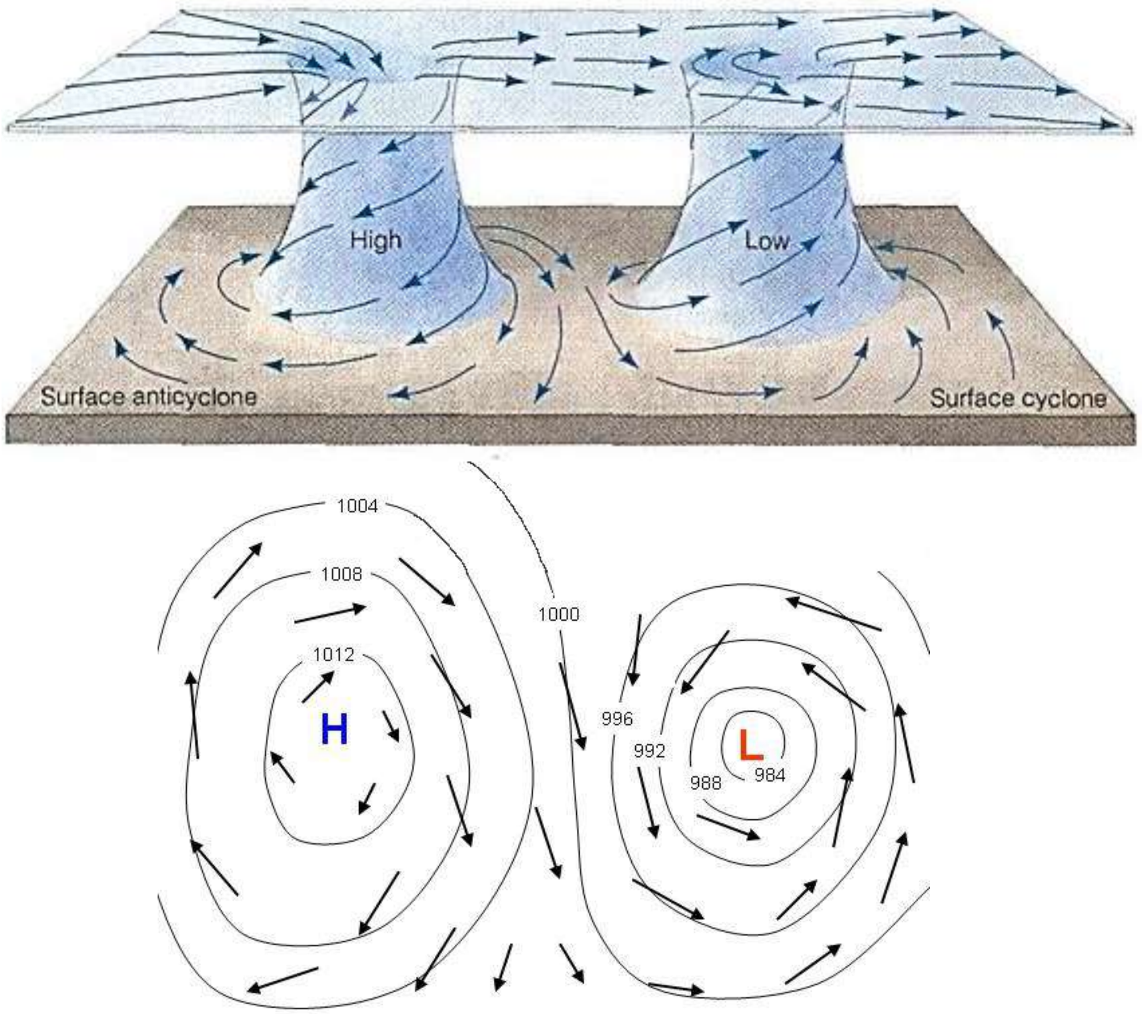
Wind resources

Local Wind Resource

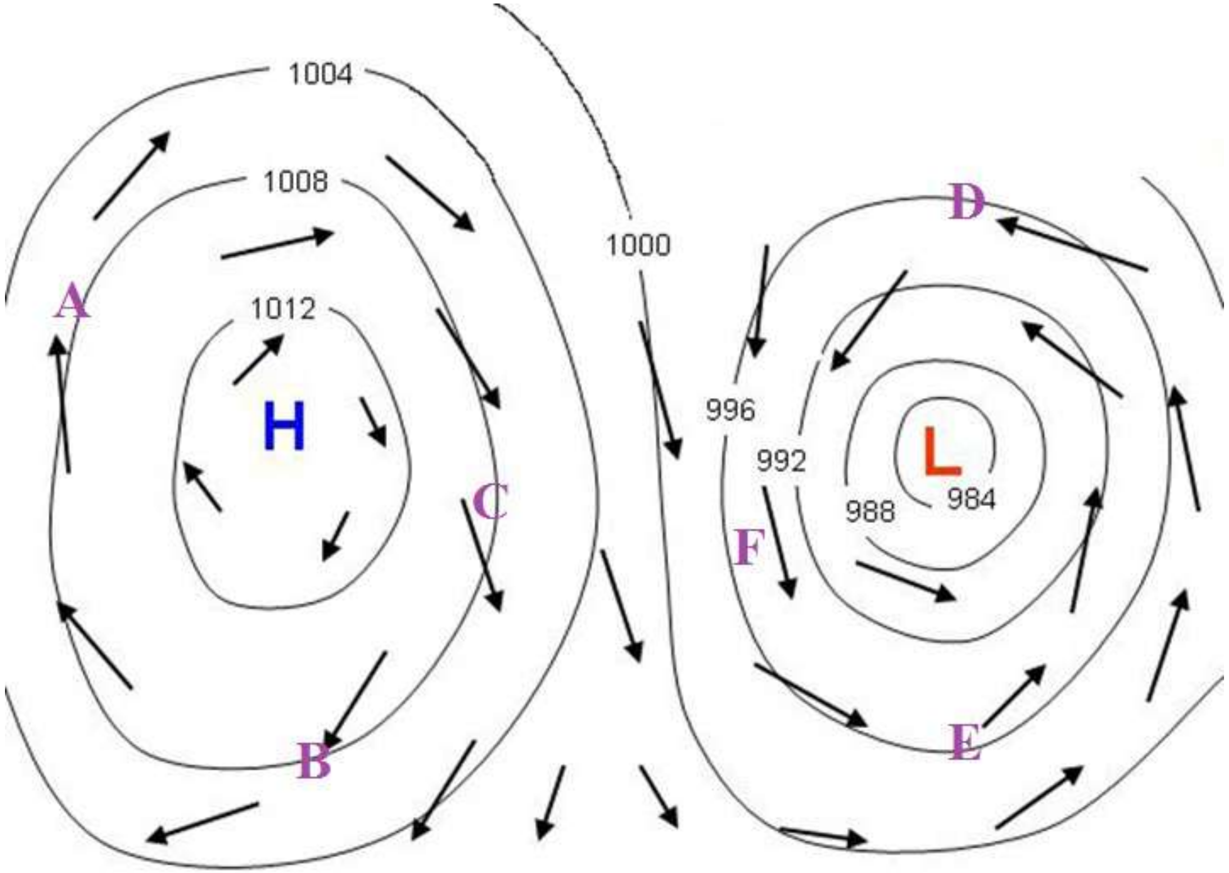
High and Low Pressure areas

The presence of areas of high and low pressure cause the isobars to be curved.

