NREL WAVES TO WATER PRIZE PROGRAM: SENSIVITY ANALYSIS OF ALTERNATIVE MARKETS

2022 Engineering for Change

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Introduction

Overview

Isle Inc., in collaboration with Engineering for Change (project team), performed a Sensitivity Analysis of market alternatives to evaluate commercialization barriers for the Waves to Water (W2W) competitors. This analysis included interviews with organizations and end-users in three market categories (1) Disaster Relief, (2) Commercial/Industrial, and (3) Municipal, Residential, and Government. The disaster relief category included multilateral, bilateral, and nonprofit organizations involved in humanitarian response and disaster relief. The commercial and industrial category included industrial users, consultants, and equipment developers and providers. The municipal, residential and government category included utilities, municipalities, residential developers, and government entities. For each category, the project team selected organizations that provided a well rounded experience and set of drivers for adopting W2W technologies. In addition to the project team's efforts, fellows from NREL/DOE completed interviews with government organizations to understand their potential to engage with W2W technologies, and these findings are summarized in a separate summary document.

In addition to this Sensitivity Analysis a Capability Matrix was also developed. This accompanying document is a visual matrix to summarize the drivers for each organization.

Additional insights/Outreach:
The project team received feedback from one Commercial/Industrial organization that strongly encourages a funded pilot model to advance technologies. The team also received feedback that other companies had considered similar technologies in the past, but were not interested in exploring these solutions at this time.

Types of Systems Being Used

Below is a list of some notable technology deployments being used by the organizations surveyed.

Disaster Relief

Energy

- Solar deployments and energy storage
- Small portable photovoltaic generators to replace 2-10 kW diesel generators
- Lithium iron phosphate battery or Lithium Ferrophosphate (LFP) batteries

Water

- Capacitive deionization for brackish water desal
- Lamella filters for clarification as an inexpensive option
- Groundwater and boreholes
- Electrolysis/on-site generation of sodium hypochlorite
- WaterSol
- Basic flocculation kits, batch chlorination, and sand filtration
- Water trucking, noting that it is expensive
- Reverse osmosis (RO), noting that operations and maintenance (O&M) is difficult

Commercial/Industrial

Water

- Large scale desalination systems with RO

- Desalination equipment and wide range of water treatment technologies
- RO desalination systems including small-scale desalination products including owner/operations
- Advanced RO desalination systems and various membrane systems

Municipal/Government/Residential

Energy

- Large scale battery installations, small hydro and CoGen systems
- Hybrid microgrids
- Ground storage heat pumps and other energy and water systems

Water

- Desalination facility
- Large desalination facility

Technical Considerations

The following section includes technical considerations for the adoption of W2W technologies including cost and related drivers, size needs, capabilities for installing and operating systems, and overall reliability needs. Each section is broken down by the market segment.

Cost

Disaster Relief

In general, cost was a medium to high barrier for the disaster relief organizations. The time it takes a system to be installed versus the time it will be in operation is a large cost consideration.

For emergency response scenarios, cost was seen as less of an issue, but more of a challenge with longer-term installations and operations and maintenance (O&M) needs. For emergency scenarios, bottled water is seen as a viable short-term, albeit expensive option, that is a fraction of the overall emergency costs. Emergency deployment is often a race against the clock, especially domestically, so the fastest deployed and available technologies are best. For emergency projects the WASH budget can be 5-30% depending on timeline and what already exists, and there is no time to do a technology alternative assessment.

For longer term disaster relief installations, the cost of O&M is much more important than the capital cost of systems; therefore, robust systems with lower O&M needs are desirable. However, for acute situations, it is difficult to convince decision makers for a higher upfront cost for low O&M longer term costs. The timing for decisions on longer-term systems is short, and even at the onset, organizations are trying to identify long term solutions (boreholes/wells/connection to main water/replacing electrical pumps with solar panels) often in the first days/weeks. Furthermore, the majority of funding typically is allotted in the first few weeks and then decreases as time goes on, so deploying longer-term installations while funding is highest is advantageous.

