United Nations Development Account Project on Developing the Capacity of ESCWA Member Countries to address the Water and Energy Nexus for Achieving Sustainable Development Goals

Final Regional Policy Workshop on the Water-Energy Nexus

11- 12 December 2017, Beirut, Lebanon

Economic and Social Commission for Western Asia

Assessment of the use of Photovoltaic Solar Systems for Pumping Irrigation Water in Egypt within the framework of Water-Energy Nexus

UNITED NATIONS

الاسكوا

ESCWA

Objectives

- To provide technical and economic guidance to help support the rational development of water use and energy use in new lands

- To provide support to policy makers to help encourage development and promote sustainability of the water resources

Overview

- Technical aspects of groundwater pumping
  - Definition of the problem
  - Determining needs and sizing
  - Challenges and drawbacks of solar water pumping
- Economic and cost analysis
  - Basic cost
  - A levelized cost approach
- The regulatory problem
  - How and why to regulate a shared resource
- Conclusions
  - Technical, economic, and regulatory conclusions
- Recommendations: what do to

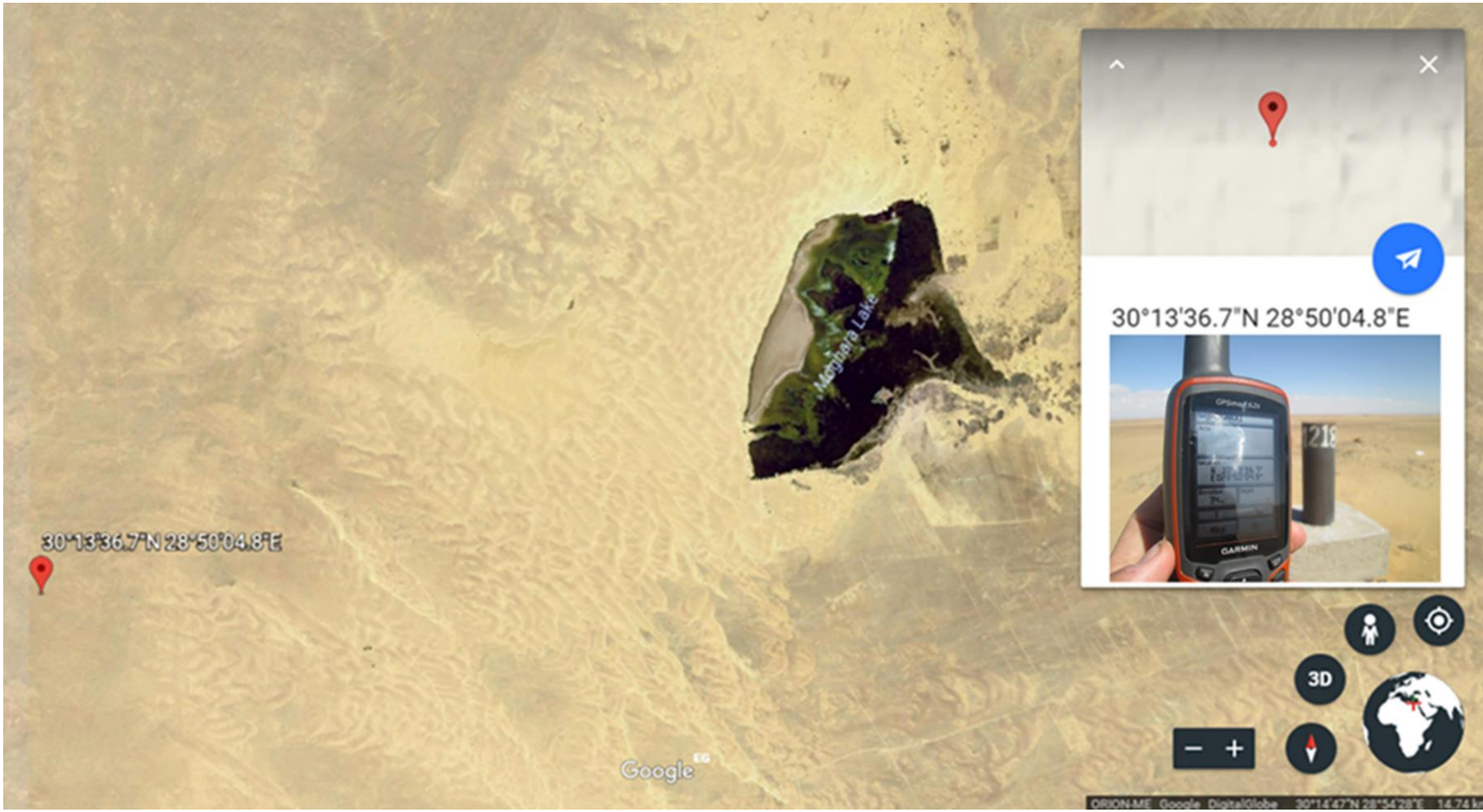
Moghra - far from resources

Definition of the technical problem: what are we talking about and why?