This imposes a centrifugal force



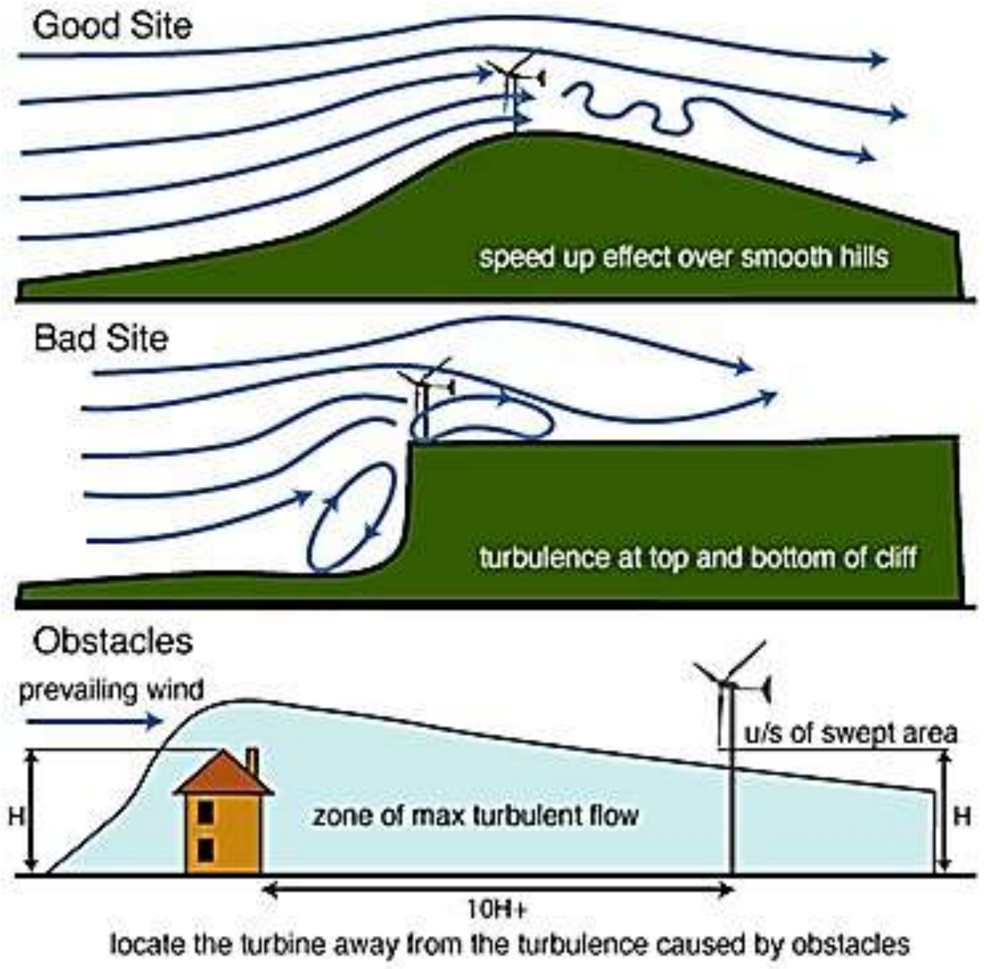
Wind Direction



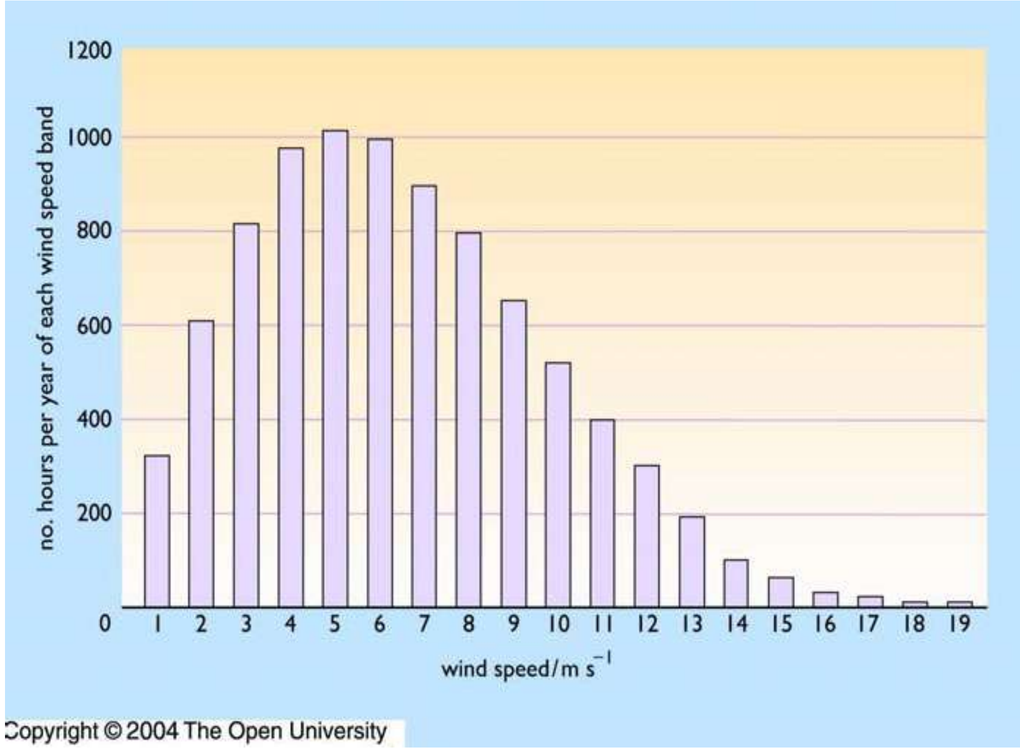
Variations of Wind speed and direction

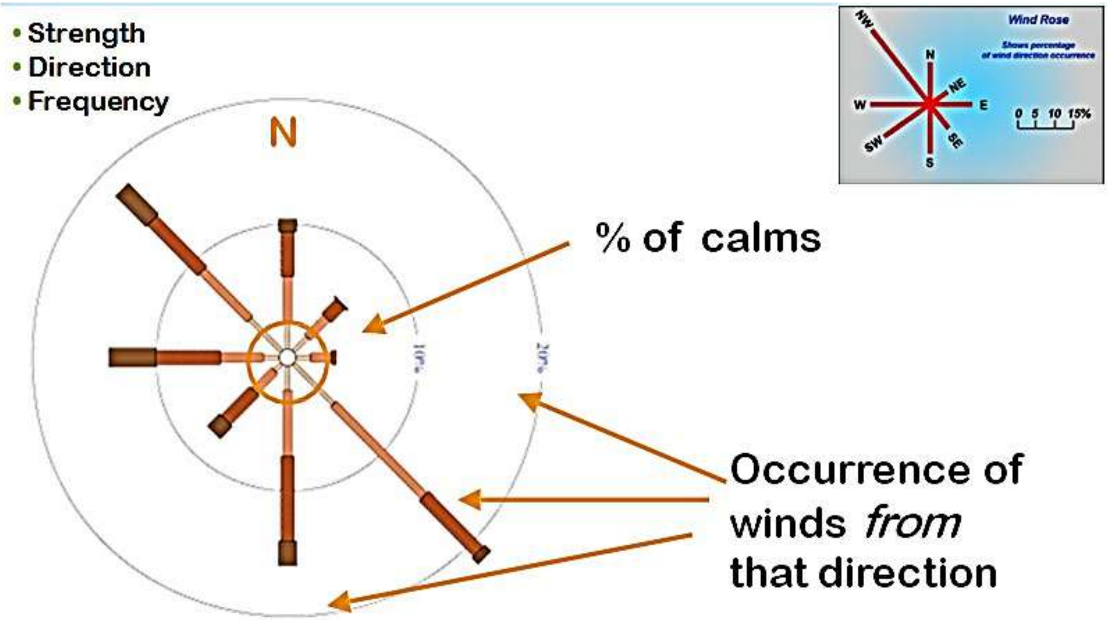
Variations due to location

Wind speed and direction are dependent on local topography and ground cover

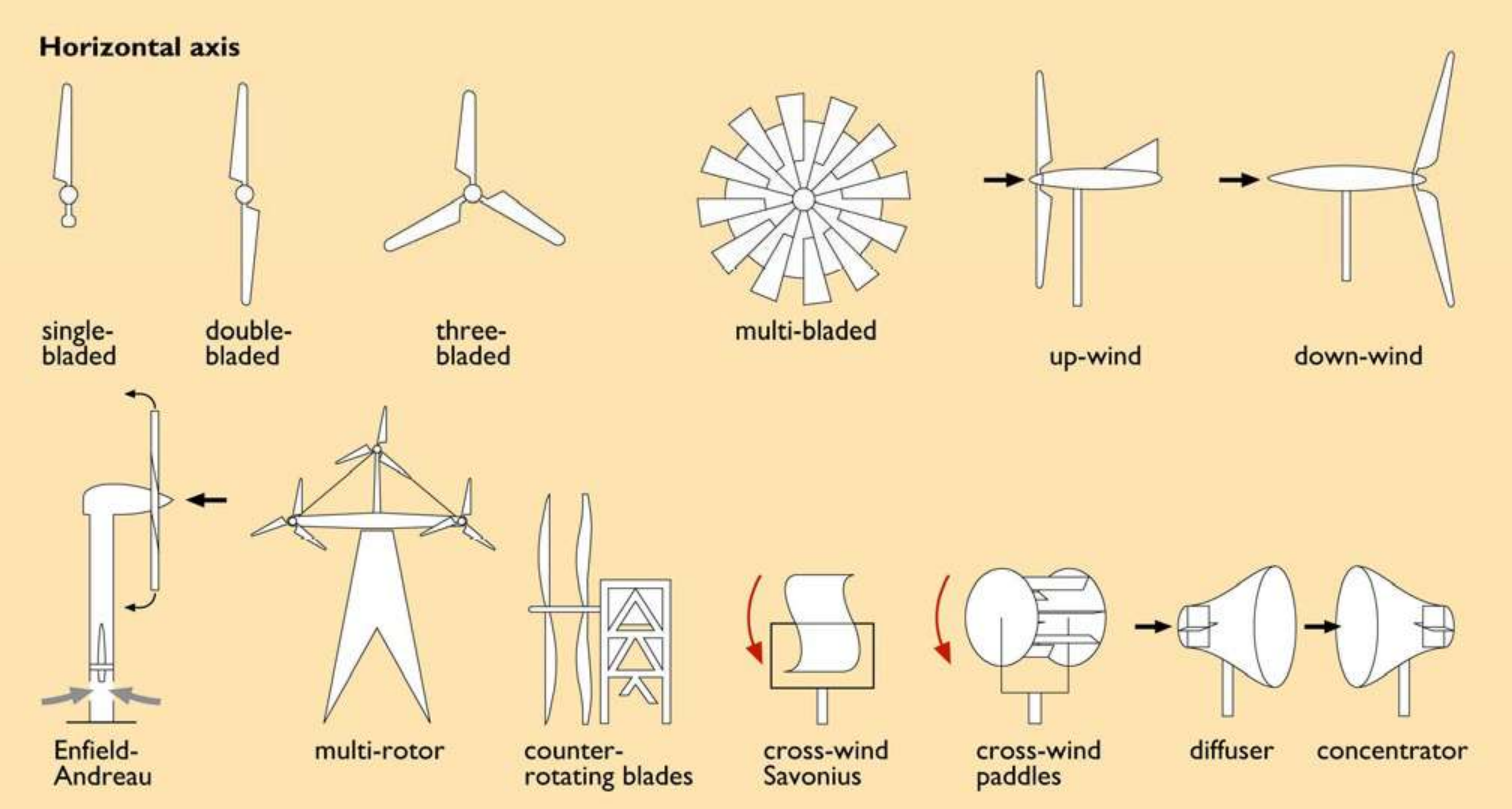