Innovative, low-cost desalination remains a gap in the market (Israelis and Australians have progressed in this space, but it is a requirement to have an exceptional product in terms of CAPEX and OPEX) to penetrate the market. The International Red Cross was identified as an organization using more expensive devices through European disaster relief according to an interviewee.

Commercial/Industrial

In general, costs remain important in the view of these organizations but may be driven by end-users. The primary driver for adopting a technology is whether it can bring added value, which is typically tied to lower costs. Developed countries are able to deploy costly desalination systems, but it would be difficult for developing countries without external funding. Industrial clients are willing to pay for high quality products and do not waste time with lower quality products.

There were some differences in responses regarding the most important costs, with one interviewee noting that O&M costs for desalination systems, including membrane maintenance, are often more costly than the energy costs, and another noting that the energy can be 30-60% of overall operating cost for desalination. In addition to generating energy, the presence of energy recovery systems are important to help decrease the energy needed by extracting waste energy from the desalination process. It was noted that island electricity is expensive (five times the cost of some US states), which drives the economics for these types of systems. An additional cost driver is transferring water inland, which is extremely expensive and can be higher than the cost of treatment.

Municipal/Government/Residential

Cost was also generally important for municipal and residential organizations. For one coastal city, when looking at renewable options, cost is a big driver for their local community choice aggregation (CCA) partnerships. One Caribbean organization noted that cost for Caribbean nations is important and few can afford to look at environmental impacts as the main drivers. They are being approached by solar power organizations and looking at relatively short payback periods less than 10 years.

For one government official interviewed, cost is dependent on application. If the solution matches with their agency requirements, then cost is less important. In general the return on investment (ROI) payback period on new systems is closer to the 2-5 year payback period.

Limitations on Water/Energy Resources and Resilience Drivers

Disaster Relief

The limitations on water and energy as a market barrier varied among the disaster relief organizations, but tended to be a higher market barrier compared to the other organizations surveyed. Market opportunities are considered limited in scenarios where reinstating the existing systems are the top interest or where local municipal connections or other water sources (i.e., wells/boreholes) are almost always readily accessible. However, the limitations on water resources are growing in some organizations' experience with alternatives in emergency scenarios like water trucking being very expensive. Anecdotal potential applications were cited, including in Ghana where there was a struggle to source treated water for medical purposes such as dialysis.

Sites with extended electricity grid recovery times or no grid would be the best use case as the wave power systems would have a cost intensive installation process. For some disaster relief installations, early money/investment helps sustain O&M, but this can often rely on diesel, which is available in the short term, but later (year 5-10) leads to excessive O&M costs.

From a resilience and sustainability perspective, there is a growing focus on sustainability and green humanitarian support. Carbon considerations are a growing area of interest for disaster relief organizations including the COP26 strategic framework (2020), and emissions reductions and operational carbon are starting to be part of conversations. An example was provided of the International Federation of Red Cross adopting the Climate and Environment Charter for Humanitarian Agencies and UN's Greening the Blue initiative. Organizations are in discussion with each other about the tipping point for sustainability as a driver, but questions still exist about when wave-power will move from a "luxury" to being "cost-effective", similar to solar, and require justification for use as an alternative to solar.

While the environmental impact for the solutions selected may be high, in certain applications there is nothing that can be done because life-saving is key. One organization did note that environment and health impacts remain a concern with activities such as plastic burning from water bottles.

Commercial/Industrial

These organizations generally had a lower market barrier than disaster relief organizations as capacity building for water and stable energy needs are of interest.

In Africa, most countries have power issues; therefore, consistent wave power with large storage tanks for back-up may be a viable solution. In general, electricity is the more predictable piece of the operation (compared to water); however, in emergency situations, diesel generators are typically needed. The high pressures required for Seawater RO may be a challenge from an energy perspective, and alternative systems like forward osmosis may be an attractive alternative. One interviewee noted that they are always looking for new technologies to bring down the cost of desalination and work in tandem with their products. Anecdotally, resorts in Zanzibar own their own desalination plants and are generating their own power.