- Off-grid pumping of ground water
- Not on-grid – because that's simple
- Not surface water, there is none in the areas we are concerned with
- Groundwater allows me to be "off the water grid" – now I want to be "off the electricity and diesel grid" as well

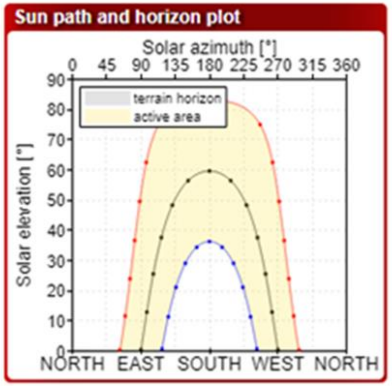
The Challenges

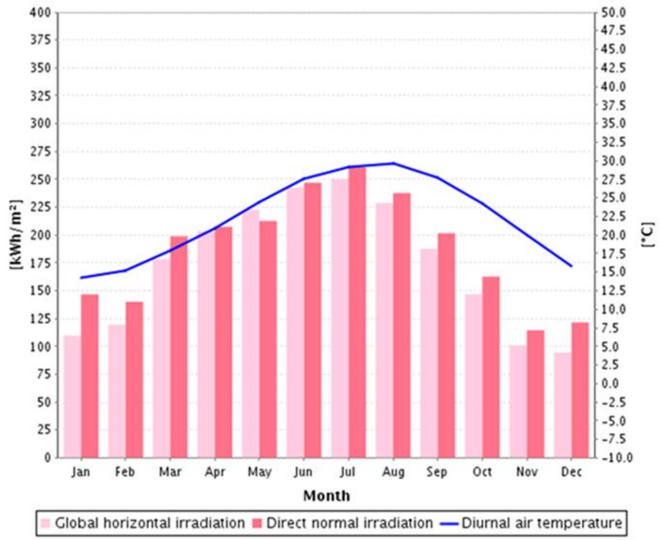
- How much water do I need?
- When do I need it?
- What size pump and solar system do I need to achieve it?
- Am I better off using solar or diesel?
- There are several variables - the answers depend on your assumptions (i.e. one season vs. multiple seasons; are there uses for PV when it's not irrigating, and so on)


Moghara Lake
30°13'36.7"N 28°50'04.8"E
30°13'36.7"N 28°50'04.8"E
GARMIN
3D
Google
ORION-ME Google DigitalGlobe 30°14'47"N 28°54'28"E 14.74 km

The area surrounding: Al Moghra at present

Conditions in Al Moghra





Month	GHI	DNI	TEMPER
Jan	110	147	14.3
Feb	119	140	15.2
Mar	178	199	17.9
Apr	204	207	21.0
May	223	213	24.4
Jun	243	247	27.6
Jul	250	261	29.1
Aug	229	238	29.6
Sep	188	202	27.7
Oct	147	163	24.3
Nov	101	115	19.9
Dec	95	122	15.9
Year	2085	2252	22.2

What size solar pump do I need?

Flow	Depth to Water (m)								
Cu. m/day	30	60	90	120	150	180	210	240	270
100	3.4	6.8	10.2	13.6	17.0	20.4	23.8	27.3	30.7
200	6.8	13.6	20.4	27.3	34.1	40.9	47.7	54.5	61.3
300	10.2	20.4	30.7	40.9	51.1	61.3	71.5	81.8	92.0
400	13.6	27.3	40.9	54.5	68.1	81.8	95.4	109.0	122.6
500	17.0	34.1	51.1	68.1	85.2	102.2	119.2	136.3	153.3
600	20.4	40.9	61.3	81.8	102.2	122.6	143.1	163.5	183.9
700	23.8	47.7	71.5	95.4	119.2	143.1	166.9	190.8	214.6
800	27.3	54.5	81.8	109.0	136.3	163.5	190.8	218.0	245.3

With error ~±20%.....

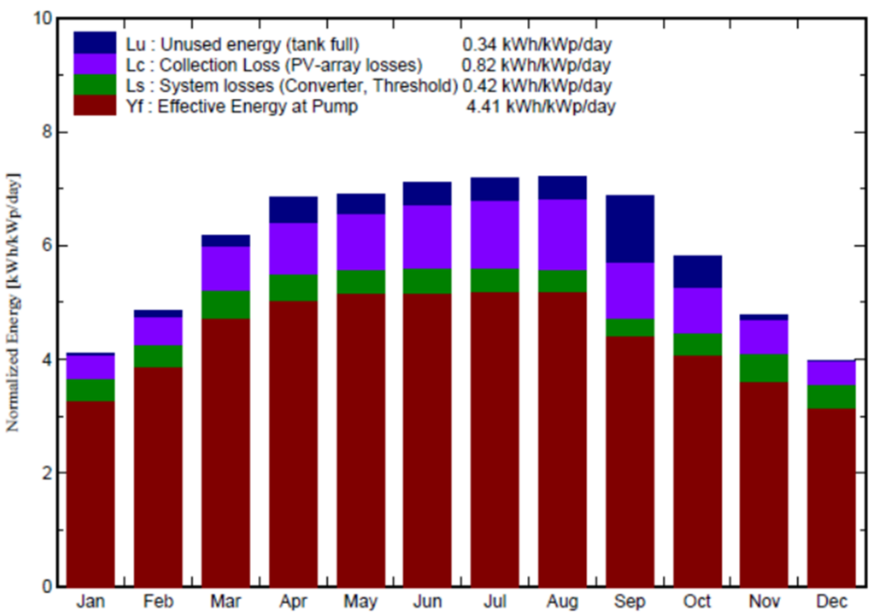
Simulation for a 49.5 kW PV unit and 37 kW pump

