EDDI

electrodialysis desalinator
for irrigation

ABSTRACT

When looking to use Samsung's Artik to help solve drought-related problems affecting California, we set out to have the biggest impact possible. In our irrigation research we found a common practice called leaching, in which farmers use more water than necessary to remove salt from their soil. Since salinity in irrigation water can lead to degradation in soil quality, lower crop yields, and permanent crop damage, farmers will use up to 20% more water than the plant actually needs.

This is huge when you consider that 80% of california's water consumption by humans goes towards agriculture. This method has been practiced for generations, and in addition to wasting a precious resource, it creates runoff water which is normally 5 to 10 times higher in salinity than that of the irrigation water and contributes to rampant salt pollution of local waterways.

To address this issue, we built an ElectroDialysis Desalinator for Irrigation, affectionately known as EDDI. In Electrodialysis, an electric field is used to separate salt ions from the water, producing low-salt water that is ready for irrigation. While desalination is not a new concept, we are approaching it from a different angle by putting the technology for it directly into the hands of the farmers that are impacted the most by low-quality groundwater.

We estimate that adopting our system can save farms more than 60,000 gallons per acre per year, while increasing their crop yields by 15%. As a "smart" desalinator, EDDI reduces the amount of energy needed for a typical desalination system, making it cost-effective for farms both small and large. Furthermore, by implementing a recirculation system, we maximize the usable water and contain pollutants for safe disposal.

THE PROBLEM

During drought situations, groundwater typically becomes overly salty because it is being pumped out of the ground faster than it can be replenished. When this happens, salts that would typically be diluted by running groundwater stays in the water table.

When this increasingly-salty groundwater is used for crop irrigation, the salt tends to accumulate in the surface soil, and stunts growth of crops. To combat this, farmers use a practice called leaching, where they use more water than they need so they can dilute the soil salts and remove it from their land via runoff. This is both an inefficient use of water, and an ecological challenge. Over the past century, surface and groundwater has been getting saltier both in California and globally. This is due to a combination of decreased rainfall and higher water use. Most farmers do not know how to solve this problem, and information about it is not readily available.

THE SOLUTION

We decided to give farmers another option: remove the salt before they irrigate. With this option, farmers can use electricity to separate the salt from their water, allowing them to use only the water that they need to grow their crops at the maximum yield they can achieve.

In short, we built a desalinator for individuals, and it's called EDDI.
Here are some facts about EDDI:

- EDDI is an appliance. Its size makes it perfect for smaller farms, and it connects into existing utilities.

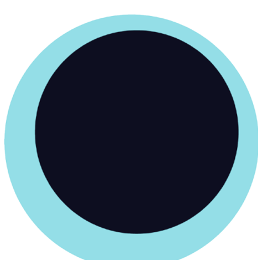
- EDDI is scalable. Simply add more layers and voltage, or chain two devices together and you can increase your desalting capacity.

- EDDI is intelligent. The EDDI will automatically decide when to remove salt from irrigation water. You can control it and monitor it from any internet-connected device in the world. With the EDDI web application, you can easily visualize your water's salinity, and how much salt is being removed. You can even download a spreadsheet to analyze your groundwater and plan for your next year.

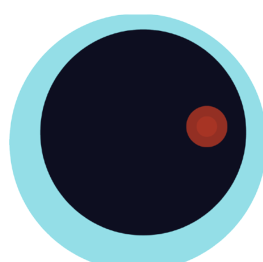
WATER IMPACT

To estimate the amount of water the EDDI will save, we took San Joaquin county as a case study.

In San Joaquin Valley, the top producing agricultural crop is almond, which happens to be very salt intolerant. In order for San Joaquin Valley to produce their 2014 annual yield (1.87 billion pounds of almonds), it would have to use over 600 billion gallons of water. If the San Joaquin Valley almond farms used EDDI to desalt their irrigation groundwater (assuming a reduction of dissolved salt from 1,500 ppm to 750 ppm) the region would save over 31 billion gallons of water, or approximately $63 million a year.