Additional water capacity development is a major driver, but will depend on the location. There are more challenges on water than power in Africa because of industrialization and population growth, and water discharges are creating more environmental stress. Functionally, transfering seawater inland is very costly, and will limit the application of these technologies. For island and coastal communities, it is an ongoing evolution to upgrade and replace old systems and improve desalination systems to bring the cost of water down.

Municipal/Government/Residential

These organizations also had a low market barrier due to the requirement of expanding water sources in scarce areas and interest in environmental and sustainability drivers.

A coastal American City has a carbon neutrality (2035) and local renewable energy goal (2030) that are drivers for new energy technologies. The interviewee stated the city is interested in a resilience approach which includes bottled water. They currently pump water up a mountain, which provides the potential for energy savings.

The Caribbean market has additional drivers for water and has deployed a significant amount of desalination systems including in Trinidad and Tobago, Aruba, and Curacao. Energy is also a driver with high prices for energy being a consideration. Trinidad and Tobago is currently looking at green energy, but this would require subsidies. In another Caribbean nation, the organization interviewed is the only grid in the area, and all other sources rely on diesel energy or distant grids. Likewise, water resources are scarce in this location, requiring well water that needs treatment.

For a federal agency's applications, resilience-focused infrastructure is predicted to see a big influx of funding, and resilience is becoming a bigger driver. The water needs for their operations is still extremely important and some applications rely on diesel fuel being shipped which is not sustainable.

Size or Scale of System

The size and scale of systems was dependent on the application and scenario. The following water requirements were shared:

Disaster Relief

- 240,000 L/day (10 cubic meters/hour) with a goal cost of ~$15,000 (most of the time, cost is around $60,000). These are typically small scale, village maintainable systems
- 50,000 L/day minimum of drinking water. Some installations may require far more, for example in Gaza where water would be used for preventing groundwater intrusion
- 5-15 L/person/day for a few hundred in a village, to hundred of thousands of people depending on situation
- 500 L/day for patients as a high demand for medical purposes
- The sphere guidelines can serve as a good reference

For some organizations, the quality of water is not the paramount concern, and expressed that 90% of water used in an emergency/outbreak may be used for disinfection/cleaning rather than drinking.

In regards to energy system sizing the following were shared:

- Smallest system might just power wifi and a refrigerator in some instances
- Portable systems up to 200 kW facility generators are common
- Hospitals will use 1-5 MW
- FEMA Trailers will use 10-50 kW
- Batteries were expressed as being an issue for some organizations.

Commercial/Industrial

- ~1.9 ML/day (0.5 mgd) is the lower end for a camp of people and ~3.8 ML/day (1 mgd) approaches municipal size
- 11.3 ML/day (3 mgd) for modularized systems utilizing 3 containers, or can be built in prefab buildings to replace ~50 containers
- 100-300,000 L/day is a range of many systems
- 1-5 ML/day for mining applications
- 5 ML/day (5,000 cubic meters per day) for small hotels in Africa, but for cities at least 50 ML/day (50,000 cubic meters per day) would be needed
- Cities need something at scale for the economics to work out, and infrastructure may be needed to support the system
- ~2.7-5.5 kL/day (0.5-1 gal/min) expandable to ~27-33 kL/day (5-6 gal/min)
- For some installations, the question is "what is the largest single-phase pump that can be powered?"

Municipal/Government/Residential

- Less than 1 MW for energy projects, typically
- There is a large range of what is needed from supporting 500 personnel abroad to very large domestic applications. For some installations, an energy or water system might be back-up, but that same size might be a prime source of energy and water for a more remote location. Projects can range in cost from $200k to $2-3M
- ~ 378 kL/day (100k gpd) to ~3.8 ML/day (mgd) sizing
- Expanding solar-powered community microgrids from 2 to 24 grids in a Caribbean nation for 80,000 people

Ease of Deployment/Installation

Disaster Relief

In general, the ease of deployment was seen as a medium or high barrier for disaster relief due to the response time needed and requirements of specific projects.