Main simulation results

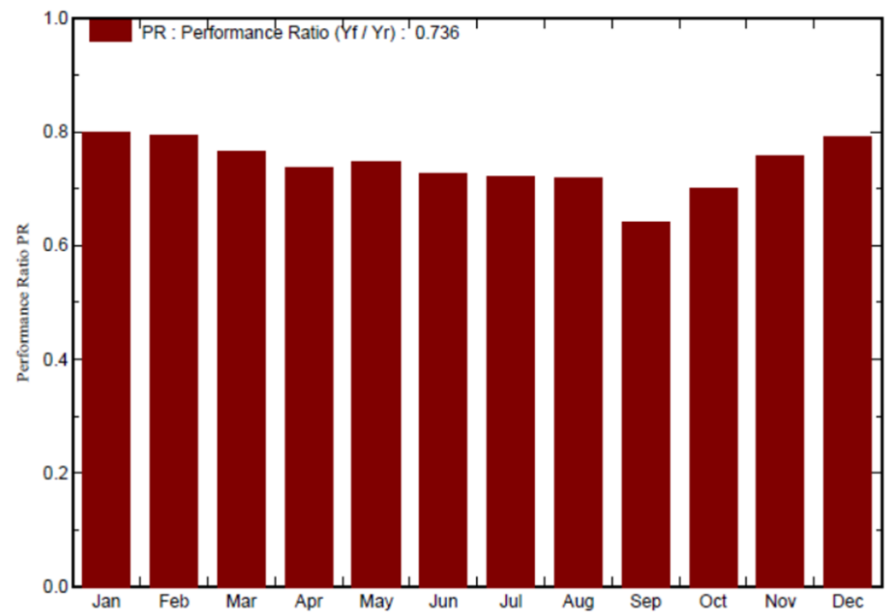
System Production

Water Pumped	**184573 m³**	Specific	342 m³/kWp/bar
Water needs	200900 m³	Missing Water	8.1%
Energy At Pump	79672 kWh	Specific	0.43 kWh/m³
Unused PV energy (Tank full)	5014 kWh	Unused Fraction	5.4 %
System efficiency	86.2 %	Pump efficiency	70.9 %

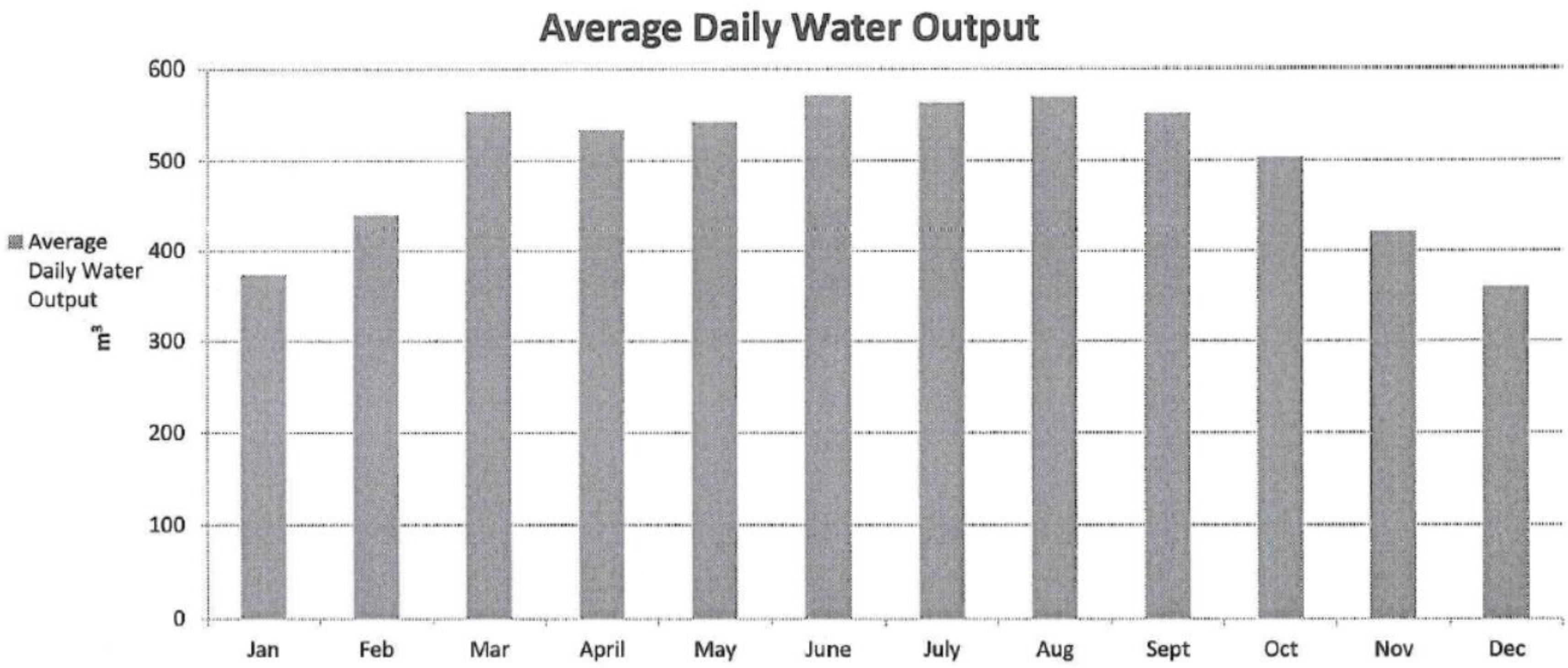
Normalized productions (per installed kWp): Nominal power 49.5 kWp



