Please Note: This report is a good faith effort by RTI International to accurately represent information available via secondary and primary sources at the time of the information capture. Photo credit: Sedron Technologies.
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II. Senegal’s Sanitation Landscape

III. The J-OP Solution

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VI. Appendix
BMGF and local partners are working together to deploy the world’s first commercial J-OP in Dakar.

Project background: Achieving high levels of sanitation coverage requires both the use of improved sanitation facilities and a robust ecosystem that ensures fecal sludge (FS) is contained, collected, treated, and disposed. To this end, the Bill & Melinda Gates Foundation (BMGF) is funding the research and development of innovative FS treatment technologies. The Janicki Bioenergy Omni Processor (J-OP) is one such system that uses a combustion process to convert dewatered solids into useful byproducts: surplus renewable electricity, heat, water, and pathogen-free ash.

To de-risk the technology and enable widespread commercial deployment, the BMGF, along with numerous local and international partners, are supporting the construction of the world’s first commercial-scale J-OP in Dakar, Senegal. This pilot project is occurring in two phases, beginning with a pilot installation (Phase 1) and followed by a commercial installation (Phase 2). The objective of Phase 1 is to prove technical viability, bolster local capabilities, and achieve integration with the FS ecosystem, whereas Phase 2 is aimed at validating technical performance at scale and proving financial viability. The pilot J-OP has been operating in Dakar since 2015, and the commercial J-OP is expected to be installed in early 2019.

About this document: This document describes the efforts undertaken by Delvic Sanitation Initiatives (DSI), the BMGF, and other project partners in the installation and operation of the pilot unit, as well as project planning steps taken toward the siting, construction, and ongoing operations of the future commercial unit. The purpose of this document is to communicate learnings to others interested in developing a J-OP project.

Additional resources: To support business plan development and the identification of markets for J-OP water, AfriDev Consulting conducted a preliminary market assessment of drinking water, distilled water, and coolant across four regions in Senegal. That and several additional reports on the J-OP can be found in the “Resources Center” of the STeP website. [http://stepsforsanitation.org/resource-center/](http://stepsforsanitation.org/resource-center/)
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Senegal is a growing part of the African economy but struggles to meet some of its people’s basic needs.

**Senegal’s Sanitation Landscape**

- **Population:** 14.7 M
- **Urban population:** 6.52 M
- **Rate of urbanization:** 3.53% (2015–2020)
- **GDP:** 39.64B USD (est. 2016), GDP growth rate 6.7% (est. 2016)
- **Poverty headcount:** 46.7% of the population lives below the poverty line (2011).

**Summary:** Senegal is an independent presidential republic with 14 administrative divisions. The Senegalese economy is largely driven by mining, construction, tourism, fishing, and agriculture. The large and growing youth population is due to the continued desire for large families, low use of family planning, and early childbearing. High illiteracy, unemployment, and poverty rates hamper the country’s development.

**Dakar (Capital City)**
- **Population:** 3.52 M (2015)
- **Unemployment:** 16.7% (2017)
- **Population age:** 50% of population under the age of 18
- **Under 5 infant mortality:** 44/1000

Reliance on on-site sanitation has grown as the urban population has increased.

Urban areas in Senegal are increasingly reliant on on-site sanitation (OSS), such as latrines and septic tanks. Dakar makes up about 50% of the urban population in Senegal, and from 2000 to 2015, the share of the urban Senegalese population dependent on OSS increased to 54%.\(^1,2\) This prevalence of urban OSS suggests significant fecal sludge availability for a J-OP. In addition, sewer connectivity declined between 2000 and 2015, with less than 15% of the urban population having access to piped sewers in 2015.\(^1\) Given the fact that sewer expansion has not kept pace with urban population growth, it is likely that policy makers will continue to focus on OSS systems as a viable alternative in the nearer term. OSS will require a full fecal sludge management (FSM) value chain, and the J-OP offers unique treatment capacity.

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**SENEGAL’S SANITATION LANDSCAPE**

Source:
Today, deliveries exceed the design capacity of Dakar’s four fecal sludge treatment plants by 5-8X.