A few organizations noted that containers are not well suited for immediate disaster relief and systems are not likely to work for acute emergencies, citing the extended shipping timelines and cost being prohibitive to alternative solutions. To the contrary, another interviewee recommended containerizing the system for easy shipment/transport and have supplied systems to a US city during disaster relief; therefore, the location of deployment will impact feasibility of containerized systems.

New technologies are not typically introduced right after a disaster, but new technologies can be brought in during the early recovery phase. From a competition perspective, solar systems are "plug and play", so they would be looking for Wave energy "kit" systems that are similar. Battery storage has been found to be an issue, particularly with longevity of equipment.

Many of the disaster relief organizations have teams or partner organizations working in-country that would be responsible for deploying the technology and operations. One noted that they work with the local ministry of health for emergency response activities. Local governments are also typically a partner if they will be taking over the system longer term. In the US, one interviewee has had success with volunteer fire departments and suggested secondary responder organizations for small energy deployments. Another organization is also currently in a partnership with the UN for disaster relief to help with logistics of deployment.

Commercial/Industrial

The organizations that were surveyed for the Commercial/Industrial segment were typically designers and equipment suppliers, and generally rely on outside contractors for system deployment. One organization can do small projects like replacing membranes and UV components, but they do not perform full turnkey system installations. Another was capable of manufacturing packaged systems that can be deployed in a relatively quick time frame (i.e., weeks). These organizations in general have experience collaborating with local contractors and have experience deploying complex technologies.

For one organization's deployments, about 80% of their systems are built on-site and 20% are in containers. They can also deploy prefab buildings for larger installations. From experience, US deployments require a separate designer and contractor which takes time, but outside the US it is easier to mobilize.

In the example of Africa, a lack of outside funding for O&M is an issue, so systems can be installed and within a year can be out of operation if there is no expertise and no funding. An African based organization provided an example of an installation for water station monitoring, in which the end-user could not afford to buy spare parts and the system became inactive. In the Caribbean, more high pressure desalinations systems are being deployed; therefore, deployment is already more commonplace.

One interviewee commented on the different challenges faced between on-shore and off-shore deployments and noted that floating platforms would be a more desirable installation from a water quality perspective; however, wave energy systems off-shore may be more challenging.

Municipal/Government/Residential
Deployment is a higher market barrier for this group of organizations requiring more formal contracting and installations.

For energy projects, the coastal city would need to outsource work and have it deployed through a Power Purchase Agreement (PPA) turnkey project.

In the Caribbean, generally third party contractors will perform installations, but models do vary. Several contractors have models where they manage construction and might use local contractors for deployment. One facility studied had the construction and operational risk on the contractor, which was an alternative delivery method.

Operations and Maintenance Needs

Disaster Relief
Disaster relief has a lower market barrier for O&M from the standpoint that systems are typically operated for shorter periods of time; however, during that period, O&M considerations were important. Beyond the importance of maintaining low O&M costs, the disaster relief organizations expressed several other areas of consideration for O&M. Some had local partners like local ministries of health or Doctors Without Borders that will run operations on the ground. One organization provides operations and maintenance for their deployed energy systems but partners with local groups such as Fire Departments.

Another organization noted that they are usually in the country for two years then try to hand over a system which is challenging. Once local authority takes over the system, they are responsible for any large challenges, and the handover is a weak link in this process.

Other Notes:

- Data collection occurs, but no direct actions from data
- Small scale membranes require frequent replacement
- Solar systems used to be stolen in the past but that is no longer an issue

- Sometimes solar panel components are in short supply

Commercial/Industrial
Some of these organizations hand-off operations to others; however, some did have the capability to perform operations.

O&M contracts are different depending on location, with the US model typically having the end-user own the system and pay for contract operations on an hourly basis. In these instances which are a “pass through model” there is often little incentive to optimize O&M or install more expensive equipment to reduce O&M. In the European model of true design, build, own, operate, there is an incentive to reduce O&M costs and find financial benefits for the operator.