Performance Ratio PR

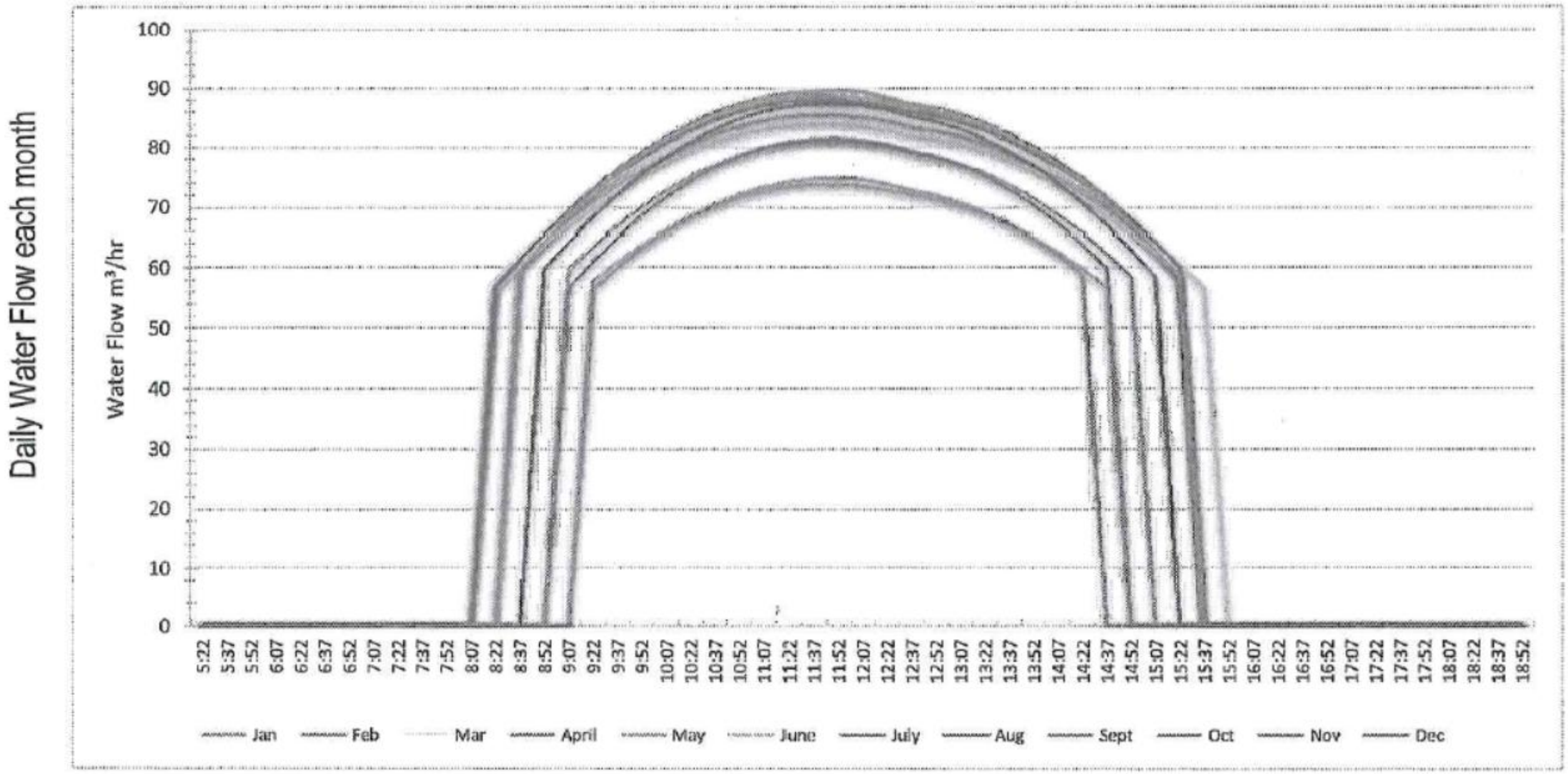


Simulated daily water output (40 kW pump, 100 m water depth)



Credit: GTS

Simulated water flow rates by month (40 kW pump, 100 m water depth)

