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Solar Irrigation for Agricultural Resilience (SoLAR)

Will Solar Irrigation deepen the groundwater crisis in South Asia?

Summary Report of Webinar 6

5 February 2021

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List of Abbreviations

IWMI	International Water Management Institute
SIP	Solar Irrigation Pumps
ATREE	Ashoka Trust for Research in Ecology and the Environment
GDP	Gross Domestic Product
GW	Groundwater
CGWB	Central Ground Water Board
STW	Shallow Tube Wells
DTW	Deep Tube Wells
FiT	Feed-in-Tariff
NDDB	National dairy development board
NW	North West
NDDB	National dairy development board
BWDB	Bangladesh Water Development Board
SoLAR	Solar Irrigation for Agricultural Resilience

Webinar 6: Will solar irrigation deepen the groundwater crisis in South Asia?

The sixth and final webinar was held on the 5th of February 2021 and was attended by 54 participants from 13 different countries. It was moderated by Dr Alok Sikka, IWMI, India.

South Asia is the world's largest user of groundwater. Groundwater irrigation has been critical to agricultural production in the region, and its depletion in parts of South Asia is a threat to future food security in the area. Climate change is further expected to affect recharge through increasing variability in rainfall. Intensive groundwater irrigation in the region has mainly been farmer-led, benefiting from state policies like subsidised electricity and credit. Studies have shown that energy price plays a vital role in determining farmers' pumping behaviour. Farmers who face lower marginal costs of pumping tend to pump more intensively than farmers who face a higher marginal cost. While up-front costs of solar irrigation pumps (SIPs) are high, running costs are virtually zero. This gives rise to the widespread apprehension that SIPs may promote groundwater over-exploitation, especially in groundwater scarce parts of South Asia.

Against this background, this webinar focused on questions such as:

- What is the current state of evidence on the impact of SIPs on groundwater pumping?
- Is groundwater over-exploitation a concern everywhere in the region?
- Is it inevitable that SIPs will lead to groundwater over-exploitation, or is it possible to design SIP programs in ways that provide incentives to farmers to reduce groundwater pumping?
- What would make or break such incentive programs?

Table 1: Schedule of webinar 6

Webinar	**Date & time**	**Speakers/Presenters**	**Panellists**
Webinar 6	5 February 2021(3:00-5:00 PM IST)	Dr Veena Srinivasan Dr Meha Jain Dr Wolfgang Kinzelbach Dr Mainuddin Mohammad	Dr Tushaar Shah Dr Anwar Zahid Dr Simi Kamal

YouTube link of webinar 6: https://www.youtube.com/watch?v=CQxF5zNoYL8

I. Presentations

a) How do we solve India's groundwater problem? Mapping Problem Typologies and Solutions

Dr Veena Srinivasan, ATREE, India, presented in this session.

The speaker discussed how to define and quantify sustainable groundwater abstraction levels and how that can be used to analyse where solar irrigation (with feed-in tariff) can work in India. The groundwater problem is showcased as a case of the Goldilocks problem. It is overexploited on the one hand, and on the other, it is the case of groundwater poverty (in rainfed) regions where too little irrigation is a problem as farmer's don't earn enough. This is visible in India, where there is large scale groundwater abstraction for irrigation that has led to overexploitation, but broader indicators showcasing farmer's wellbeing haven't improved. The speaker proposed that though a lot of money is being spent by the government through several programs/schemes (such as MGNREGA, Har Khet ko Pani), farmers welfare indicators are going in the wrong direction reflect that either we are not putting enough money in the right solutions, or we are scaling the wrong things or a combination of both.

To define what should be done and what will work, first, there is a need to explain (and quantify) the sustainable abstraction level. A traditional approach to defining sustainable abstraction (management) has been based on the bucket model, where the assumption is that as long as abstraction is less than some (or some % of recharge), groundwater development is sustainable. However, this ignores the surface-groundwater connections. Any groundwater abstraction converted to ET leads to a change in base flows/surface water flows. Historically, groundwater was in equilibrium with recharge going to base flows/surface water flows. Over time, with groundwater abstraction reducing levels, groundwater no longer has any connection with surface water, and there, this bucket model might be more applicable.