**Cambérène**
- **Overall installed capacity:** 100 m³/day
- **Construction date:** 2006
- **Daily throughput:** 540 m³/day
- **Technologies used:** Screening, settling tanks, passive drying beds, anaerobic tank, effluent discharge to wastewater treatment plant (WWTP)

**Tivaouane Peulh**
- **Overall installed capacity:** 400 m³/day
- **Year of operation:** 2018 (est.)
- **Daily throughput:** TBD
- **Technologies used:** Screening, settling/thickening, covered drying beds, effluent from drying bed to be sent to adjacent WWTP

**Niayes**
- **Overall installed capacity:** 60 m³/day
- **Construction date:** 2007
- **Throughput:** 498 m³/day
- **Technologies used:** Screening, settling tanks, covered drying beds, anaerobic tank, effluent discharge to adjacent WWTP

**Rufisque**
- **Overall installed capacity:** 60 m³/day
- **Construction date:** 2007
- **Daily throughput:** 483 m³/day
- **Technologies used:** Screening, settling tanks, passive drying beds, anaerobic tank, effluent discharge to WWTP
Data from Dakar suggests remaining fecal sludge is being unsafely disposed.

Because of limited access to treatment facilities and weak enforcement mechanisms, only 31% of the city’s fecal sludge was properly collected and treated in 2015. This presented a significant opportunity to improve human health and the environment.

The J-OP is a community-scale FSTP technology that destroys pathogens and generates useful byproducts.

The J-OP

The J-OP is a community-scale fecal sludge and biosolids processing unit that generates clean water, electricity, heat, and ash from waste. Based on patent application no. WO 2016-077241 and the associated family of granted patents and applications, the intellectual property and licensing rights are retained by the Bill and Melinda Gates Foundation for the licensing, manufacturing, sale, and distribution of the technology in accordance with the Foundation’s Global Access Policy.

The J-OP plays a critical role in the sanitation value chain by expanding fecal sludge treatment capacity and creating value-added end products that support a sustainable business model. The J-OP’s material outputs achieve complete pathogen destruction, while the water meets World Health Organization (WHO) and U.S. Environmental Protection Agency (EPA) drinking water standards. One J-OP can serve a community of hundreds of thousands, depending on the solids content and type of waste streams processed.

The sanitation value chain shows steps typical in safely managing waste from capture to reuse. Although the J-OP is a treatment solution, it requires a functioning sanitation ecosystem to ensure adequate inputs and opportunities for reuse.

Image source: Bill and Melinda Gates Foundation
The J-OP separates inputs into a liquid and solid substrate, which fuels a steam engine and generator.

**HOW THE JANICKI OMNI PROCESSOR WORKS**

1. Solid Fuel Combustion
2. Steam Power Generation
3. Water Treatment

**THE J-OP SOLUTION**

99.9% PURE WATER TO FINAL WATER TREATMENT

**JANICKI BIOENERGY**

STeP Sanitation Technology Platform
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DSI and BMGF’s project is being executed in two overlapping phases.

Phase 1: In March 2015, Sedron Technologies (formerly Janicki Bioenergy) installed the pilot unit at the Niayes FSTP, in partnership with the BMGF. The purpose of the pilot was to prove out technical viability, enhance DSI’s operating capabilities and achieve integration with ecosystem development activities (see slide 22). DSI was responsible for providing dried fecal sludge fuel to the pilot plant, while Sedron Technologies provided the technical hardware and managed initial operations with DSI and Office National De L'Assainissement Du Senegal (ONAS).

Phase 2: During 2015 and 2016, DSI and BMGF transitioned to the implementation of a Phase 2 J-OP. DSI became the operator of the pilot unit and began the marketing, business planning, and fundraising necessary to successfully implement the commercial unit. In 2019, the commercial unit will be installed at the Tivaouane Peulh FSTP with the purpose of proving technical viability of a v2 double engine system, as well as business model viability based on the sale of outputs.
The commercial unit has a near 2X capacity and includes options to operate in power or water mode.