80%
of California's water used by humans is used in agriculture



10-20%
used to leach salinity from the salt

USER EXPERIENCE

Our goal in designing the EDDI app is to empower farmers with real-time knowledge about their water and inform the irrigation choices that a farmer must make. When a user lands on our app, they can view their fleet of EDDIs, and see if any of them are running inefficiently. To do this, we designed a data-oriented interface with modern automation tools and visual cues.

To see the details of an EDDI, they can click an EDDI device on the list, which will bring them to that device's Dashboard. On the Dashboard, users can read and visualize the current sensor readings for the salinity of each water inlet and outlet, as well as how much water is moving through the device. Users can quickly determine if the readings are good or bad based on if the tabs/meter color is blue or red. On the Troubleshoot page, users can see their device's current running status and turn it on or off.

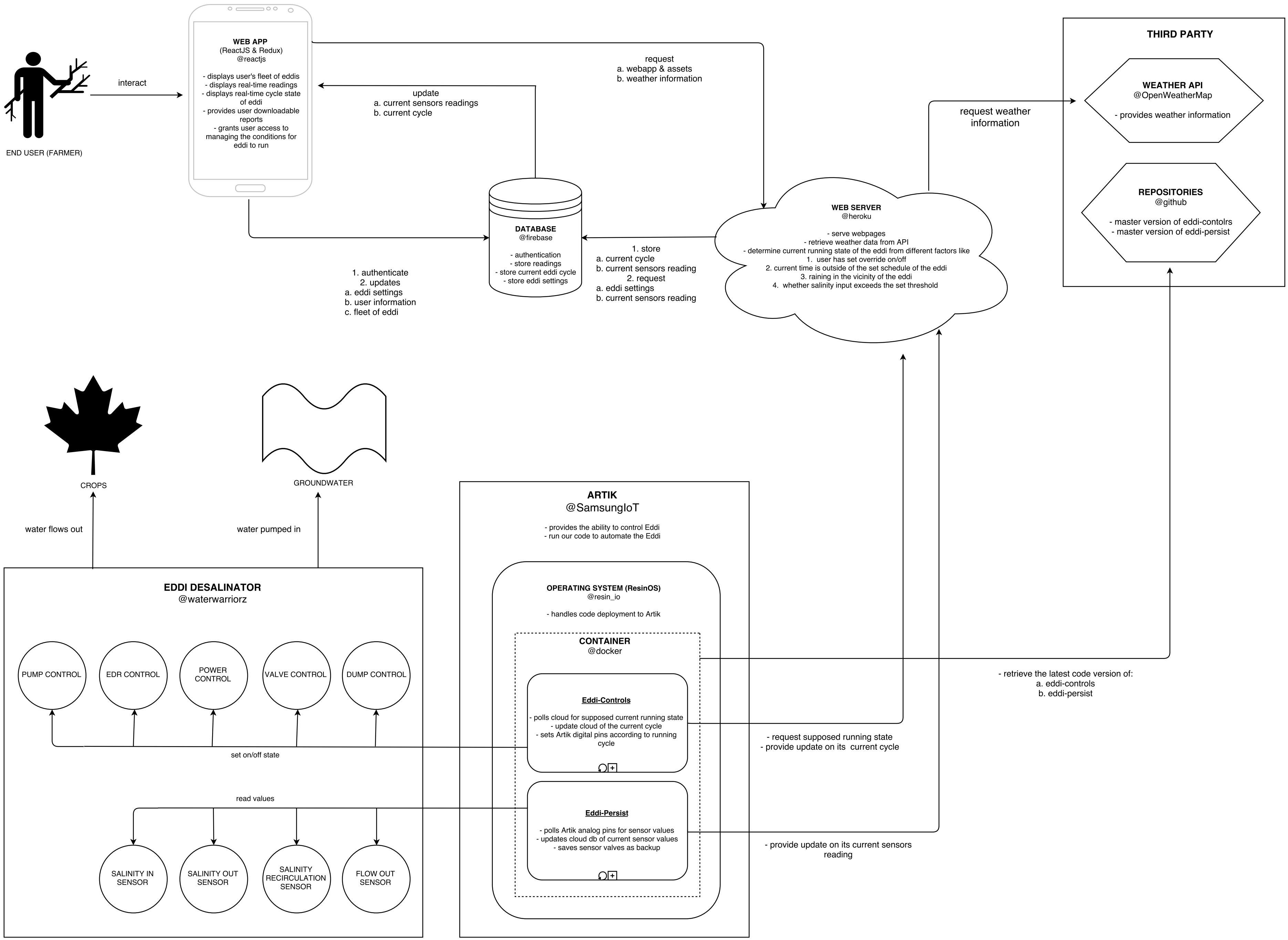
Additionally, we have an automatic mode which uses a decision algorithm based on the watering schedule, the water salinity, and the current weather. With the settings page, users can define the important characteristics of the EDDI like the zip code of where the desalinator is residing in and the type of crop that the EDDI will be irrigating. Users can also view local weather data like rain and temperature to better understand EDDI's running state and make better decisions for their irrigation.