However, the main question is, once we have defined sustainable abstractions levels, how do we tweak policy to put the limit on abstraction. Some measures include a hard limit on GW abstraction and auction wells in developed countries where agricultural contribution to GDP is low and robust environmental lobbies. The same won't work for India, where agriculture contribution to GDP remains significant, employing a large labour force. Under this case, the speaker discussed how solar irrigation feed-in tariff (FiT) could be used as an incentive to limit abstraction. The FiT approach in solar irrigation indirectly set a price for groundwater to reduce demand. However, the FiT should be assessed and vary depending on the local context and opportunity cost of water.

To identify the FiT at the district level, the speaker presented a framework for spatial district-level analysis to assess the same in areas where electricity pumps are used and connected to the grid. The analysis consists of estimating the opportunity cost of groundwater and sustainable abstraction level to arrive at optimum FiT. An investigation is at the preliminary stage.

Table 2:Q&A with Dr Veena Srinivasan

Sl no	Question	Answer
1	**Alok Sikka:** How to incorporate the dynamic demand in the proposed analysis?	Indeed, demand is not static as price varies. For solar irrigation, it is challenging to control abstraction if crop prices are high as then FiT doesn't provide enough incentive. It works well in areas where groundwater is not valuable (decided by crops, markets). Within error margins, from the framework, we will be able to identify broader typologies.
2	Will water prices in informal water markets be a good enough proxy for willingness to pay?	I don't know how extensive markets are in India. It could be a good proxy where it does.
3	**Shilp Verma:** Very interesting, Veena, but I doubt even developed countries have been able to enforce limits on groundwater depletion strictly. Depleted aquifers in the western US, southern Europe, and Australia keep depleting further**.**	It's not known how much groundwater there is; for example, in Australia, the cumulative volume of permits is more than available water. I believe the Muray Darling basin is re-doing many of their water allocations; again, Mainuddin and Peter may say more.
4	**Namrata G:** How can incentives for low water-intensive crops work compared to putting a price on GW?	I think this is worth investigating. Not sure if any authoritative studies/models on this. This could be done by providing better MSP prices for coarse cereals.
5	**Neha Durga:** What is the difference between the map arrived by your study and the CGWB map of groundwater status?	We haven't created a map yet - that was just a cartoon. I imagine the map will look quite different since it will be dominated by prices etc.

b) Climate change, groundwater depletion, and agricultural production in India

*Dr Meha Jain***,** *Assistant Professor, School for Environment and Sustainability, the University of Michigan, presented in this session.*

The speaker focused on linkages-feedbacks among climate change, groundwater depletion and agriculture production in India. Indian agriculture is expected to face some of the most adverse impacts from warming temperatures and is also the hotspot of groundwater depletion. The speaker presented the results of the analysis on these linkages that are posted as two questions:

- What are the impacts of warming temperatures on groundwater depletion and agricultural production?
- Are there adaptation strategies that can reduce the negative impacts of groundwater depletion?

Analysis used datasets on crop water stress derived using remote sensing data, groundwater well depth and weather across India. Results show that both deeper GW depth and the higher temp is increasing crop water stress. Every 1-degree Celsius increase leads to a slight increase in crop water stress (rising by 5-6 %). This suggests that farmers are adapting to increased temperatures. Following this, data showed that higher temperature is related to deeper GW levels showing farmers are adapting to increased temperature by increasing the use of irrigation to minimise stress. This could further accelerate groundwater overexploitation. Results were projected for the future (2050) using RCP scenarios, showing that GW depletion rates could quadruple compared to current rates but won't be uniformly distributed spatially.