Two operating modes allow project developers to match system design to markets for end products, although they have varying input requirements.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Pilot J-OP</th>
<th>Commercial J-OP</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Footprint</strong></td>
<td>472 m²</td>
<td>&lt;500 m² (excluding dewatering and effluent treatment)</td>
</tr>
<tr>
<td><strong>Labor Required</strong></td>
<td>2–3 people per shift</td>
<td>2–3 people per shift</td>
</tr>
<tr>
<td><strong>Overall Capacity</strong></td>
<td>6.3 dry tons per day</td>
<td>15 dry tons per day</td>
</tr>
<tr>
<td><strong>Technology</strong></td>
<td>V1 single engine J-OP</td>
<td>V2 double engine J-OP</td>
</tr>
<tr>
<td><strong>Inputs</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wet Sludge Entering Dryer</td>
<td>10.5 tons per day</td>
<td>25–31 metric tons per day</td>
</tr>
<tr>
<td>Feedstock Types Accepted</td>
<td>Dewatered fecal sludge</td>
<td>Biosolids, dewatered fecal sludge, biomass (sawdust, woodchips of uniform size)</td>
</tr>
<tr>
<td><strong>Outputs</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gross Electricity Production</td>
<td>110 kW–115 kW (design)</td>
<td>215 kW</td>
</tr>
<tr>
<td>Net Electricity Production</td>
<td>55kW</td>
<td>42kW</td>
</tr>
<tr>
<td>Water Production</td>
<td>1,080 liters per day</td>
<td>7,250 liters per day</td>
</tr>
<tr>
<td>Ash</td>
<td>1.588 tons per day</td>
<td>Pathogen-free. Quantity dependent on ash content of the incoming feedstock</td>
</tr>
<tr>
<td>Heat</td>
<td>Low grade waste heat available for local use</td>
<td>Low grade waste heat available for local use</td>
</tr>
<tr>
<td>Air Emissions</td>
<td>Meets applicable EPA/local air standards</td>
<td>Meets applicable EPA/local air standards</td>
</tr>
</tbody>
</table>
The project is a multi-year endeavor aimed at achieving the successful demonstration of the J-OP.

<table>
<thead>
<tr>
<th>J-OP PILOT PROJECT DESIGN</th>
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<tbody>
<tr>
<td><strong>Phase 1 Activities</strong></td>
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<tr>
<td><strong>Phase 2 Activities</strong></td>
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<tbody>
<tr>
<td>Funding</td>
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<tr>
<td>Project design</td>
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<tr>
<td>J-OP Mfg.</td>
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<tr>
<td>Site selection, Permitting</td>
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<td>Installation and commission</td>
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<tr>
<td>Operations and maintenance</td>
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<tr>
<td>FSM ecosystem development</td>
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<tr>
<td>Feedstock delivery</td>
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<tr>
<td>Product offtake</td>
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</table>
Several partners have been enlisted to perform critical tasks across the project’s lifecycle.

<table>
<thead>
<tr>
<th>Partner</th>
<th>Funding</th>
<th>Project design</th>
<th>J-OP Mfg.</th>
<th>Site selection, Permitting</th>
<th>Install and commission</th>
<th>O&amp;M</th>
<th>FSM ecosystem</th>
<th>Feedstock delivery</th>
<th>Product offtake</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delvic</td>
<td>✔</td>
<td>✔</td>
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<td>ONAS</td>
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<tr>
<td>Bill &amp; Melinda Gates Foundation</td>
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<tr>
<td>Sedron Technologies</td>
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<tr>
<td>USAID</td>
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<tr>
<td>Stone Family Foundation</td>
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<td>Vitol Foundation</td>
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DSI has contracted with SGS, a global inspection, verification, testing, and certification company to ensure compliance with regulations.

DSI and ONAS are expected to engage in a power purchase agreement for the electricity generated by the Phase 2 J-OP. Electricity will be used to offset usage by the ONAS’s WWTP.

USAID’s WASH-FIN program is supporting the project, while support from their Development Innovation Ventures (DIV) division was awarded May 2018.

Stone Family Foundation and Vitol Foundation are supporting marketing of J-OP end products.
DSI and ONAS are responsible for project development and operations with support from BMGF and Sedron.

**Overview**

- Delvic Sanitation Initiatives (DSI) is a Senegalese owned and operated company whose mission is to provide sanitation solutions adapted to West African market needs.
- A commercial and industrial public agency responsible for the management of the sanitation sector in Senegal.
- Sedron Technologies is an American engineering firm that designs and manufactures sanitation and waste management machinery.
- The BMGF is a global, private foundation based in Seattle, Washington, that conducts programmatic and grant-making activities to help all people lead healthy, productive lives.