Wind Speed Frequency Distribution



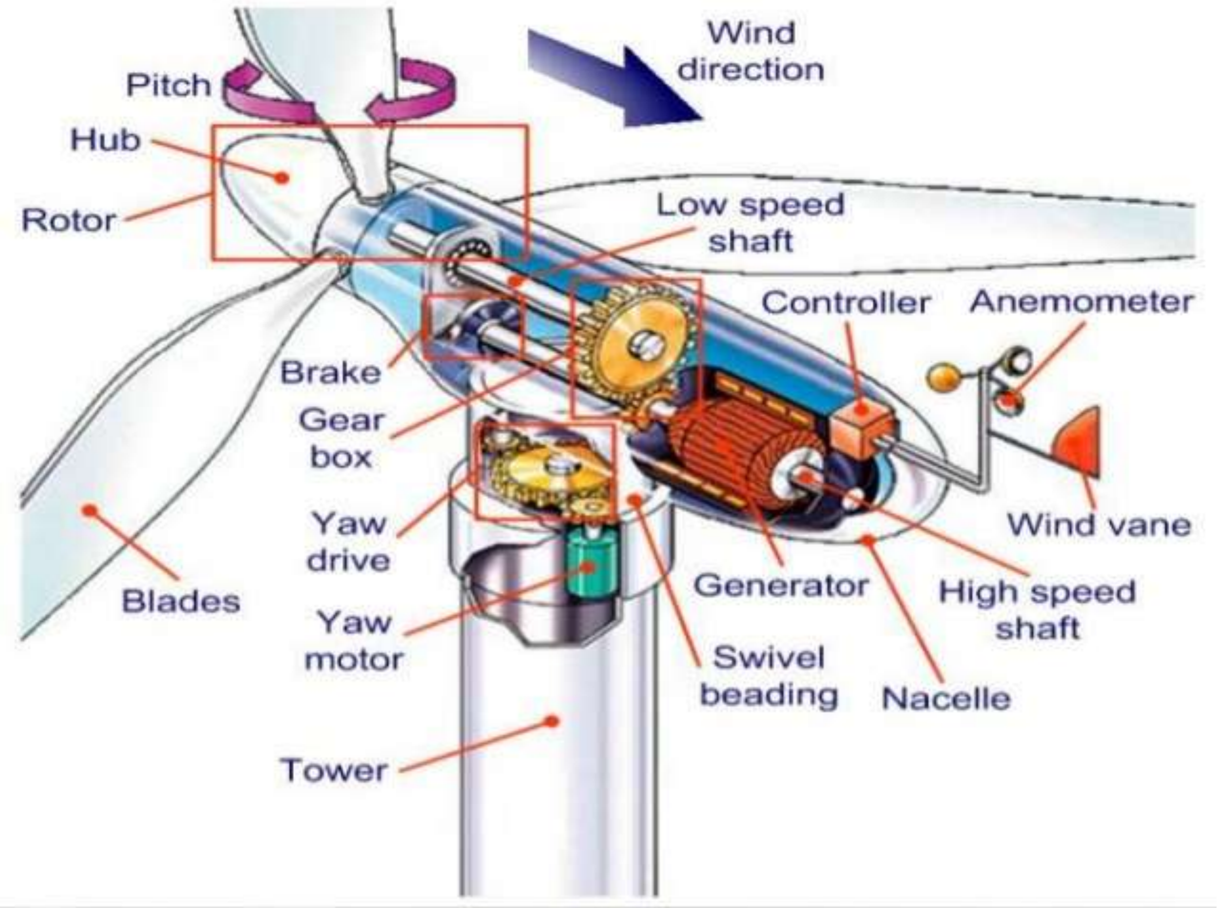


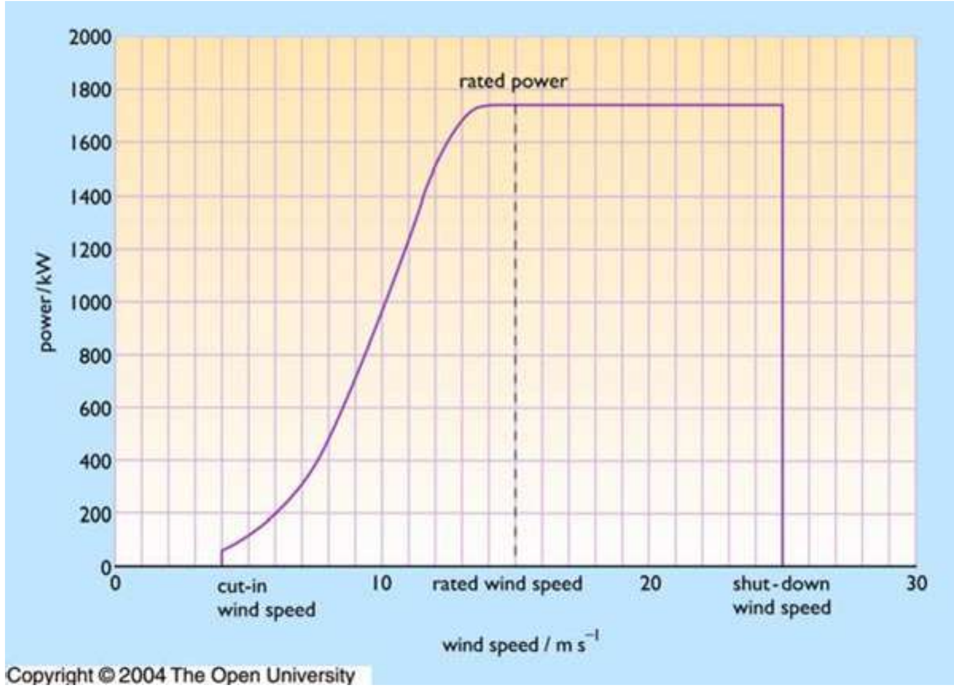
HAWT types



Horizontal axis
single-bladed
double-bladed
three-bladed
multi-bladed
up-wind
down-wind
Enfield-Andreau
multi-rotor
counter-rotating blades
cross-wind Savonius
cross-wind paddles
diffuser
concentrator