In another analysis, the speaker discussed the possible adaptation strategies and the potential impact of groundwater depletion. RS products were used to assess winter production along with weather and village level irrigation datasets. Winter crop areas were overlaid with GW stress areas from CGWB and village level irrigation source dataset. Results show that up to 20 % of winter crop area is irrigated by unsustainable groundwater and can be potentially lost (worst case, upper bound) in the future if groundwater in these areas is not available due to depletion. The capacity of canal irrigation to mitigate this was analysed, and results show that canal irrigation is less reliable and is associated with relatively lower production. In future, even if all unsustainable GW irrigation is replaced with canal irrigation, still 7 % of winter cropped areas can be lost.

The analysis does not directly assess solar irrigation, but results can determine where solar should be prioritised. The increase in temperature and the associated increase in demand should be taken into account while planning SIP. This spatial analysis identifying potential areas susceptible to crop can be used for prioritising solar irrigation implementation to incentivise saving groundwater.

Table 3:Q&A with Dr Meha Jain

Sl no	Question	Answer
1	**Upali**: Groundwater depletion in the northwest is not mainly due to winter crops but also due to rice irrigation. How do you account for this?	So, in our study, we did not use model data but empirical data. We believe that as we measure post-monsoon actual groundwater depths, the impacts of rice irrigation are captured in the analysis.
2	What is the timing for the winter crop? Is it from October to November? I noticed West Bengal shows minimal winter cropped area, though it grows many summer Boro paddy from December to May.	We define winter cropped using RS data from Nov to Mid-April and identifying if the peak happens within that period.
3	**Peter Ravenscroft:** Have you accounted for the depths of CGWB monitoring wells? 80-90% is dug wells and frequently records a parched water table. Irrigation wells are generally much deeper and experience dry season water levels that are metres or tens of metres deeper. Veena has a paper on this: https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/2019GL083525	Thanks for this critical point. In our analyses, we separate the effect of dug wells and tube wells and find that most of the associations I showed are found for deeper tube wells. This is something we will try to better address in subsequent presentations! Veena, thanks for sharing your paper. I'm looking forward to reading it!
4	**Kashi Kafle:** As you use cultivated crops to measure crop water stress, how do you account for potential reduction in crop cultivation due to deepening groundwater and higher temperatures? Perhaps, only those farmers who were better off to start with could adapt to these stresses and be able to cultivate? Just curious.	Thanks for this great question. We didn't account for reductions in crop area in the first paper I described, but we do have some other papers looking at changes in: (1) crop area and (2) crop type due to groundwater depletion. We find that groundwater depletion is associated primarily with reductions in

		the area in the winter season.
5	**Soumya:** I was curious how non-classical measurement errors associated with remotely sensed data might impact your findings. Also, what is the unit of observation in your regressions; as well data, crop stress, and temperatures are measured at different spatial and temporal resolutions.	We don't believe that there is a significant non-classical error based on extensive validation done in different parts of India. Unit of observation is well level, and all other dataset is resampled to the same unit. A second analysis was at the village level.

c) Metering groundwater wells: Some experience from China and transferability to solar wells

Dr Wolfgang Kinzelbach, ETH Zurich, presented in this session.

The speaker summarised the experience of monitoring groundwater abstraction in China and how that can be used for monitoring solar pumps in India. To limit the groundwater use, quota and price are instruments used, but both require metering to know how farmers are abstracting. Similarly, water balance assessments also need assessment of resources and abstraction.

Abstraction can be measured by installing traditional water meters and smart water meters. However, their upscaling potential is limited by the cost, susceptibility to vandalism, tampering and cost of operation and maintenance. Alternative to direct measurements is indirect estimations by using methods such as by using energy, use time and land use and irrigation norms. Each is associated with its limitations. For example, in Luotuocheng irrigation district, Gansu, China, smart meters installed are operated by a swipe card, which carries the water right at the beginning of the season and provides real-time measured pumping data. But the transfer of the same to other parts is prohibited by cost and technical maintenance.

The speaker then discussed the experience from China, where energy was used as a proxy to get indirect estimates of groundwater abstraction. Research tool place in North China district with about 8000 wells, majority of which are small and primitive but for all, electricity consumption is metered. Pump tests were carried to monitor water abstraction, energy use and pumping head to develop energy-water conversion factors. On average conversion factor was 2.62 m^3/kWh in shallow aquifers and 1.32 m^3/kWh in deep aquifers. This conversion factor was used to get regional estimates of groundwater abstraction. The conversion factor is not too sensitive to pumping heads in deeper aquifers, and to cover long term decline, tests can be repeated once every 4-5 years. Results show that this approach can give abstraction estimates with sufficient accuracy of ± 20% and can be used for planning and water balance studies.