**Project Activities**

- Operates the four FSTPs in Dakar
- Joint operation of the pilot unit at Niayes, with ONAS
- The exclusive partner with BMGF to operate the J-OP in West Africa
- Manages the emptying truck purchase program
- Emptying truck maintenance services (but not desludging service)
- Manages several FS programs that aim to create a robust FS supply and treatment ecosystem
- Original FSTP operator
- Joint operation of the pilot unit with DSI
- Asset management for sanitation infrastructure including capture, treatment, storage, vehicles, equipment and land, buildings and other dependencies
- Responsible for designing, manufacturing, and installing both the pilot and commercial units
- Provided technical support throughout Phase 1
- Will be responsible for component retrofits for the commercial unit, once operational
- FS ecosystem funding and program support
- Partner for installation and operation of the first J-OP
- Contractual agreements with DSI for transition and operation of the Phase 2 J-OP
- Partner with DSI to pursue additional funding for J-OP operations
To leverage existing infrastructure and fecal sludge flows, both J-OPs will be co-located with existing FSTPs.

The pilot J-OP was located at Niayes to leverage existing FSTP and space availability.

- The Phase 1 Pilot J-OP required an adjacent FSTP to pre-process incoming fecal sludge.
- Niayes was the only location of the three area FSTPs with adequate free space on-site.
- Raw fecal sludge is brought to the FSTP and dewatering is completed in the drying beds. The resulting solids are then moved to the J-OP to be used as “fuel.”

The commercial J-OP will be located at the Tivaouane Peulh FSTP to maximize fecal sludge deliveries and leverage available space.

- Meets permitting requirements of the DEEC (Senegal’s EPA) in terms of space needed, including on-site drying bed capacity.
- Infrastructure in place for efficient unloading of fecal sludge emptier trucks.
- Wastewater treatment infrastructure can be utilized for dewatering and effluent treatment.
- Located 20 minutes from Dakar.

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Phase 1 achievements demonstrate the technical viability of the J-OP technology.

Throughout the initial years of the pilot, run time and quality of runs on the pilot unit have improved significantly. The unit continues to run on a near daily basis and is now limited by the site’s fecal sludge supply. Additionally, the pilot unit reached the following key technical achievements:

- in the first year, processed an estimated 700 dry metric tons of fecal sludge,
- achieved complete absence of pathogens in the resulting outputs,
- produced clean water, and
- maintained key operating parameters such as boiler temperature within desired ranges.

Overall, the Technology Readiness Level of the pilot unit is estimated to be at Level 6 – System or prototype demonstration in a relevant environment.

Technical and operational setbacks, however, have left the generator of the pilot unit nonfunctioning to date. With no genset, electricity is not currently being generated. Rework of the genset with AVL, a world-renown developer and tester of powertrain technology, was the focus of many of the lessons learned going into Phase 2.
Dakar possessed several attributes that made it a good choice for J-OP deployment.

### Fecal Sludge (FS) Supply

**Policy & Regulations**
- Existing regulations support FSM, including these examples:
  - National Policy and Strategy for Sanitation Services
  - Sanitation Master Plans
  - Roadmap POST-MDG 2015-2025
- Strong working relationship with ONAS

**Long-Term Supply of FS**
- Projected 40% growth in FS production between 2015 and 2030
- Strategic emphasis on non-sewered sanitation solutions suggests long term access to FS supply

**FSM Ecosystem**
- Existing FS collection system and need for additional treatment capacity
- >200 desludging trucks

### Markets: Services & Products

**Payment Mechanisms Established**
- Households were accustomed to paying USD 20-45 for desludging services, and truckers pay a USD 0.54/m³ tipping fee for discharging FS at one of the city’s FSTPs. Although prices are low, these payments signal that sanitation is valued.

**Markets for End Products**
- High market value for electricity and coolant, into which J-OP water can be an input

### Institutional Capacity

**Partners and Institutions**
- Strong local partner, DSI, that was willing to (A) undertake ecosystem development, (B) operate the J-OP, and (C) advance regional deployment of the technology
- Partnership with the National Office of Urban Sanitation (ONAS), who is responsible for investing in and operating wastewater treatment plants across Senegal
Efforts to enhance the FSM ecosystem were critical to feedstock supply risk mitigation and pilot success.