Components of a Horizontal Axis Wind Turbine and power curve

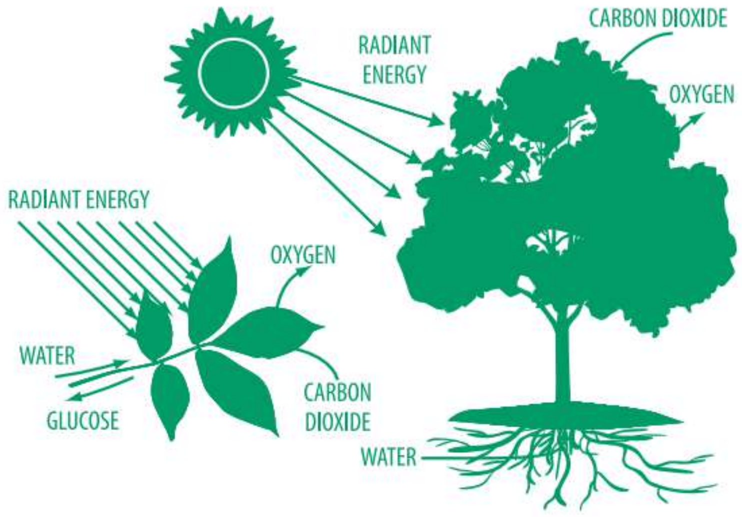




Biomass

BIOMASS

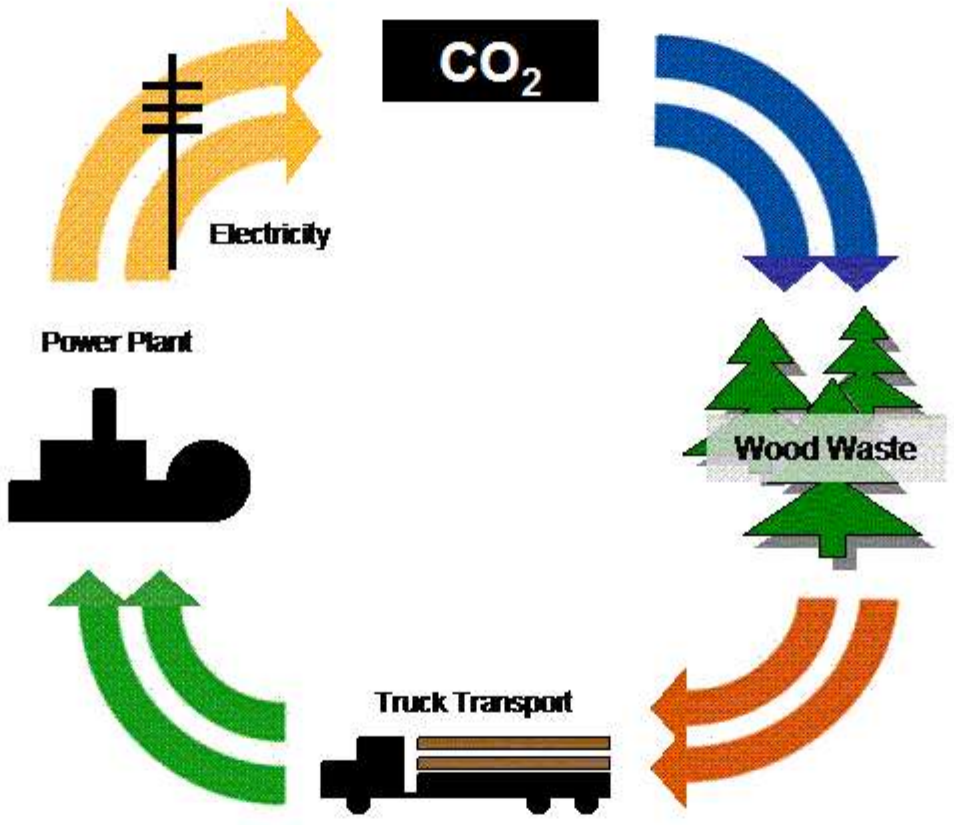
- Biomass is any organic matter—wood, crops, seaweed, animal wastes—that can be used as an energy source.
- Biomass is probably our oldest source of energy after the sun. For thousands of years, people have burned wood to heat their homes and cook their food.
- Biomass gets its energy from the sun. All organic matter contains stored energy from the sun. During a process called photosynthesis, sunlight gives plants the energy they need to convert water and carbon dioxide into oxygen and sugars. These sugars, called carbohydrates, supply plants and the animals that eat plants with energy.
- Biomass is a renewable energy source because its supplies are not limited. We can always grow trees and crops, and waste will always exist



water + carbon dioxide + sunlight ⟶ glucose + oxygen

$6\ H_2O + 6\ CO_2 + \text{radiant energy} \longrightarrow C_6H_{12}O_6 + 6\ O_2$