This approach can be applied to solar wells as well. However, it will require more effort, and slight modifications are necessary. In solar wells, energy varies during the day, but volume is proportional to energy, measured for solar pumps. Recorded power output can be used along with volume estimate conversion factor for different pumping heads. In Gujarat, India, where solar irrigation is being used extensively, it provides an excellent area to implement the same as metering is being adopted universally and automatically.

Table 4:Q&A with Dr Wolfgang Kinzelbach

Sl no	Question	Answer
1	How to account for different pump types for which conversion factor can be different?	You can determine pump efficiencies of wells and use the pump manufacturing data to get conversion factors. Efficiency can be more easily averaged, but that can give you a village or number of pumps together, so you need to get the different relationships for different sets.
2	**Aditi:** For a place that is hydro geologically diverse, I would assume that you will need to work out the energy-water volume extracted relationship for each of the hydrogeology?	You need to get this for different hydro geologies as drawdowns will be different for different aquifers. If you do several tests, you can get the relationship.
3	**Veena Srinivasan:** Do you have a sense of the cost of the meters?	The cost of a meter is about 6000 CNY. For a well with 150’000 m3/year and a water fee of 0.2 CNY/m3, one gets 3000 CNY per year. That is enough to repay the loan and pay for the maintenance.
4	**Kashi Kafle:** What is the marginal benefit of doing a pump test for every single pump across different hydrogeologies to develop the conversion factor over using smart meters to measure the volumes of water pumped out?	For covering the variety, you may need 300 pumping tests in a region with a few thousand wells; if every pumping test costs about 50$, that is quite affordable. You can get the estimate of the area. When you categorise wells according to pump power (which was the most crucial

		influence factor), static depth to groundwater and transmissivity of the formation, you get an excellent look-up table even for the single well.

d) Groundwater usage among electric and diesel farmers, and implications for SIPs in Bangladesh

Dr Mainuddin Mohammad, Principal Research Scientist, CSIRO Land and Water, presented in this session.

The speaker discussed and summarised results from studies that measured groundwater abstraction for Boro rice under different energy systems and its implications for groundwater sustainability. In Bangladesh, agriculture has gone through a transformation driven by the use of groundwater made possible through a rapid increase in the adoption of shallow tube wells (STWs). Especially, North West (NW) region has seen enormous growth in irrigation from groundwater, covering 97% of the irrigated area. Due to this, GW levels fall in some parts of the northwest region, increasing the use in deep tube wells (DTWs) or STW with submersible pumps as the water table drops below the suction limit in some areas. Data shows that saturation has reached in terms of cropping area and have stabilised in the NW region. There is a general and strong perception that overuse of water for Boro rice (~ 2500-3000 litre/kg) is the only cause of groundwater decline in the NW region. For this reason, a lot of water-saving irrigation technologies such as AWD, conservation agricultures are being promoted. However, field evidence on boro rice water use is limited.

The speaker presented the results from a recent study where water use and productivity of Boro rice in the NW region was monitored for diesel, electric and solar irrigation systems by extensive field monitoring during 2015-2018. Results show that cost of irrigation can be up to 35 % (average of 20-25 %) of the total cost of irrigation and vary widely as tariff rates differ a lot across irrigation systems. Generally, DTW running on electricity area is cheaper than STW which are mostly run on diesel. Solar irrigation is found to be costlier than STW. Comparison of water applied to water demand shows that water use for Boro rice is very efficient. On average, for boro 1402 lit/kg and in 2016-17, 1086 lit/k was supplied to the field. Not all of it is used as some of it is returned to the aquifers. Actual water use (ET) was 661 lit/kg in 2018 and 584 lit/kg in 2017, which shows that the general assumption overestimates the water application.