Industrial clients typically get water from municipalities and further treat it themselves; therefore, they are more likely to be familiar with more complex systems. In the island/coastal community scenarios, end-users tend to prefer to move water at lower pressures and boost pressures at the point of treatment. In practice, pulling raw water from near-shore will result in more contaminants and fouling of pre-treatment systems than deeper off-shore intakes.

Municipal/Government/Residential
In general, low maintenance needs were desired to improve the chances of technology adoption for these organizations. In most cases these organizations have staff capable of operating systems or can contract operations.

For the coastal American city, they don’t have the staff capacity to operate and maintain a new system, and prefer to work with PPAs and have others manage O&M, installation, etc. For a different company, a contractor or principal investigator is always hired for pilot testing, and if the project is successful the facility staff will pick up the O&M responsibilities. An example was provided of ground source heat pumps demonstrated in the US and a few other facilities, and then deployed more permanently. Another organization has trained and qualified technicians in the Caribbean that provide training to contractors and subcontractors in the local language, and noted that O&M manuals need to be translated into local languages.

In the Caribbean, O&M responsibilities vary by nation, and in Aruba and Curacao facilities are built and operated following operating procedures to maintain product warranties. In the Bahamas and Cayman Islands, operations may be contracted out to companies.

In Africa, depending on the country/municipality, there is a mix of both contract operations and relying on their own municipal teams; however, some countries such as Kenya use almost entirely contract operators for their facilities.

System Reliability and Downtime

Disaster Relief
Unsurprisingly for disaster relief organizations, reliability was paramount. Back-up storage capacity was noted with storage of up to three days potentially being required. For systems to be more reliable, tech providers might

consider a hybridized system that has an auto start diesel generator if other systems fail. The other way to increase reliability is to have technical personnel on-site for troubleshooting, but this requires a large human investment.

Commercial/Industrial

In general, reliability was also seen as an important factor for these organizations. Where reliability is paramount for municipalities, some systems, like industrial users, don't rely on municipal systems but rather have their own systems that provide redundancy to municipal systems.

An example was offered of resorts in Mexico that are utilizing their own treatment system because it is less expensive water than "City" water, and if the system experiences downtime, the resort can default to using municipal water. Another similar example was offered regarding hotels in Antigua that have their own water systems independent from the municipal water system.

Municipal/Government/Residential

For some municipal water utilities, there is already redundancy built into the system, so there is no driver for replacing base load systems; however, increasing capacity can be a driver that allows for some downtime. Desalination in general is less reliable than conventional water treatment, but the goal is to have 95% or higher up-time.

Reliability can depend on the end goal. For carbon neutrality, reliability is not a large issue, but for resiliency on-site, this must be considered. On the water side, reliability is a very big concern.

De-risking Opportunities

Outside Support and External Funding

Disaster Relief

The disaster relief organizations typically have money to execute their missions but are hesitant to take on new or unproven technologies. However, one organization was interested in support funding as they rely on outside funding to execute their mission.

One potential venue for supporting system deployment is through FEMA reimbursement, which requires local municipalities requesting a particular solution as they are the entities getting reimbursed. Consideration of immediate install ("response") to longer term rental or use ("reconstruction") can be considered for deployment. Relief organizations sometimes deploy technologies at no cost to prove performance then work out a longer term arrangement, as it is difficult to charge high prices for newer or unproven technologies.

Commercial/Industrial

Outside funding was seen as advantageous by most of the commercial/industrial organizations, which could include government entities paying for systems to be readily available or paying an organization to maintain and operate systems. It was noted that contract terms are important and can significantly increase technology development.

In Africa, outside funding is generally needed to advance projects, but the biggest issue is that they don't fund O&M. The interviewee recommended funding for O&M for five years of operations at a minimum.

As a technology product developer, an interviewee mentioned their organization's R&D arm may be interested in these technologies. If they are well aligned with their core business, they may offer discounts and tech loans to develop projects. Their ventures division can fund TRL 3 or 4 technologies if they align with company interests. External government funding has helped fund some research.