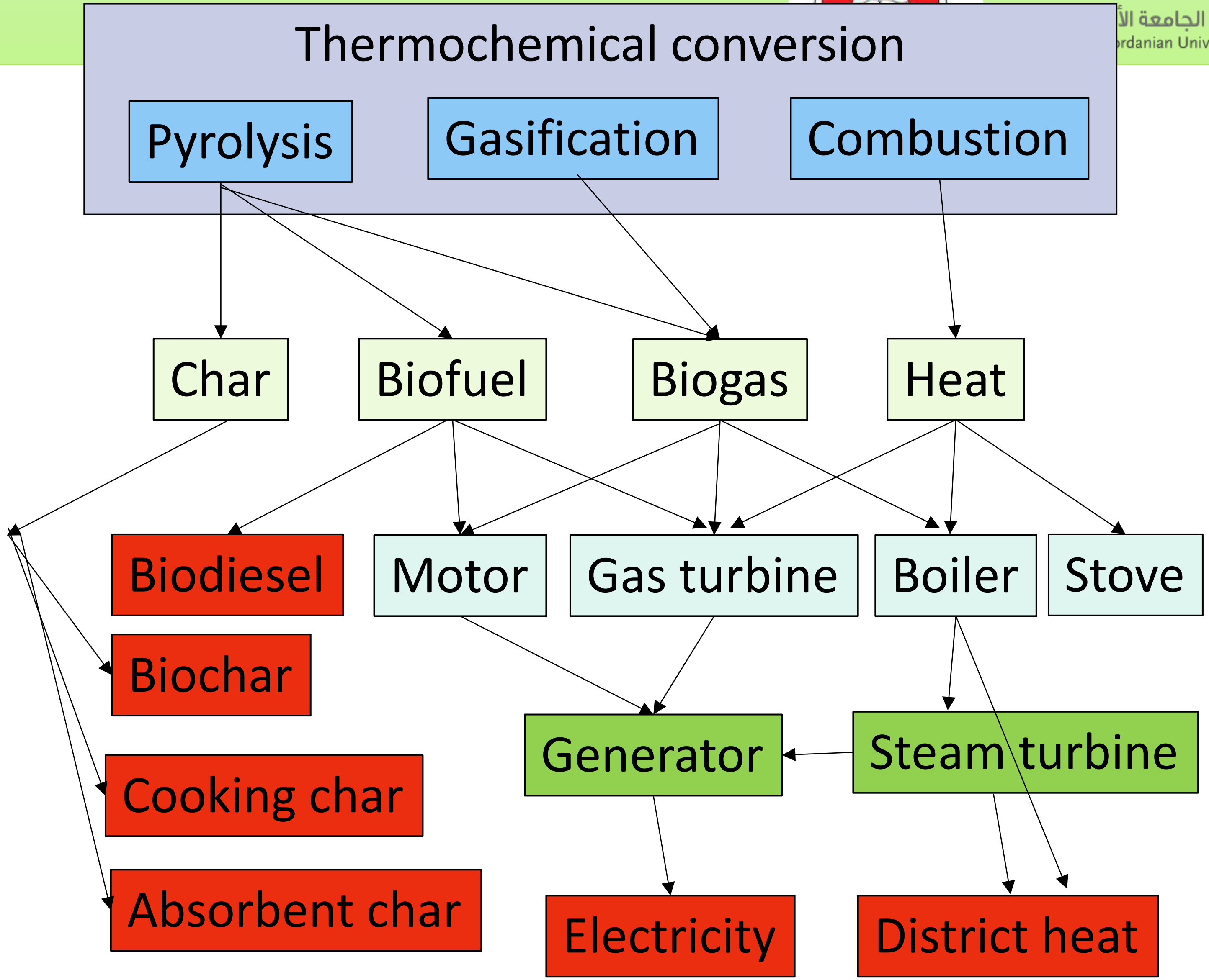
CO2 cycle



http://www.renegy.com/images/BiomassCycleChart_001.gif

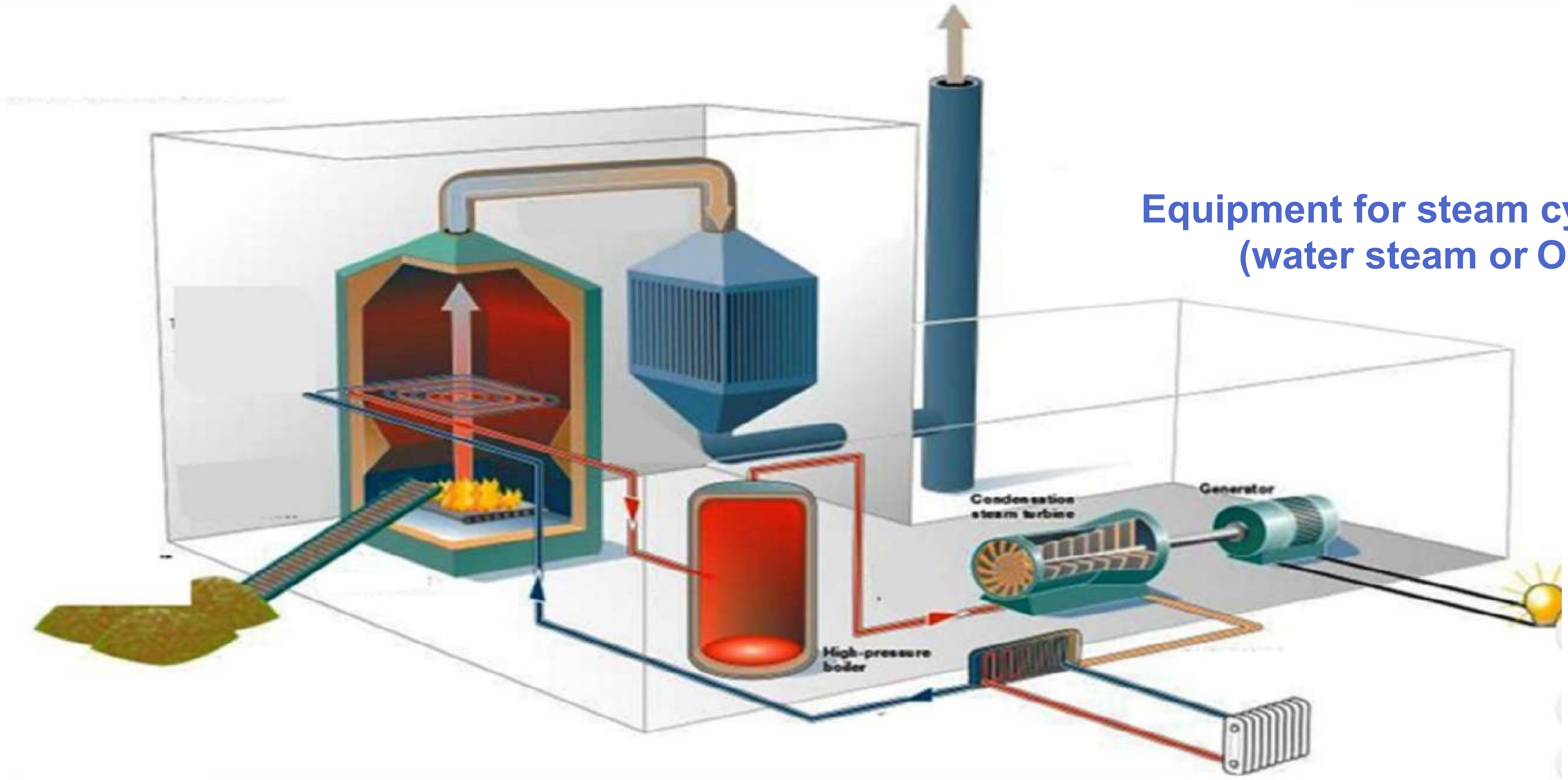
Thermochemical conversion of biomass

- Thermochemical conversion processes such as pyrolysis and gasification use low moisture biomass and biowaste to produce electricity, heavy oil or gas fuels
  - Pyrolysis (Slow, intermediate, fast and flash)
  - Gasification (Fixed bed, fluidized bed)
  - Combustion (Fixed bed, fluidized bed)



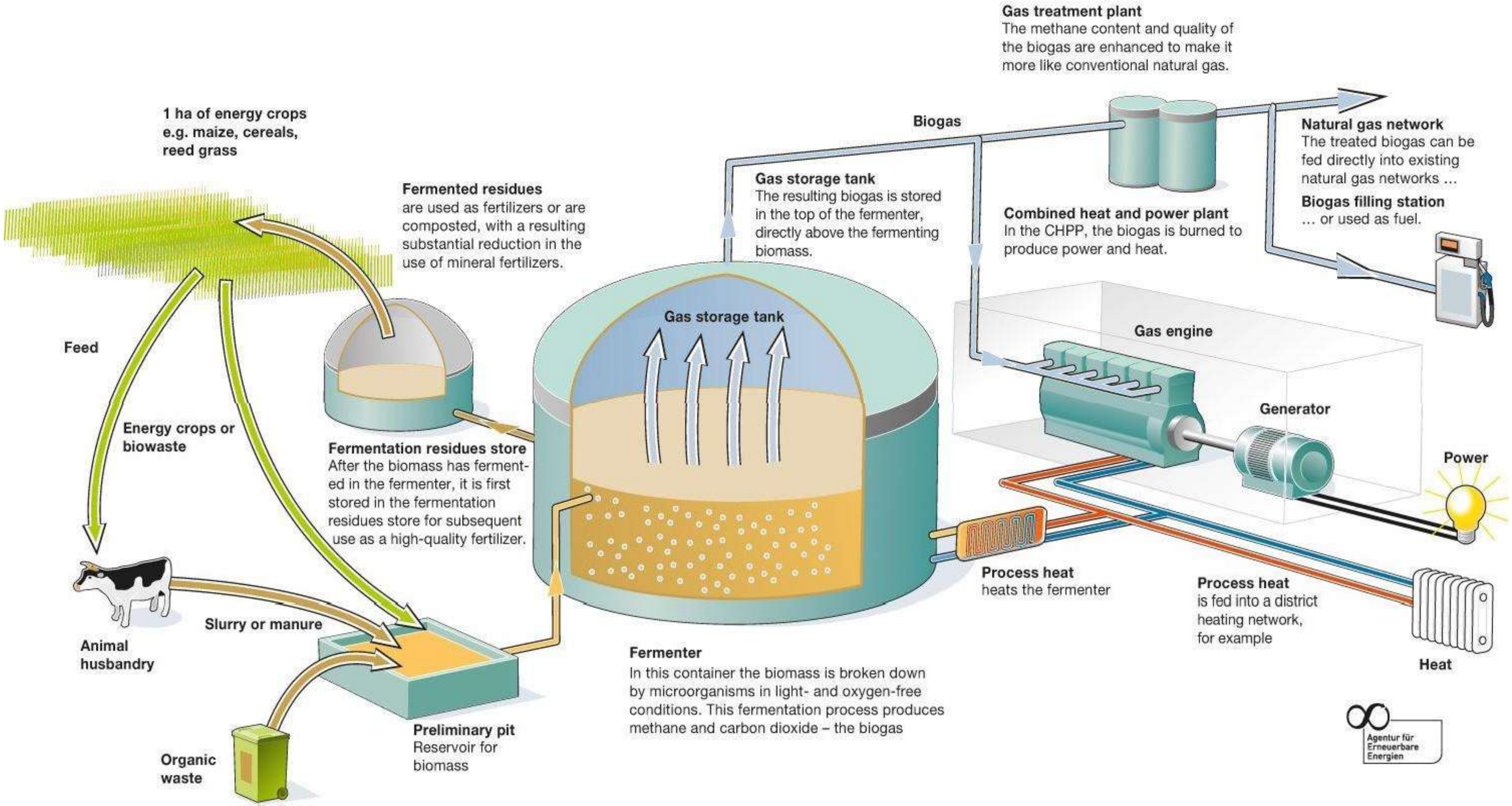
[A. A. Ahmad, et al, 2016]

Heat production for steam generation



Equipment for steam cycle (water steam or ORC)