### Problem
- Inefficiencies in the market, resulting in high emptying prices yet low wages.
- Aging emptying equipment, informal operations of desludging operators, and lack of specific pit emptying laws.
- Relatively high cost of mechanical emptying, low household savings, and limited access to credit, resulting in a decreased ability to pay for mechanical emptying services.

### Objectives
- Establish competition, improve quality of service, increase emptier income, and reduce the cost of emptying.
- Serve as a research tool to identify the most effective strategies to address market inefficiencies.
- Establish conditions for fecal sludge collection, transportation, unloading, and discharge.
- Create certification standards and penalties for infringements.
- Develop household savings for sanitation services to increase the capacity and willingness of households to pay for mechanical emptying.
- Promote mechanical emptying (thereby reducing the practice of manual emptying).
- Companies can now anticipate truck upgrading and maintenance through the Program for the Structuring of the Fecal Sludge Market (PSFSM) guarantee fund.
- A draft decree has been introduced, establishing a certification process for desludging truck operators.
- 1,496 households have taken out a subscription, (40% of households were approached to join the system).
- Nearly 10% of subscribers have been provided a first emptying service.

### Impact
- In late July 2014 (after one year of operation), the call center had provided 4,867 people with at least one emptying service; and significantly decreased the average price of an emptying service.
- Companies can now anticipate truck upgrading and maintenance through the Program for the Structuring of the Fecal Sludge Market (PSFSM) guarantee fund.
- A draft decree has been introduced, establishing a certification process for desludging truck operators.
- 1,496 households have taken out a subscription, (40% of households were approached to join the system).
- Nearly 10% of subscribers have been provided a first emptying service.
However, FS supply and market risk will require continued intervention to ensure financial viability.

<table>
<thead>
<tr>
<th>Risk</th>
<th>Probability of Occurrence</th>
<th>Level of Impact</th>
<th>Risk Mitigation Effort</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not enough fecal sludge (FS) to optimally run the J-OP</td>
<td>High</td>
<td>High</td>
<td>• Consolidate FS across FSTPs&lt;br&gt;• Improve FSTP to maximize sludge recovery&lt;br&gt;• Upgrade J-OP to co-treat solid waste</td>
</tr>
<tr>
<td>Cannot sell electricity at profitable price</td>
<td>Medium</td>
<td>High</td>
<td>• Negotiate long-term power purchase agreement with ONAS</td>
</tr>
<tr>
<td>Cannot sell distilled water products at profitable volume and price</td>
<td>Medium</td>
<td>High</td>
<td>• Perform market analysis to validate market&lt;br&gt;• Develop partnerships for selling products</td>
</tr>
<tr>
<td>Commercial-scale J-OP does not meet expected performance</td>
<td>Medium</td>
<td>Medium</td>
<td>• Obtain grant funding to undertake improvements to the J-OP based on pilot plant experience&lt;br&gt;• BMGF to provide grant funding for commissioning and testing to demonstrate expected performance</td>
</tr>
<tr>
<td>J-OP operations do not meet business expectations</td>
<td>Medium</td>
<td>Medium</td>
<td>• USAID-DIV grant awarded to support 10-month demonstration to validate acceptable business performance</td>
</tr>
</tbody>
</table>
Technical lessons learned in Phase 1 have resulted in a commercial unit with a 2x dry mass capacity.

In-country presence and remote monitoring of the unit provided many learning opportunities that have resulted in adjustments to ensure the system is more robust and well-suited for the conditions in Dakar.

**Overall structure**
- New material and coating are required to protect against the harsh UV and salty air of Dakar

**Generator**
- Thorough training and documentation on the technology and operations is critical to ensure safety and consistent functionality.
- Commissioning of the unit is critical to ensure that performance targets are met.

**Fecal sludge processing upgrades**
- Sludge drying beds had a sand base that caused problems in the boiler. The beds have since been replaced with stone pavers.
- Drying beds were covered to improve drying in the rainy season.
- Flocculation was added to capture more fecal sludge solids at the FSTP.

**Maintenance**
- Introducing new technology in a region means that parts may not be readily available in local markets. Efforts were made to ensure reliable local sources for maintenance items.
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Photo credit: Sedron Technologies
Adjusting J-OP operating parameters allows for optimization of revenue-generating end products.