ARTIK SOFTWARE

Every EDDI has an Artik board which helps manage all of its operations. The EDDI uses ResinOS (provided by Resin.io) to handle any app upgrades that we push out. Inside that environment, there are two running processes, Eddi-Persist and Eddi-Controls.

Eddi-Controls is in charge of running and orchestrating the different components of the desalinator. Inside this process, there are two looping subprocesses. One subprocess constantly asks our web server whether it should continue to run or be turned off. The other subprocess will check against the response of the first, and then determine the next cycle (OFF, PRIME, CHANNEL A, CHANNEL B) that the EDDI should run.

Eddi-Persist is in charge of data collection at the different checkpoints of the EDDI. Salinity of the input water is collected to provide farmers with a better understanding of their groundwater supply, as well as decide whether the EDDI needs to desalinate at all. Salinity of the output water is collected to understand if the desalinator is currently working. Salinity of the recirculation water is recorded to help the machine determine when it should dump the concentrated salt solution. Finally, the water flow rate is recorded to understand how much water is being moved and provided to the rest of the irrigation system.


END USER (FARMER)
interact
WEB APP
(ReactJS & Redux)
@reactjs
- displays user's fleet of eddis
- displays real-time readings
- displays real-time cycle state of eddi
- provides user downloadable reports
- grants user access to managing the conditions for eddi to run
update
a. current sensors readings
b. current cycle
request
a. webapp & assets
b. weather information
1. authenticate
2. updates
a. eddi settings
b. user information
c. fleet of eddi
DATABASE
@firebase
- authentication
- store readings
- store current eddi cycle
- store eddi settings
1. store
a. current cycle
b. current sensors reading
2. request
a. eddi settings
b. current sensors reading
WEB SERVER
@heroku
- serve webpages
- retrieve weather data from API
- determine current running state of the eddi from different factors like
1. user has set override on/off
2. current time is outside of the set schedule of the eddi
3. raining in the vicinity of the eddi
4. whether salinity input exceeds the set threshold
request weather information
THIRD PARTY
WEATHER API
@OpenWeatherMap
- provides weather information
REPOSITORIES
@github
- master version of eddi-contolrs
- master version of eddi-persist
CROPS
GROUNDWATER
water flows out
water pumped in
EDDI DESALINATOR
@waterwarriorz
PUMP CONTROL
EDR CONTROL
POWER CONTROL
VALVE CONTROL
DUMP CONTROL
set on/off state
read values
SALINITY IN SENSOR
SALINITY OUT SENSOR
SALINITY RECIRCULATION SENSOR
FLOW OUT SENSOR
ARTIK
@SamsungIoT
- provides the ability to control Eddi
- run our code to automate the Eddi
OPERATING SYSTEM (ResinOS)
@resin_io
- handles code deployment to Artik
CONTAINER
@docker
Eddi-Controls
- polls cloud for supposed current running state
- update cloud of the current cycle
- sets Artik digital pins according to running cycle
Eddi-Persist
- polls Artik analog pins for sensor values
- updates cloud db of current sensor values
- saves sensor valves as backup
- retrieve the latest code version of:
a. eddi-controls
b. eddi-persist
- request supposed running state
- provide update on its current cycle
- provide update on its current sensors reading