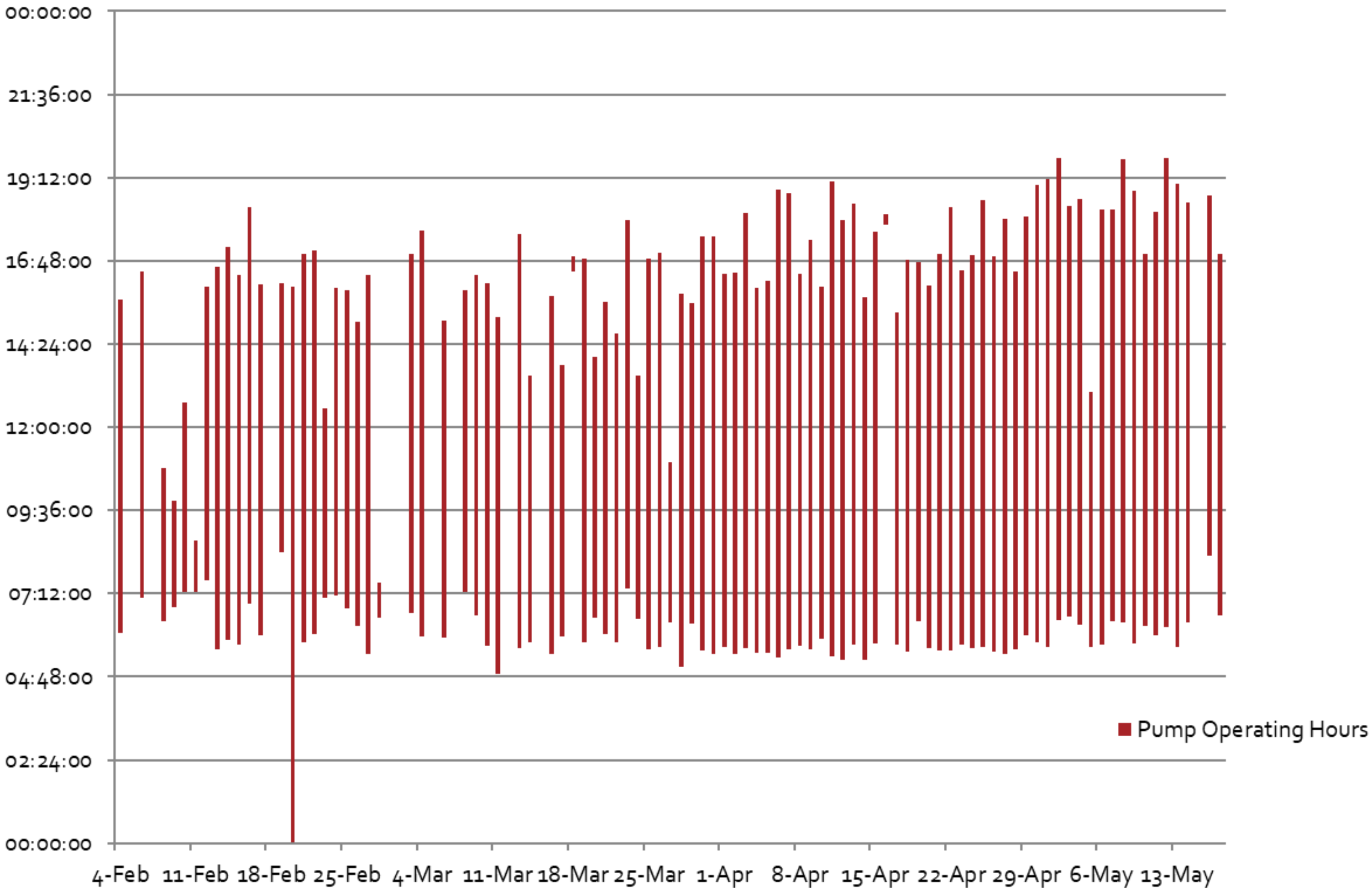


Credit: GTS

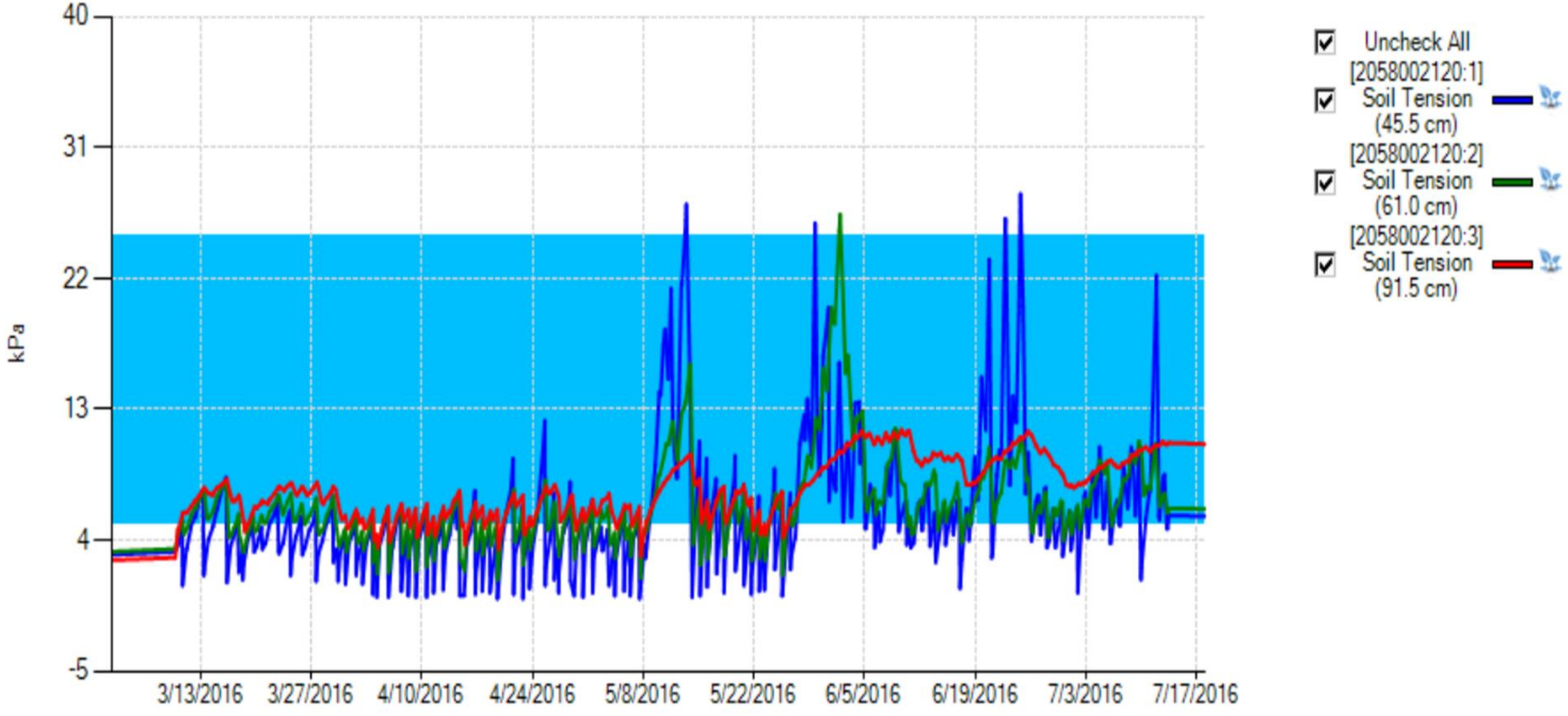
The problem

- is that irrigation presently runs like this

Example of typical irrigation on a typical farm



Measured soil moisture (tension)