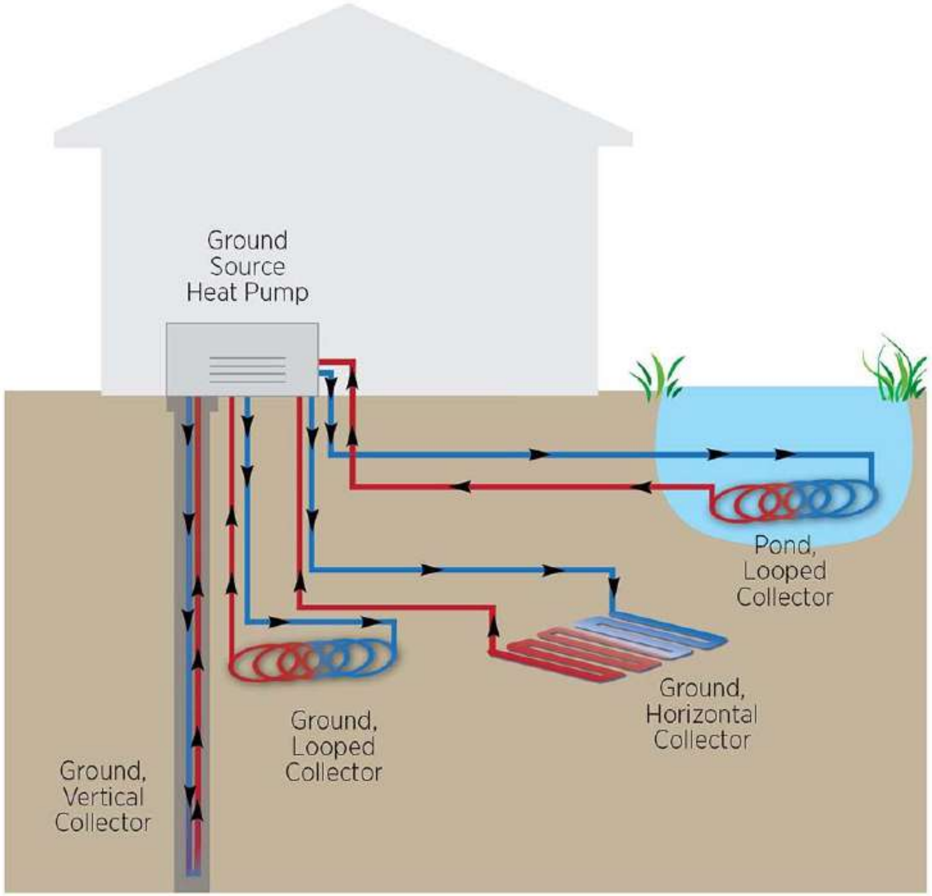
Digestion
(SEWAGE, BIOMASS FEEDSTOCK, SLUDGE)



Other Renewable energy resources

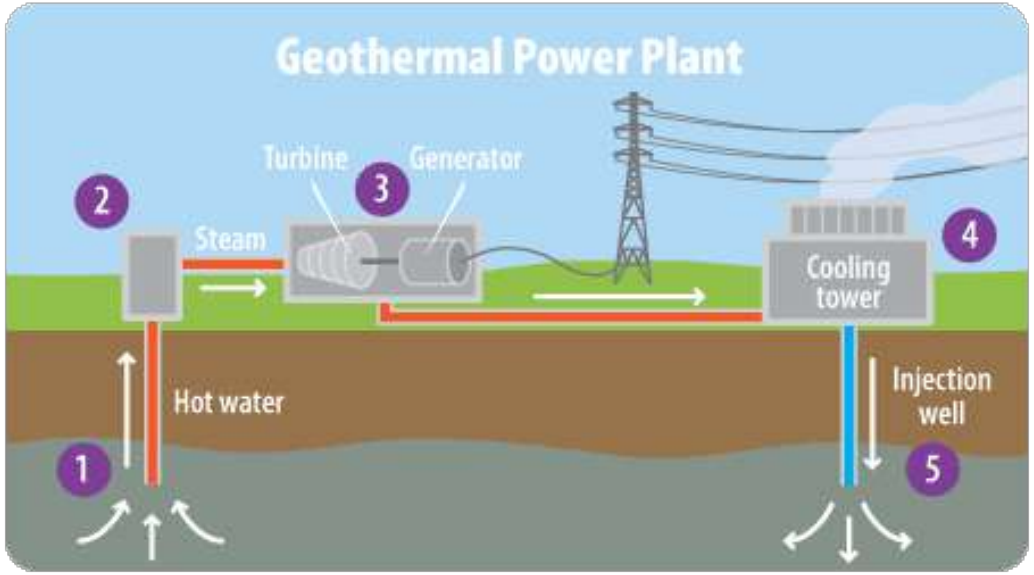
Geothermal Direct use

- Horizontal ground loops are the most cost effective and common system for residential homes, when enough land is available to lay out a system and trenches are easy to dig. Piping is laid in trenches which range from 30-120 m in length.
- Borehole Heat Exchange
- This type uses one or two underground vertical loops that extend 150 meters below the surface.
- Ground looped ideal for a wide variety of properties with various land/garden sizes and shapes.
- Pond looped ideal for any property including house boats, so long as the water source is large enough to hold the amount of pipework needed to provide the required heat load for the property.



High Temperature: Producing Electricity

- When the temperature of a hydrothermal resource is around 150 C and up, it can be used to generate electricity. Most electricity-producing geothermal resources have temperatures from 160-375 C, but geothermal reservoirs can reach nearly 550 C.
- Deep wells are drilled and steam from reservoirs is used to drive turbines and produce electricity
- Normally takes place by using heat present in the deeper subsurface at depths of 3 to 5km.
- In specific areas one does not need to drill that deep (e.g Iceland)

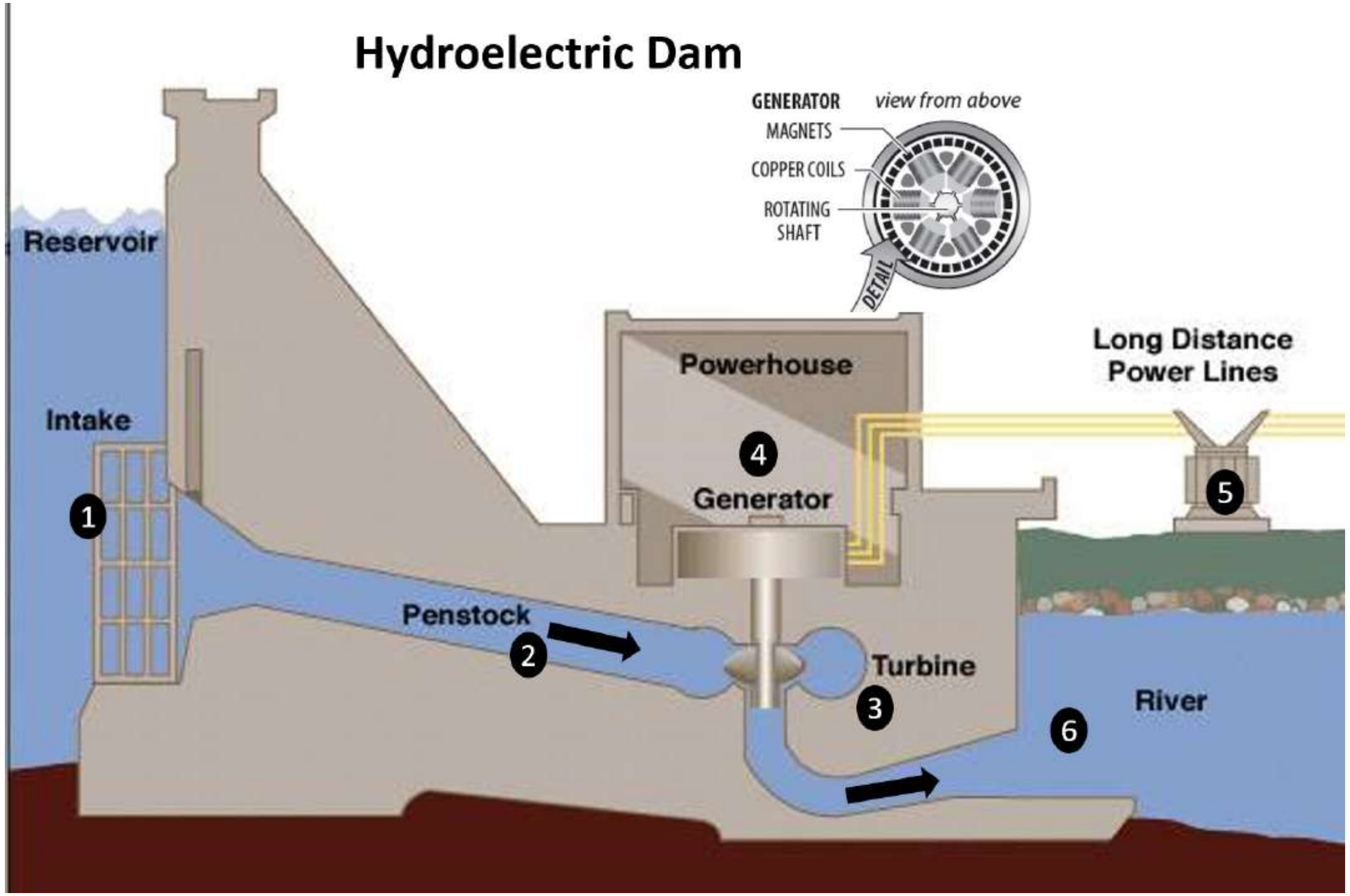


1.Hot water is pumped from deep underground through a well under high pressure.
2.When the water reaches the surface, the pressure is dropped, which causes the water to turn into steam.
3.The steam spins a turbine, which is connected to a generator that produces electricity.
4.The steam cools off in a cooling tower and condenses back to water.
5.The cooled water is pumped back into the Earth to begin the process again.