HARDWARE

EDDI consists physically a number of layers of plastic frames, and membranes. The frames and selectively permeable membrane layers create water channels over which voltage is applied, as is standard in EDR. Outside the stack of membranes lies a clamping system to pressurize the system and make it leak tight, and the necessary plumbing to distribute water. Overall there is one input for ground water, and two outputs. One output is for the dilutate which goes to the crops, the other output is for concentrated water which is disposed.

In terms of electronics there are a number of necessary components attached to the piping system. Firstly there is a small recirculation pump to keep water mixing in the concentrate side. There are seven electrically controlled valves for directing water between cycle states. Three conductivity sensors measure the salinity of the water, one for each inlet and outlet. Two flow rate sensors monitor the quantity of water, going in and out.

Together the UI, software and hardware provides farmers control and understanding of the machine that they are relying on to be help manage their livelihoods.

VISION FOR THE FUTURE OF THE INTERNET OF THINGS

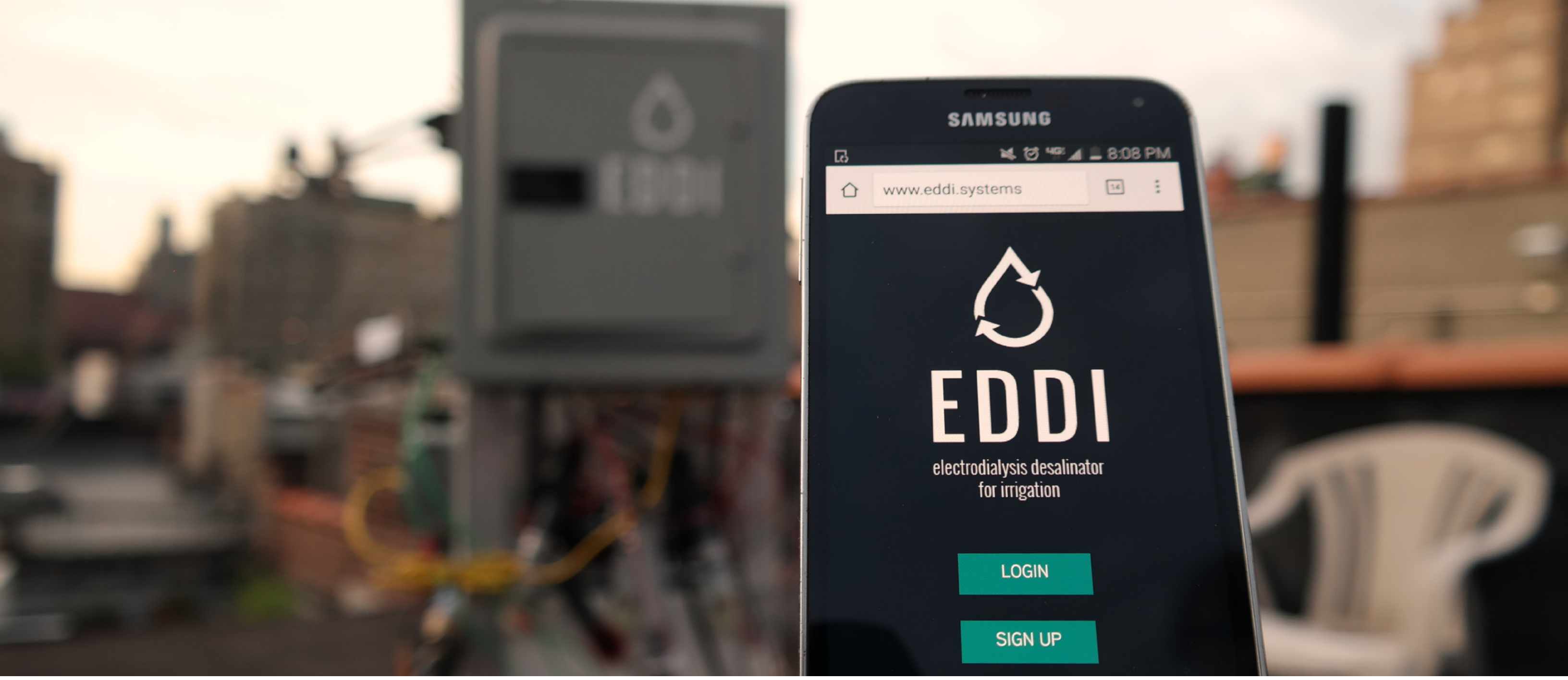
IOT opportunities are everywhere in irrigation. From upstream flow control, to flow monitoring, leakage finding, water quality sensing, and soil chemistry tracking there is potential for a large network of smart objects. EDDI will play an important role in this future network. Data from weather, soil, and groundwater combine in the EDDI to optimize efficiencies.