The operating parameters of the system may be adjusted to optimize for power generation or water production or to strike a balance between the two. Additionally, the water generated might be sold as potable water or upgraded to a higher-value end product, such as coolant. DSI built a financial model to explore the economic feasibility of three scenarios for the commercial unit based on market dynamics in Dakar.
Market research indicated that in Dakar, coolant is the most valuable of J-OP end products.

DSI evaluated the economic viability of a future commercial installation in Dakar by examining the markets for electricity, drinking water, distilled water, and ash.

<table>
<thead>
<tr>
<th>J-OP products</th>
<th>End markets considered in the commercial phase of the pilot</th>
<th>Market value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity</td>
<td>Electricity prices in Senegal are among the highest in the world, making surplus electricity generation highly valuable. Currently, electricity produced by the J-OP is used for self-consumption by the J-OP but also to meet the electricity needs of ONAS. Note: Current regulations require 1 MW of generation in order to export to the grid.</td>
<td>$0.2 per kWh</td>
</tr>
<tr>
<td>Drinking-quality, potable water</td>
<td>A diversified market for drinking water exists in Dakar. If selling into the drinking water market, DSI’s preliminary research suggests an opportunity to enter the bottled water market that exploits the gap between the sachet and premium water markets.</td>
<td>$0.14 per liter</td>
</tr>
<tr>
<td>Blended coolant product</td>
<td>Local coolant manufacturers are importing inputs from France and selling it into the local market. Blending distilled water from the J-OP with glycol presents an opportunity for DSI to diversify their operations and produce a high value end product locally.</td>
<td>$1.08 per liter of coolant</td>
</tr>
<tr>
<td>Ash</td>
<td>With a strong agricultural economy, local cash and food crop farmers have demand for cheap and effective soil amendments. Pathogen-free ash produced from the combusted fecal matter can be sold as fertilizer to farmers.</td>
<td>$0.15 per kg</td>
</tr>
</tbody>
</table>

1 Local market values were estimated by field and secondary research undertaken by Deloitte and AfriDev Consulting under contract to DSI and BMGF. All calculations assume an exchange rate of 560 CFA to 1 USD. To learn more about the water market estimates, view the report on Senegalese water markets at [http://stepsforsanitation.org/](http://stepsforsanitation.org/).
Financial modeling suggests the production of coolant may be the most financially viable scenario.
By prioritizing coolant sales, the commercial J-OP may achieve an estimated 20-year NPV of 2.1M USD.

### PHASE 2 FINANCIAL PROJECTIONS

### Annual Costs (thousands of USD)

<table>
<thead>
<tr>
<th></th>
<th>Power-mode</th>
<th>Water-mode (coolant)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depreciation and provisions</td>
<td>121</td>
<td>121</td>
</tr>
<tr>
<td>Additional cost of producing coolant(^1)</td>
<td>151</td>
<td>775.5</td>
</tr>
<tr>
<td>Staff costs</td>
<td>121</td>
<td>121</td>
</tr>
<tr>
<td>External services and other purchases</td>
<td>157</td>
<td>154</td>
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<tr>
<td>Transportation</td>
<td>12.9</td>
<td>12.9</td>
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<tr>
<td>Consumables</td>
<td>7.4</td>
<td>7.4</td>
</tr>
<tr>
<td>Marketing</td>
<td>11</td>
<td>11</td>
</tr>
</tbody>
</table>

**Total Annual Costs = 570k - 1.2M USD**

### Annual Revenues

<table>
<thead>
<tr>
<th></th>
<th>Power-mode</th>
<th>Water-mode (coolant)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output (1,000s)</td>
<td>874</td>
<td>176</td>
</tr>
<tr>
<td>1,000s of USD</td>
<td>437</td>
<td>88.1</td>
</tr>
<tr>
<td>Electricity</td>
<td>874 kWh</td>
<td>176 kWh</td>
</tr>
<tr>
<td>Drinking water</td>
<td>398 L</td>
<td>56.9 L</td>
</tr>
<tr>
<td>Coolant</td>
<td>279 L</td>
<td>302 L</td>
</tr>
<tr>
<td>Ash</td>
<td>949 kg</td>
<td>144 kg</td>
</tr>
<tr>
<td>Output (1,000s)</td>
<td>1,431 L</td>
<td>1,551 L</td>
</tr>
<tr>
<td>1,000s of USD</td>
<td>1,431 L</td>
<td>1,551 L</td>
</tr>
</tbody>
</table>

**Total Annual Revenues = 679k - 1.78M USD**

\(^1\)Cost of producing coolant has been estimated but is yet to be validated at scale.