The speaker then discussed how increasing solar irrigation, promoted as centralised solar irrigation run by professionals, can change current agriculture irrigation systems. Solar irrigation provides environmental benefits (low emission, renewable energy) and can provide other services such as rice milling, spice milling, etc., to the community. However, there are certain apprehensions and risks associated with solar irrigation, viz., high cost of irrigation, risk of not getting water at the right time, social issues such as influential farmers getting priority, and no other choice of irrigation for farmers in command areas. This raises the question of whether solar irrigation is beneficial to farmers or not. If by taking away options from farmers (permit systems/license for wells), Bangladesh is going back in the past by giving control to big companies and taking it away from individual farmers. The use of individual solar pumps is very limited in Bangladesh. Results show that they are primarily suitable for vegetables and cannot be used for boro rice with available solar energy.

The potential of solar irrigation on groundwater sustainability will depend on multiple factors. In areas where crop area saturation has reached (for example, NW region), more pumping won't affect the net use of water or overall water balance as consumptive water use remains the same. So, if there is no extension of crop area, solar pumping is unlikely to affect groundwater sustainability. The water balance of 9 districts in the Indo-Gangetic plains shows that in districts where rainfall is low and groundwater use is already high, expansion of solar irrigation may impact groundwater. In other districts with high rainfall and high recharge, solar irrigation impact may not be much.

Table 5:Q&A with Dr Mainuddin Mohammad

Sl no	Question	Answer
1	**Alok Sikka:** In Bangladesh, other areas like SW (Khulna) and the upland regions mean that solar irrigation may be at risk?	Pumping more does not mean water is lost unless it goes to sink and won't impact groundwater resources. A lot of recharge is happening through the dry season with rice irrigation. If farmers use surface and groundwater that is saline, we will have losses as return flow is non-recoverable.
2	**Mohammad Faiz:** Dr Zahid shows groundwater declining in the NW area. What could be the reason if the cropping area has reached saturation? Or are there spatial differences or something else?	There are spatial differences, and in the Barind region, the decline is not related to the crop area which has saturated. The reason is that there is a significant decline in rainfall during the last decrease and loss of recharge because of plough plain formation in rice cultivated areas.
3	**Marie-Charlotte Buisson:** Why are SIPs	It is a matter of training, and also, they need

	managed by professionals explains a quite efficient use of groundwater from your study sites? Is it a matter of training? They could also expand irrigation to 'satisfy' farmers and justify the relatively high tariff.	to cover the whole command area. Even in the other STWs, we found that there is not much oversupply of water as the owner needs to cover the command area. The tariff for SIP is based on the area for the whole season for rice. They need to supply water throughout the season – as irrigation is not a factor here. The charge for other crops such as maise and wheat is based on irrigation. I hope this clarifies your point.

II. Panel Discussion

Solar power as a remunerative crop: Gujarat's experience with Dhundi, Mujkuva, Sky and lessons for KUSUM

Dr Tushaar Shah, Emeritus Scientist, IWMI, spoke in this session.

The speaker presented the experience of the solar pilot project IWMI started in Dhundi in 2014. It was started in 2014, the early days of solar when there was a growing concern about solar irrigation's impact on groundwater sustainability. The Dhundi project was initiated to showcase how paying farmers for the solar energy they generated can be used as an incentive to avoid overexploitation of groundwater. In Dhundi village, 11 farmers using expensive diesel were offered solar pumps, a microgrid was created, which was connected to an 11 KV line, and evacuation of energy was monitored. Energy Company offered these farmers a 25-year contract to buy surplus electricity at 4.63 INR/kwh.

The Dhundi project was conceptualised keeping some hypothesis that this mechanism can provide an additional source of risk-free income, incentivise conservation of GW and energy, provide farmer reliable, uninterrupted daytime power supply, reduce the footprint of GW irrigation, reduce DISCOMs subsidies and reduce AT&C losses on solar feeders. The project has been running for close to 6 years now, and data show that 60-65 % of generated solar power is evacuated every year. Also, income from selling solar energy is similar to income farmers get from growing crops. The profits are somewhat higher as Dhundi farmers were using expensive diesel pumps. Thereafter, with support from the National dairy development board (NDDB), another pilot was done in Mukhjawa village, where farmers were using electric pumps. There, farmers agreed to use solar pumps even because they have to surrender their electricity connections for 25 years. Data shows the same pattern with 55-65 % energy is evacuated.