If soil sensors indicate that the soil is too salty this week, EDDI can kick into high gear to clean it out. If incoming water is more concentrated than usual, EDDI can communicate to the smart flow control valve up stream to slow down flow, allowing more ions to be removed. Built-in IOT features of the ARTIK mean EDDI will be prepared for the connected future of irrigation.

FAQ

What is Electrodialysis?

In electrodialysis, an electric field is used to separate salt ions from water. In order to divide the salty water from the clean water, the desalinator is divided into channels, and ion exchange membranes are placed between each channel. As the water moves through the EDDI with an electric field applied, the salt ions will migrate into every other channel, leaving a low-salt water that is ready for irrigation. The resulting salty water is recirculated into the salty channels to pick up more salt until it becomes too salty to use. At this point, the brine waste is released from the EDDI and the channels are refreshed with new water. Periodically, the direction of the current is changed, swapping the salty and clean channels inside the EDDI, to help clean off the ionic membranes and keep the device functioning efficiently.



Why can't it be centralized? Why is small scale the best option?

Small scale desalination allows the optimal level of desalination to take place for any given ground water quality and crop tolerance. We think this efficiency gain is more significant than the economies of scale in a larger desalination plant, which would likely use another desalination process.

Where does the concentrated water go?

There are a few options for what to do with the brine waste, and the best solution depends on the locality. Brine disposal is an issue tackled by other industries and desalination plants in particular. Some places dispose of it in normal sewage which flows eventually to the ocean. Other places set aside an area to create evaporation beds which collect the brine, let it dry and produce salts which can then be used for a variety of purposes. Worst case scenario would be putting it back into the groundwater system, which is not the most sustainable option, but does not deposit more salt in the aquifer than would leaching. Finally, new research in the area points to methods that can convert brine and CO2 into useful industrial chemicals.

Why Electrodialysis?

We chose to use Electrodialysis Reversal (EDR) as our form of desalination for a number of reasons. EDR is similarly energy efficient and cost effective compared to the other common desalination process, Reverse Osmosis (RO). Unlike RO, it does not remove minerals which may be beneficial to the plants from the water, but rather removes only the salt. The ion exchange membranes involved in EDR are self cleaning and long lasting, requiring minimal maintenance. EDR machines are also inherently modular. We've designed EDDI with this in mind. To grow in capacity users can buy more layers and in our intended final product it would be easy to insert new layers.

How much energy is needed?

For a small device like our prototype, which can dilute enough water for 1 acre of strawberries, we estimate the power demand when running to be about 250 Watts.