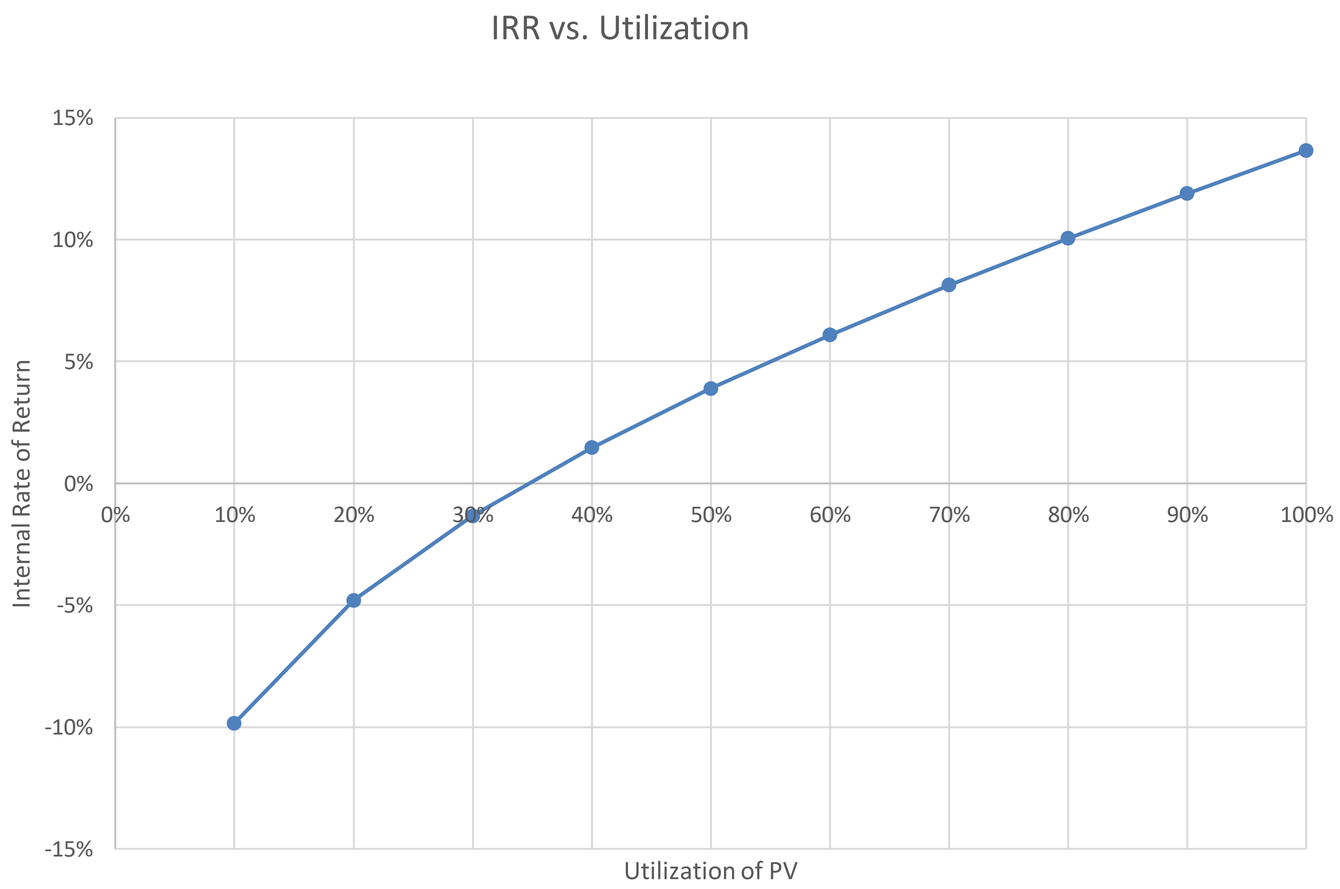
Economics – What will it cost?

Flow	Estimated Capital Cost (thousand USD)								
Cu. m/day	30	60	90	120	150	180	210	240	270
100	3.8	7.7	11.5	15.4	19.2	23.1	26.9	30.8	34.6
200	7.7	15.4	23.1	30.8	38.4	46.1	53.8	61.5	69.2
300	11.5	23.1	34.6	46.1	57.7	69.2	80.7	92.3	103.8
400	15.4	30.8	46.1	61.5	76.9	92.3	107.7	123.0	138.4
500	19.2	38.4	57.7	76.9	96.1	115.3	134.6	153.8	173.0
600	23.1	46.1	69.2	92.3	115.3	138.4	161.5	184.6	207.6
700	26.9	53.8	80.7	107.7	134.6	161.5	188.4	215.3	242.2
800	30.8	61.5	92.3	123.0	153.8	184.6	215.3	246.1	276.8

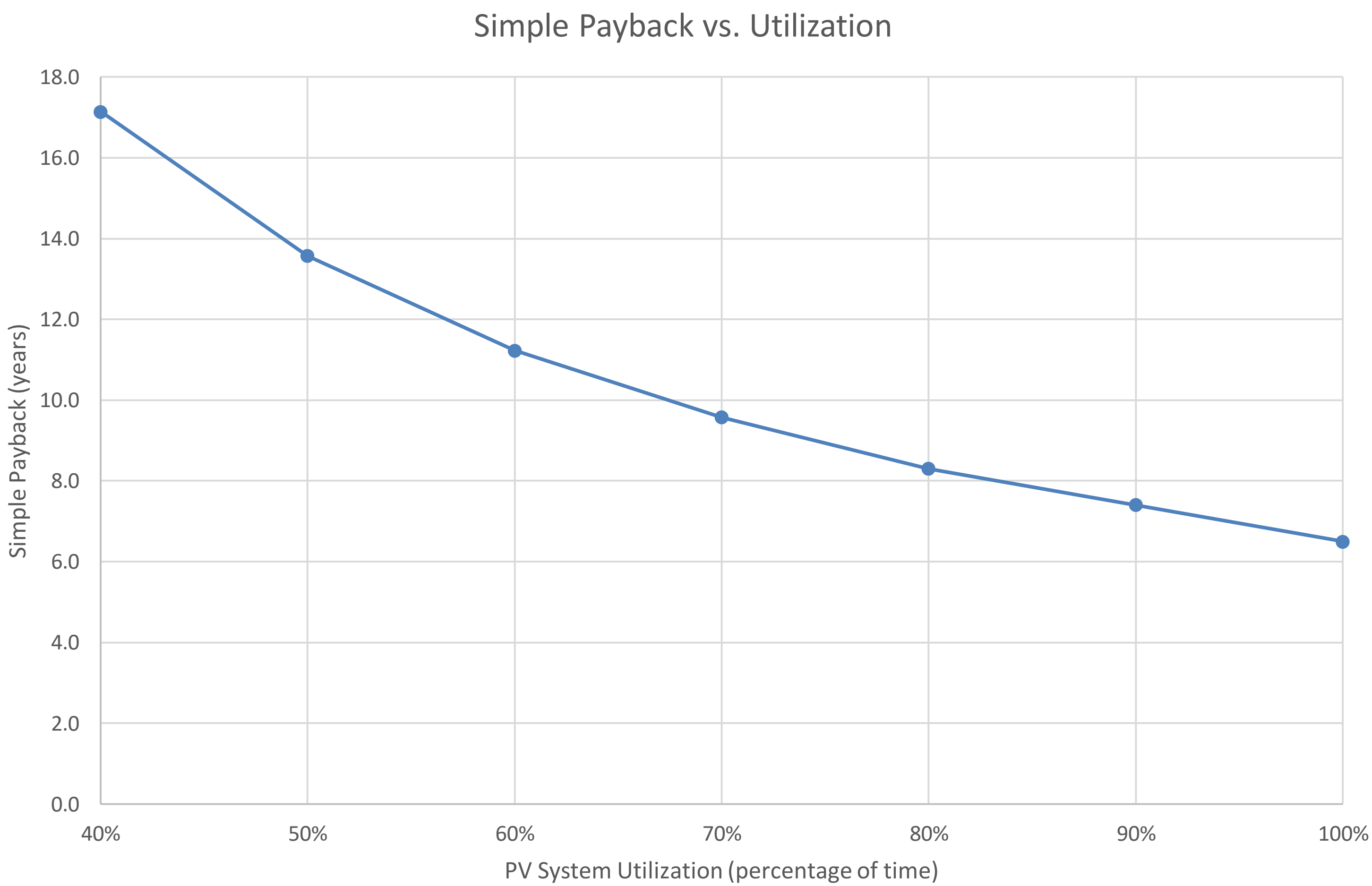
What is the return (compared to diesel)?