Municipal/Government/Residential

Outside funding was seen as very helpful for these organizations, in particular, the municipal entities. For the coastal city, outside funding is required. They don't typically have capital investment for energy upgrade projects and rely on PPAs. In a different instance, outside funding won't make projects move to the top of the list, but matching money can help push projects along if only $1-3M is needed from budgets.

Appetite for Early Stage Technologies

Disaster Relief

For disaster relief organizations, appetite for adopting new technologies varied and generally depended on if that organization was already using earlier stage technologies. Some organizations default to low cost, simple water treatment solutions and cited cost, O&M, and training as major roadblocks to adopting these types of solutions. In general, the disaster relief organizations are more risk averse and need technologies to be mature and trialed in humanitarian response scenarios.

The following are some additional notes on appetite for early stage technology:

- One interviewee explained that they only try new technology when economically advantageous.
- They noted that the market is saturated with technologies for disaster relief and emergency response; they are reached out to 1-2 times a month with people saying they have a technology for water treatment that they think could be used for disaster relief.
- One aid agency is looking at early stage tech for disinfection, and are also looking into available technologies for preventing seawater intrusion in Gaza by pushing the seawater back.
- A multilateral noted that proposed innovations from private companies are reviewed by experts and approved by this organization for scale-up and published on companion sites.

Commercial/Industrial

In general, the commercial/industrial organizations were more interested in earlier stage technologies than the disaster relief organizations:

- The African market is open to innovation and an interviewed organization is constantly introducing new products in the seven countries they work in. If a product can be demonstrated they will introduce it.
- Another organization is interested in new technologies/co-development that are close to their core technology offerings. Pumping based technologies were identified as an additional area of interest.
- Another has completed projects with solar and desalination with universities and governments and has a history of working with new technology providers with co-learning and financial flexibility.

- Another is interested in deploying new technologies, but technology selection is typically dependent on the end-user/owner's specifications and risk tolerance.
- A European model that allows for concessions can stimulate early stage technology adoption and cost savings.

Municipal/Government/Residential
In general, municipalities and governments understand the risks inherent with early stage technologies and are interested in deploying novel solutions:

- One city has experience with a large scale battery installation and has deployed CoGen systems. They are interested in small hydro opportunities and have worked with Pressure Reducing Valve solutions.
- One organization has an increased appetite for early stage technology when costs are defrayed and if energy service companies (through an energy service contract) are engaged and taking on some of the risk.
- In the Caribbean, some areas are very arid and know the risks of early stage technologies. Some are happy to take on those risks or will pass on the risk to the contractor.
- Another organization does R&D and is interested in phasing out diesel for their hybrid systems.

Procurement Process

Regulatory and Permitting

Disaster Relief
Most of the disaster relief organizations were not familiar with or had not encountered regulatory or permitting issues relevant to the wave energy system deployment. The organizations did cite standards and requirements on the water testing side; however, those were dependent on the stage of emergency versus recovery. In general, the higher barriers were a result of requirements of some organizations needing to abide by both in-country rules and regulations in addition to home-country or international standards. Only the one noted the key challenge of disposal of brine waste that would be relevant for reverse osmosis systems.

Standards and Certification:

- Certification is a serious consideration - before technologies can be used, they need to be certified in-country which can become quite complex/time intensive
- Standards have become a bigger issue
- There is a large gap in regulating mobile, off-grid solar systems
- Signed waivers may be required in case of issues, but regulations are not typically enforced during disaster relief
- When there is a sanction on the country, applying for exceptions is needed. Additional consideration is needed to ensure technologies cannot be abused

Water Quality Testing and Enforcement:

- Some organizations are using traditional chlorine disinfection, which is an acceptable and proven method, so certification is typically not a challenge
- Water quality testing occurs, but as long as there is chlorine residual that is typically sufficient.