These pilots created the base for Gujarat's SKY scheme, where 82 feeders, approximately 5000 tube wells were solarised. SKY scheme has a rich monitoring system with real-time data on consumption and evacuation. Early data from the SKY scheme shows that of the 2190 farmers solarised in feeders, 908 (25 %) have refused to solarise. The results have been profitable for distribution companies saved on subsidies for farmers who solarised (range of 800-1500 INR/hp). Farmers have been able to earn nearly 700-2300 INR/hp for evacuating energy (20000-35000/year income).

However, early data shows on energy reduction, the more direct indicator on energy and groundwater saving is mixed. In the west and south Gujarat, energy use is more after SKY, whereas, in central and north Gujarat, there is a significant reduction in energy after SKY. More recent data shows that energy evacuation also differs across regions ranging from as low as 16 % in South Gujarat to 67% in North Gujarat. The early results have proven many early hypotheses correct (income for farmers, reliable power supply, reduction in subsidy, reduced C footprint, and reduced AT & C losses). There is proof of energy savings but not groundwater so far.

Table 6:Q&A with Dr Tushaar Shah

Sl no	Question	Answer
1	**Upali:** Tushaar- Any idea of water sold (if any) from solar pumping and water consumed (CWU)? Can't CWU be generated from crops grown and area under crops?	We have data on the water selling for Dhundi and Mukhjawa but not on CWU.
2	**Marie-Charlotte Buisson:** Do farmers still use electric connections from other tubewells, or do they use diesel pumps as well? We can very well see a reduction in energy consumption without a drop in water consumption.	No, diesel pumps are in use, which is expensive.
3	Also, do we know if new electricity connections are being given? Or is there an embargo on new connections? Is it possible for a farmer with an existing SKY scheme to get another electricity connection?	I think in Gujarat, new grid connections are not given or is very limited. Wherever there is a pending application, off-grid is given. Neha Durga: Regarding new connections, that has nothing to do with solar. The

		existing rule applies, i.e. one cannot get more than one connection on one survey number, and a well is necessary for getting a connection.
4	**Archisman Mitra:** Do you think other than the incentive, just daytime supply might have reduced water abstraction since wastage during night time over-pumping no longer happens?	Yes, but there are many other confounding variables too.
5	**Aditi:** Now electricity available is for twelve hours in solar feeder instead of eight hours in non-solar feeders. It is also possible that part of the energy selling to the grid is coming from these extra four hours.	Not quite, they can import power for twelve hours but export only solar energy. They cannot divert grid power to export.
6	**Aditi Mukherji:** Farmers have access to twelve hours of grid power? Earlier, they had eight hours. So, is it possible they are still pumping eight hours' worth of water and selling those extra four hours' worth of electricity? Is that not possible?	**Tushaar Shah:** They sell solar energy to the grid; they use only grid power for irrigation. They are billed for the balance; if they import more than export, they pay and vice versa. Average solar hours are much less (like closer to 7). So, expanding grid hours should not make a difference if they have to evacuate power on the net.

Alok Sikka proposed two questions to the panellists:

1) Where do you situate yourself and your countries in this debate? The impact of SIPs will differ depending on a range of interventions.

2) What do you think we can do so that SIPs don't accelerate current groundwater exploitation?

Ms Simi Kamal, Pakistan, responded that the panellist pointed that solar impact on groundwater is convoluted by a range of factors (who abstracts water, by what means and financial mechanisms, etc.), making it hard to give a definitive answer. A range of assumptions to answer this such that open markets with farmers making decisions to maximise profit do not exist. Also, hydrology aspects such as surface-groundwater connections change the meaning of water loss. As shown in presentations, areas with high rainfall and saturated crop areas may not have an impact. One way would be to license groundwater use and set limits, but that will require considering various factors such as urban-rural linkages, water balance, agro-ecological zone mapping, and crops.