- It depends….

What is the return (compared to diesel)?



Simple Payback



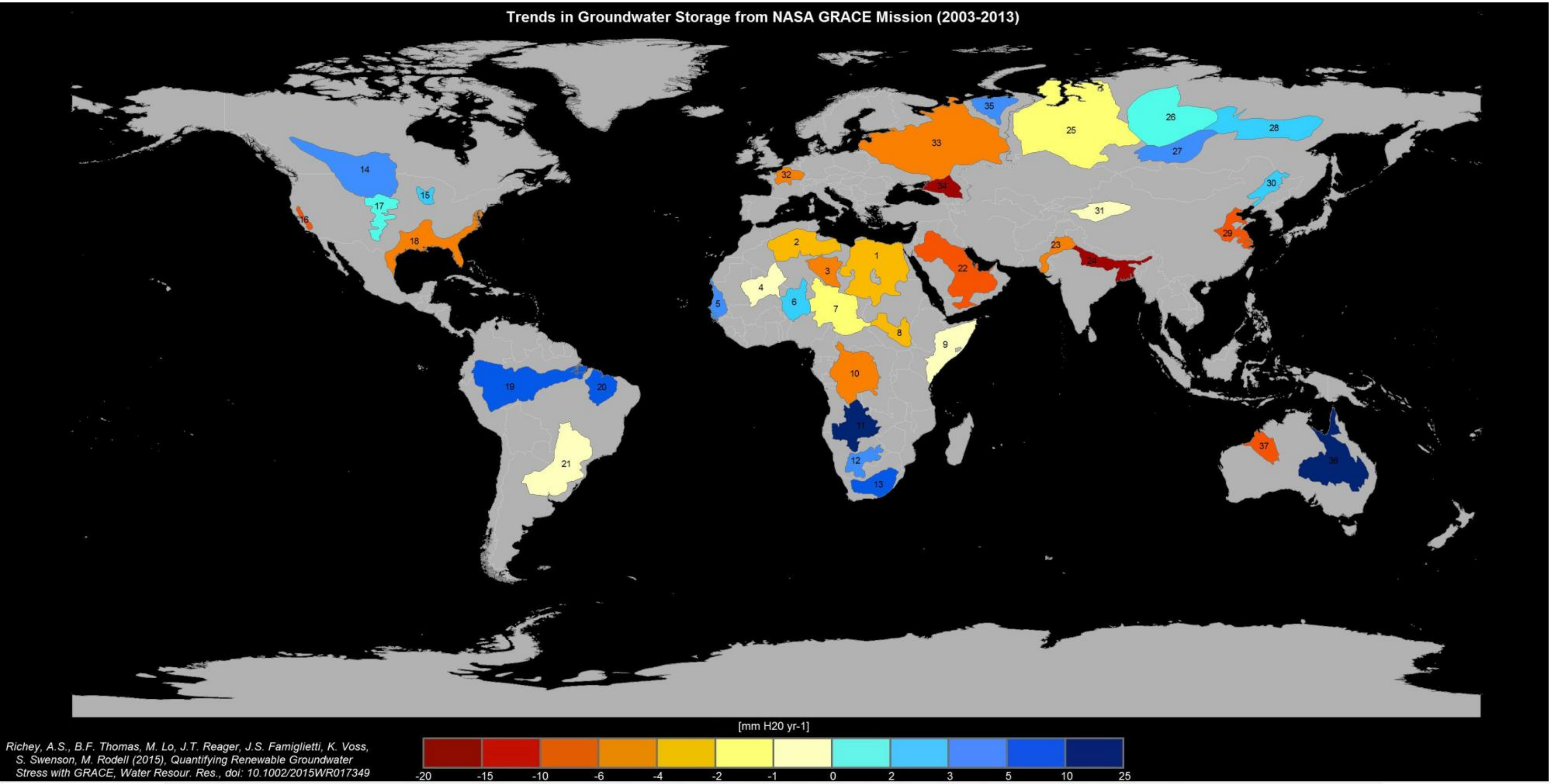
But it doesn't matter, because…

- Most diesel system are run incredibly inefficiently.
- The "return" of a solar PV system depends very strongly depends on how it is utilized.
- We are considering prices today, but prices are changing rapidly – solar will be economical sooner rather than later.
- The most valuable, and irreplaceable, component of the system is free.