Note: All calculations assume an exchange rate of 560 CFA to 1 USD. Analysis assumptions are located in the appendix. Revenue figures are adjusted for inventory.
The model for Dakar suggests that the cost of coolant production will have the greatest impact on NPV.

**Operating costs**
Operating expenses such as the cost of producing coolant and assumptions about the life and maintenance of the J-OP still need to be refined.

**Financing**
Because the Dakar J-OP is heavily subsidized, weighted average cost of capital (WACC) and CapEx are not expected to have a significant impact on actual financial performance. These factors may have greater influence on financial performance in subsequent installations.

**Methodology:** Each input was varied within a triangular distribution determined to be the best estimate for Dakar. Ranges are shown in the appendix. Eight other variables were evaluated and shown to demonstrate minimal sensitivity (<10% of the largest standard deviation found).
PHASE 2 FINANCIAL PROJECTIONS

For any J-OP (not only in Dakar), cost of capital, water demand, and ash are also likely to be important.

Methodology: Each input was varied in a triangular distribution with low and high points varying 10% from the midpoint. Ranges are shown in the appendix.

*Water-based product demand estimated as a percentage of maximum demand. Any excess production sold to emptiers.
Future J-OP installations should consider value-added end products and financing options.

**Value-added end products:** In Dakar, neither the market for electricity nor potable water is sufficient to achieve a positive NPV at 20 years. The sales price of coolant is believed to be >3 times the sales price of potable water, and this difference drives an increase in profitability. Others considering J-OP installations should invest resources in identifying or creating a market for value-added, water-based products.

**Cost of capital:** In Dakar, financing has been identified for all the required capital at a low rate of 8%. Since this variable has a significant impact on NPV, future installations should focus on markets where affordable financing can be identified.

**CapEx subsidies:** Both because it occurs early in the project and because the expense is significant, subsidies reducing initial capital expenses have an important impact on NPV.

**Ash products:** Even though the sales price of ash is low, the volume of ash generated in Dakar is significant. The large volume increases the sensitivity of NPV to the sales price of ash and the amount that is sold. The percentage of ash in fecal sludge in Dakar has been demonstrated to be approximately 40%; feedstock sources with lower ash content would decrease the sensitivity of NPV to ash price. Additionally, ash may have a high heavy metal content and that requires landfill disposal in some settings.
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Envisaged Role

| DSI will be owner and operator of the J-OP and will ensure a continuous supply of fecal sludge to the site. DSI will develop the market for J-OP outputs, including water, to support the business case for the commercial unit. | WASH-FIN will build DSI’s investment readiness, develop key investor materials, and develop and implement capital raise strategy. Support from USAID-DIV includes assessing social impact, demonstrating user demand and willingness to pay through an extended J-OP business demonstration, and measuring J-OP performance and identifying operational refinements. | ONAS will enter into a power purchase agreement for surplus electricity generated by the J-OP for use in their adjacent wastewater treatment operations. ONAS bears responsibility for providing necessary authorizations and oversight of DSI in operation of the city’s four FSTPs. ONAS has effective ownership of the machine now, and this has greatly aided in improving the working relationship. | The BMGF has been involved in a range of activities supporting the deployment of the J-OP in Dakar including strengthening DSI’s capacity to prepare for the acquisition and operation of the v2 commercial unit; upgrading the FSTPs in Dakar to support J-OP operation; facilitating/funding commercial unit commissioning, testing, transition, and training; and supporting FSM ecosystem development with the goal of directing more fecal sludge to the FSTPs and improving desludging practices. |
DSI’s next steps will focus on the business demonstration of the J-OP in Dakar, Senegal.

1. The pilot J-OP will undergo an overhaul, be equipped with next generation steam engine, and be used to support technology maturation in advance of the arrival of the commercial unit in Dakar.

2. The commercial J-OP will undergo acceptance testing and commissioning to ensure acceptable performance prior to handover to DSI.

3. DSI will build capacity and implement plans to be ready for business demonstration of the commercial unit, including establishment and refinement of the supply chain for fecal sludge and solid waste, and sales channels for J-OP products.