Hydro-power

Possible Environmental Impacts

- Fish Population
- Quality and Flow of Water
- Ecosystems of Rivers and Streams



Research projects – Energy Engineering Department

Research motivation

Renewables integration demanding

The attraction of wind and **solar energy**

The need of solving electricity outages

The need of fresh water

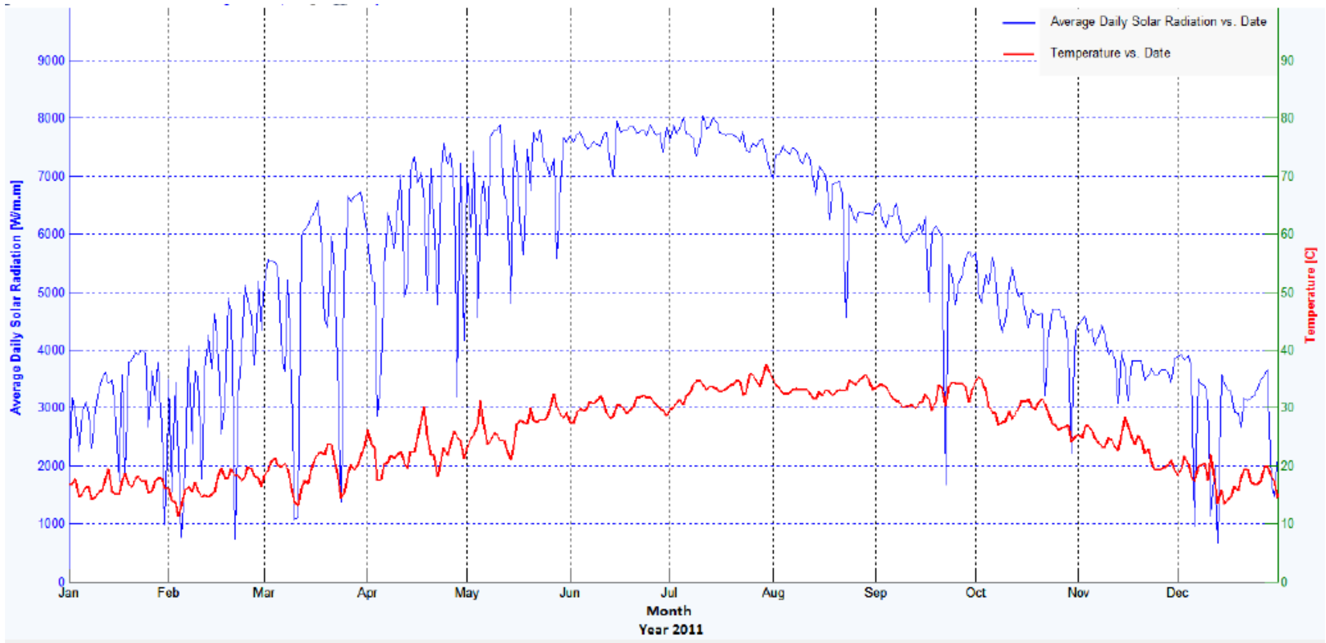
Brackish water availability

Promising RO - Desalination

Research activities - Starting

“Development and Utilization of Solar Driven Water Pumping and Desalination Units for Application in Remote Areas of Jordan”

Project Duration: 02/07/2009 – 02/07/2011 (SRSF)



Research activities – currently

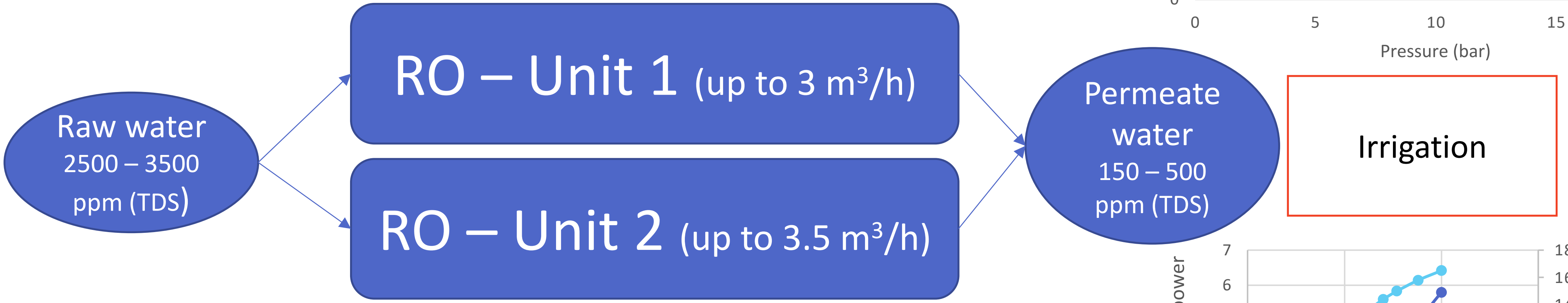
Brackish Water Desalination System powered by off-grid PV system

- 10.4 kW off-grid installation
- Reverse Osmosis desalination technique
- Produced water is used for irrigation purposes
- 24 hours energy storage backup
- System is running since 2012 continuously

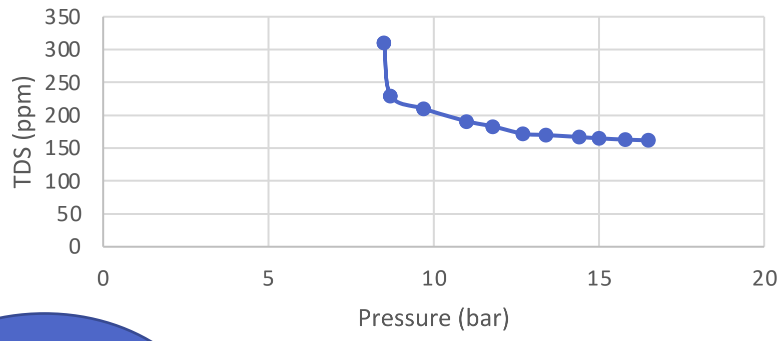
Current improvement actions

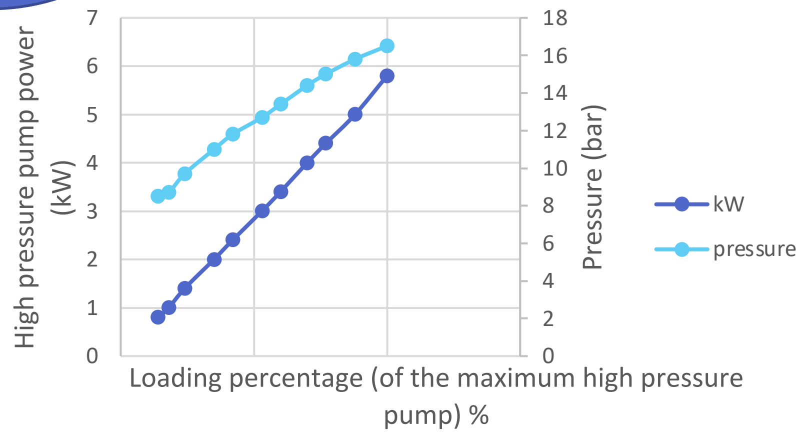
- Additional PV array with 10.25 kW, with a second RO
- Energy efficiency enhancement through refined design