Commercial/Industrial

One company expressed that they did not see as many permitting hurdles in the African market, but that corruption can become an issue for larger projects. For projects to be successful, it is important to have good community engagement and articulate benefits in the long term.

Brine discharge was brought up as a main, major concern. Approvals and regulations in Australia are complex and can take several years of studies, pilots, sampling, and modeling. It was noted that if the RO was performed in the ocean then discharges may be less of a concern.

Another company noted that emergency exemptions exist for the Safe Drinking Water Act in deploying some of their RO systems, but there are questions around if a container can be certified as a public drinking water system. Water can be used for other means besides drinking water such as starting power plants and flushing out other systems.

For permanent installations, certifications, engineering designs, and other requirements may hinder implementation. An organization provided an example of UF/RO project that was an emergency implementation but still required some permitting. Similarly, an example of FEMA funded work required a consulting engineer to handle coordination. In regions like Mexico, some of these requirements do not exist, and a turnkey system can more readily be deployed.

Municipal/Government/Residential

These organizations were generally most aware of the permitting and regulatory challenges for longer-term, permanent installations.

A big challenge in California is the permits for brine discharges and intakes with considerations of biodiversity. Local non-profits also get involved and this can be challenging to project success. Note: during the development of this Sensitivity Analysis, the Coastal Commission declined a permit for a large desalination facility in Huntington Beach.

For some agencies there can be a research exception for deployments, but for more permanent installations, permitting and NEPA are required. In addition to permitting, cost implications from Davis Bacon prevailing wages also apply and can add cost to these projects. For one agency overseas demonstrations are rare because of the costs.

In Carribean installations, the regulatory and permitting process is also onerous and can have many delays. The environmental concerns are similar to the US, but technical commissions may be a bit more lenient on certain parameters.

For energy systems in one Caribbean nation, a license is needed to operate and the regulator decides the tariff. Newer systems need to abide by license and regulations and often have to sign concessions and contractual obligations with the nation.

Other Considerations

Disaster Relief

- More islands will be needing solutions in next 20 years (e.g., Bangladesh is an example)
- Solar will remain a competitor to wave energy in most developing countries with hot and sunny climates
- Internally displaced people are often along the coasts, so wave energy may be useful even just for energy (separate from desalination)
- During the 2004 Tsunami, many locations needed desalination so there are potential in these environments
- Products need to be exceptional (CAPEX/OPEX) to penetrate the market. Israelis and Austrailians are developing low cost desalination
- Depending on the deployment location, there could be potential concerns of energy sources or pressurized water being repurposed for weapons or other purposes rather than for human health
- In emergency/outbreak scenarios 90% of the water is used for disinfection and cleaning; therefore, quantity is more important than treated quality.
- One big challenge for deploying systems domestically is a lack of creativity as it is common for fossil fuel supply chain in emergencies

Commercial/Industrial

- Solar has excelled in Africa because the climate is hot
- Wave power foremost as an energy source could be considered by establishing a power purchasing agreement (PPA) for the energy
- Coastal Washington (Islands) have various sources of desalination with high brackish water and might be an application
- New innovations should identify a combination of interested end-users and large partners who can finance/couple their membrane technology
- There may be advanced training required for off-shore type activities if things are riskier. For example, potential training like offshore platforms require individuals to be able to escape a submerged helicopter
- Additional costs for supporting infrastructure and appurtenant distribution systems need to be considered

Municipal/Government/Residential

- The government agency interviewed doesn't typically use SBIR, but have their own "limited scope" programs
- Project timelines for the federal government are long, so early stage companies need to be accustomed to and plan accordingly for that
- Generally it makes sense to expand an existing water treatment plant, but distribution system water quality is a concern.
- Desalination plants have trouble with high turbidity and pretreatment systems are sensitive to fluctuations that occur with near shore intakes; therefore, wave power and desalination may not be ideally compatible in some situations
- Pipe repair has been difficult in one Carribean application
- Connecting with the municipality in the region and local ministries to get community buy-in is necessary for projects to move forward
- Theft can still be an issue or retracting on promised land allocations

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