There are many social concerns also. For example, in Pakistan, 85 % are smallholder farmers, but 15 % of the large farmers take agenda setting and decisions. Then there are cases of urban-rural linkages where cheaper solar power is being used to abstract water for cities. What decisions we take and what regulations we set will determine the trajectory of solar irrigation, which is quite dynamic and complex. For example, at India-Pakistan borders, Indian farmers having landed on the Pakistani side have different sets of policies and regulations for solar, leading to contrasting pumping behaviour with abstraction easier on one side and bringing transboundary issues. There is a strong need to get a coherent policy on solar irrigation in Pakistan, which requires strong support from academia, training, and capacity building. There is a need to explore the possibilities of licensing and ways to regulate groundwater infrastructure at the field level.

Dr Anwar Zahid, BWDB, Bangladesh, responded that the panellist expressed that we need to know the aquifer systems better to answer how solar irrigation will impact groundwater. In Bangladesh, there are multi-layered aquifers connected, so what happens in one system affects others. Thus, increased abstraction from shallow aquifers for agriculture can impact deeper aquifers used for drinking water supply. Many regions of Bangladesh already have groundwater depletion and quality issues. Declining water levels rates range from a few cm to 1-2 m every year. In the national water policy of Bangladesh, there is a provision of requiring a license to install irrigation/production wells. District Upazila committees will provide these licenses based on the analysis of the area. If the committees allow, a person can use any source of energy, including solar for wells. National water policy also emphasises the use of surface water for irrigation wherever the surface is available and solar energy can be used. However, fresh groundwater from deeper aquifers cannot be used for agriculture as that is preserved for drinking water. Recently, many household users are replacing wells with suction tube wells using submersible pumps, which may also impact groundwater. Planning for water budget at Upazila levels can be used for sustainable management of groundwater.

Table 7:Questions to the panellists

Sl no	Question	Answer
1	**Marie-Charlotte Buisson:** Did I understand well that the committees for licenses are not yet operational? If so, how the SIPs licenses were provided so far?	**Dr Anwar Zahid:** Act is there, but committees are yet to be operational; water resource planning organisation is where they have to apply now.

Final Pitch by speakers and panellists:

- Dr Meha: We should consider the future impact of climate change in the analysis and discussions.
- Dr Mainuddin: There is a lot of generalisation about groundwater use, and we need to measure at the field to bring clarity.
- Dr Wolfgang: Other than climate change, we need to look at socio-economic pathways. For example, China's population will be half at the end of the century.
- Dr Tushaar: We are at a crucial juncture for groundwater governance. Either solar can solve the issue or make it worse depending upon solar promotion strategy.
- Ms Simi: Solar lulls us into thinking that solar irrigation is a great situation and that setting limits will be critical as we go into the future.
- Dr Anwar Zahid: There is a need for location-specific studies.

Top three take away from the webinar, and how and whether SoLAR future work can address them?

Take away 1: Set feed-in tariffs will be critical in changing farmer's energy use and irrigation behaviour to realise sustainable long-term outcomes. This will be impacted by various factors such as markets, existing tariffs, water availability and cropping patterns. SoLAR project work is different in different countries under a diverse set of biophysical, social, and scaling mechanisms can provide an excellent comparison to answer this to an extent.

Take away 2: There is a need to analyse groundwater savings in terms of actual Vs real water savings and contextualise the same in a broader context of recharge and other factors at play (rainfall, land use) to determine the impact on groundwater sustainability. SoLAR work on groundwater sustainability studies and looking at gross abstraction can also differentiate gross Vs net groundwater use.

Take away 3: In solar irrigation planning work and policies, there is a need to internalise the impact of future climate change and socio-economic scenarios on agriculture. Given that solar irrigation is a long-term investment and planning, these future scenarios can alter the future trajectories of agri-irrigation development in the region and determine how sustainable the current strategies of solar irrigation promotion are.