Desalination



Pressure with TDS



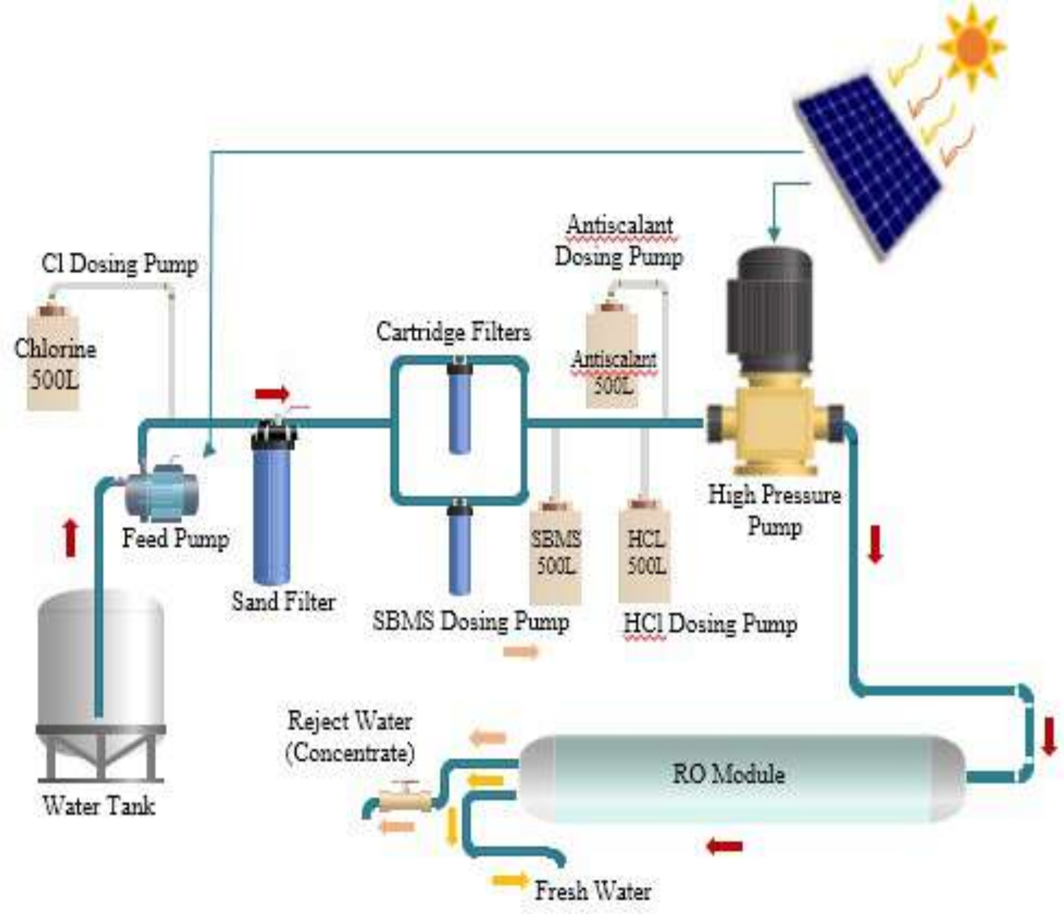


Description of the Brackish Water Reverse Osmosis Desalination Plant in the Jordan Valley

- The off-grid system comprises a 24 kWh PV array with 16 m^3 storage tanks, an RO desalination unit with three membranes in series, and a VFD controller to regulate pump pressure. It optimizes energy conservation by using solar power to pump and store water during high radiation, disinfecting stored water for safety.

- The pretreatment system, including sand and cartridge filters, enhances efficiency and minimizes membrane fouling. It adds sodium metabisulfite to counteract chlorine corrosion and employs acid and antiscalant to prevent scale formation. The RO unit adjusts feed pressure with a VFD and utilizes CPA3 membranes arranged in series.

- Permeated water is blended for uniform quality before irrigation. In some cases, it can be mixed with untreated water. Rejected concentrate is discharged outside the plant.



Achieved new project (started in 01.06.2022) (PRIMA/SRSF)

Innovative Aquifers Governance for Resilient Water Management and Sustainable Ecosystems in Stressed Mediterranean Agricultural Areas (AGREEMed)

Brackish water desalination and brine management with adaptation of renewable energy resources (Jordanian part)

- This project aims:
- Optimizing the use of solar energy and brackish groundwater for desalination and irrigation purposes. Based on an existing project that uses solar energy to desalinate brackish groundwater in the Jordan valley.
- Brine management technologies.
- To design, optimize, demonstrate, and evaluate the developed prototype.
- To initiate and promote the transfer of the technological solutions into practice.

AGREEMed – PRIMA project

Phase 2 Evaluation Highlights:

1. RO Unit Efficiency: A thorough assessment of a reverse osmosis unit in Jordan revealed a sand filter defect, necessitating its replacement with an ultrafiltration system for improved brackish water treatment.

2. Membrane Maintenance: The team disassembled and cleaned the RO membrane with hydrochloric acid, with plans for a new membrane introduction in November for further evaluation and optimization.

3. Future Prospects: The upcoming mission will comprehensively assess the system, optimize performance, and confirm alignment with project objectives while scrutinizing membrane integrity and system effectiveness.

Efficiency of PV system in the Jordan Valley

Source of Funding: Ministry of Higher Education & Scientific research

Start-End Date: 09/2015- 09/2019

Portable microwave based treatment system for on-site faecal sludge treatment for the humanitarian and development WASH sector

Funded by: DUPC2, Dutch Ministry of Foreign Affairs

Coordinator :UNESCO-IHE Delft
Start-end date: 2016-2020

Biogas Production in Local Communities in Jordan

Source of Funding: European Union (Reference: EuropeAid/136101/ID/ACT/JO)/ REEED

Contracting Authority: Ministry of Energy and Mineral Resources, Jordan

Project Partners: German Jordanian University and Hamburg University of Technology.

website (www.biogas-in-jordan.org)

Start-end date: January 2015 - May 2018.

Development and demonstration of a Hybrid CSP-biomass gasification boiler system (BIOSOL)

Funded by: project in the Budget line ERANETMED, funded by EU, HCST, GJU, COGEBIO

Coordinator: DBFZ – Leipzig – Germany

Partners: GJU, DLR, COGEBIO, LGCIE, University of Porto, University of Patras, ENIT, AES, CDER

Integrated Biomass – solar water desalination system for underground brackish water in Alghore

Source of fund: GJU – DSR

Start-end date: 8/2018-3/2021

Projects

Transformation in Water, Energy and Education(TWEED)

Funded by: Federal Foreign Office (AA), German Academic Exchange Service (DAAD) Germany,
project coordinator: TU- Berlin, Germany.
Partners: GJU, PSUT, TUB, CERTE
Start-End Date: 1/1/2019 – 31/12/2021

Salinity in Transformation

Funded by: Federal Foreign Office (AA), German Academic Exchange Service (DAAD) Germany,
project coordinator: TU- Berlin, Germany.
Partners: GJU, PSUT, TUB, CERTE
Start-end date: 1/1/2016- 31/12/2018

Outcomes

الجامعة الألمانية الأردنية
German Jordanian University

Utilization of solar energy

Agricultural improvements

Electrical reliability

Academic knowledge integration

Expanding partner's network

Research enhancement

Partners

الجامعة الهاشمية
The Hashemite University

الجامعة الألمانية الأردنية
GJU
German Jordanian University

Ministry of Higher Education & Scientific Research
The Hashemite Kingdom of Jordan

Technische Universität Berlin

Hochschule Magdeburg • Stendal

TUHH
Hamburg University of Technology

صندوق دعم البحث العلمي
Scientific Research Support Fund

DBFZ

German Water Partnership
Solutions you can trust.

UNESCO
IHE DELFT

Global Partnership for Water and Development

CERTE
Water Researches and Technologies Center

DAAD
Deutscher Akademischer Austauschdienst
German Academic Exchange Service

Hashemite Kingdom of Jordan
Ministry of Water and Irrigation

Ministry of Energy and Mineral Resources

DLR

U.PORTO

COGEBIO
la vertu du bois la souplesse du gaz

UNIVERSITY OF PATRAS
ΠΑΝΕΠΙΣΤΗΜΙΟ ΠΑΤΡΩΝ

LGCIE
LABORATOIRE DE GÉNIE CIVIL & INGÉNIERIE ENVIRONNEMENTALE

Federal Republic of Germany
Foreign Office

Thank you for your attention

Together we improve the capacities of water actors in developing integrated aquifer management plans

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