The Conflict?

Private Grower's Interests	The General Public's Interests
- Develop new lands - Minimize cost to grow and irrigate crops (minimize capital cost) - Minimize maintenance and headache - Minimize pollution	- Develop new lands - Minimize cost to grow and irrigate crops - Minimize maintenance and headache - Minimize pollution

The Conflict



1 Nubian Aquifer System (NAS)
2 Northwestern Sahara Aquifer System (NWSAS)
3 Murzuk-Djado Basin
4 Taoudeni-Tanezrouft Basin
5 Senegalo-Mauritanian Basin
6 Iullemeden-Irhazer Aquifer System
7 Lake Chad Basin
11 Upper Kalahari-Cuvelai-Upper Zambezi Basin
12 Lower Kalahari-Stampriet Basin
13 Karoo Basin
14 Northern Great Plains Aquifer
15 Cambro-Ordovician Aquifer System
16 Californian Central Valley Aquifer System
17 Ogallala Aquifer (High Plains)
20 Maranhao Basin
21 Guarani Aquifer System
22 Arabian Aquifer System
23 Indus Basin
24 Ganges-Brahmaputra Basin
25 West Siberian Basin
26 Tunguss Basin
29 North China Aquifer System
30 Song-Liao Basin
31 Tarim Basin
32 Paris Basin
33 Russian Platform Basins
34 North Caucasus Basin
35 Pechora Basin

The Conflict

Private Grower's Interests	The General Public's Interests
- Develop new lands	- Develop new lands
- Minimize cost to grow and irrigate crops	- Minimize cost to grow and irrigate crops
- Minimize maintenance and headache	- Minimize maintenance and headache
- Minimize pollution	- Minimize pollution
- Extract water freely at minimum cost	- Minimize water extraction to ensure sustainability (or at least longevity)

The Role of Regulation

- The solution for such conflicts of private and public interest is typically regulation.

- But regulation alone is not enough.

Steps for efficient and regulated water use

- Determination of resource and availability – getting this wrong means everything else is useless
- Providing overall guidance on water use and water use budgets – users are already wasting water and resources
- Providing system design guidance based on water use
- Providing live daily guidance to support irrigation activities – most farms do not know how much or when to irrigate
- Engaging in soil monitoring and efficient water use
- Regulating extractable water amount
- Measuring, monitoring and enforcing regulations on water use
- Measuring and monitoring the main resource aquifer and updating resource forecasts accordingly
- Learning from other areas who have participated in water resource management

What can we conclude? Technically

- Determining appropriate water use is the first and most important step for any efficient system design
- Water use is not just system sizing, it is operation over its life
- Using existing general practice guidelines will not work – they lead to gross over irrigation
- Every possible means for more efficient water use should be investigated (soil additives, soil measurement, shading, etc…)
- Efficient water use is not only important for energy reasons, but primarily for crop management reasons
- There is a lack of experience and knowledge in the region in developing efficient systems from ground-water extraction to utilization.
- The problem is multi-faceted, and so difficult to address in one step and will require the expertise of multiple persons
- Assistance will be needed to improve the state of water management. The market will not do it on its own.

What can we conclude - Economically

- Economically speaking, – the return on investment in solar energy depends highly on the actual utilization.
- The “feasibility” is mostly tied to the capital investment, hence the availability of financing is an important part of making solar pumping feasible.
- In some circumstances, particularly those of low utilization, diesel pumping may be more attractive.
- The availability of an alternative use for solar energy, for when it is not being used for irrigation; or the ability to level a single solar source over multiple loads greatly impacts the utilization and therefore viability of solar pumping.
- As solar PV continues to fall in price, and fossil fuels continue to rise in price, solar PV pumping will become increasingly attractive – and the market moves incredibly quickly.

What we can conclude from a public policy and regulatory perspective

- There is at the moment an absence of regulation capable of addressing the new opportunities and challenges that arise form utilizing underground water in the desert.
- There is lack of knowledge and lack of understanding in the market place.
- The private sector alone probably will not lead to an outcome much more efficient than the present (which is bad).
- In the absence of appropriate regulation precious aquifers may be depleted leading to a permanent loss for future generations.
- The nature of the water-energy nexus will require cooperation between authorities at a level that previous challenges have not.

Recommendations

- The problem is multi-faceted and will require strong cooperation on all levels between the responsible authorities (water, agriculture, land, energy) to achieve a desirable outcome.
- Strong technical guidance is needed – and needs to be developed – to guide appropriate water use.
- Technically speaking, the most crucial element is determining appropriate water use and tolerances for varying usage – water use by land area and crop are needed; system sizing tables are needed; continuous feedback based on weather to determine irrigation is needed.
- There is considerable experience in water use regulation from around the world which should be used.
- If the problem is left to economics, or if we wait until the economics make pumping attractive, the market will move much faster than policy and regulations can catch up.

Recommendations

Public bodies need to lead the way by:

- Determining bounds which we cannot cross (e.g. water usage)
- Providing guidance and technical assistance to help farmers and growers work within those bounds
- Providing clear regulations and enforcing those regulations to ensure sustainability for all users
- Continuously monitoring the available public resource (ground water) and updating regulations and best practices

Economic and Social Commission for Western Asia

Thank You

ESCWA Consultant

info@ercc-carbon.com

UNITED NATIONS

الاسكوا

ESCWA

40 YEARS