4. Pre-installation work will be completed at the Tivaouane Peulh FSTP in preparation for the commercial unit.

5. An extended demonstration of the J-OP will be performed to determine financial viability.

6. DSI plans to conclude its funded demonstration of the commercial J-OP in 2020 and then expand across West Africa.
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Acknowledgments

We would like to thank Jerry Hudson of Prosperity Innovations, LLC, and the teams from DSI and Sedron Technologies for their input to this publication.
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VI. Appendix
## Financial Analysis Assumptions for Water-Mode (coolant) Scenario.

<table>
<thead>
<tr>
<th>Assumption</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Grant Support</strong></td>
<td>• ~2M USD to upgrade FSTPs, transition of J-OP, J-OP testing/commissioning, business demo</td>
</tr>
<tr>
<td><strong>Split of Products (Coolant-Mode)</strong></td>
<td>• 100% coolant; 0% drinking water</td>
</tr>
<tr>
<td><strong>Startup</strong></td>
<td>• 50% of capacity in Year 1</td>
</tr>
<tr>
<td></td>
<td>• Coolant sales are ~1.4M liters/year</td>
</tr>
<tr>
<td><strong>Product Market</strong></td>
<td>• 100% of electricity sold</td>
</tr>
<tr>
<td></td>
<td>• 70% of other products sold</td>
</tr>
<tr>
<td><strong>Financing</strong></td>
<td>• 100% debt financing for OpEx and Capex 2.18M USD, 8%, 1-year grace + 7-year payback</td>
</tr>
<tr>
<td><strong>Output Pricing</strong></td>
<td>• Water: Not applicable</td>
</tr>
<tr>
<td></td>
<td>• Coolant: 607 CFA/liter</td>
</tr>
<tr>
<td></td>
<td>• Electricity: 113CFA/kWh</td>
</tr>
<tr>
<td></td>
<td>• Ash: 85 CFA/kg</td>
</tr>
<tr>
<td><strong>Operating Costs</strong></td>
<td>• 20-year lifespan</td>
</tr>
<tr>
<td></td>
<td>• 5-year lifespan on all remaining infrastructure (periodic replacement)</td>
</tr>
</tbody>
</table>
## Financial model variables and ranges used in sensitivity analysis.

<table>
<thead>
<tr>
<th>Investments</th>
<th>Investments</th>
<th>Debt</th>
<th>Operations</th>
<th>Ash</th>
<th>Ash</th>
</tr>
</thead>
<tbody>
<tr>
<td>Portion of cost of OP supported by the foundation</td>
<td>Portion of cost of capital (regardless of capital structure)</td>
<td>Interest rate</td>
<td>Period of inactivity in Year 1</td>
<td>Average price of ash (FCFA/kg)</td>
<td>Percentage of production of ash that is sold</td>
</tr>
<tr>
<td>Profitable Case – Water Optimized as Coolant</td>
<td>0.0%</td>
<td>8.0%</td>
<td>8.0%</td>
<td>50.0%</td>
<td>85.00</td>
</tr>
<tr>
<td>Mid Value</td>
<td>0.0%</td>
<td>20.0%</td>
<td>8.0%</td>
<td>50.0%</td>
<td>90.00</td>
</tr>
<tr>
<td>Low Value</td>
<td>0.0%</td>
<td>8.0%</td>
<td>8.0%</td>
<td>25.0%</td>
<td>80.00</td>
</tr>
<tr>
<td>High Value</td>
<td>100.0%</td>
<td>40.0%</td>
<td>15.0%</td>
<td>100.0%</td>
<td>100.00</td>
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</table>
Financial model variables and ranges used in sensitivity analysis.

<table>
<thead>
<tr>
<th>Water/Coolant</th>
<th>Water/Coolant</th>
<th>Water</th>
<th>Water</th>
<th>Coolant</th>
<th>Coolant</th>
<th>Electricity</th>
<th>Electricity</th>
<th>Coolant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial year's water-based product demand as a percentage of maximum demand. Any excess production sold to emptiers.</td>
<td>Percentage of water production that is potable water (balance is coolant)</td>
<td>Average sales price of potable water (FCFA/L)</td>
<td>Average sales price water to the emptiers (FCFA/L)</td>
<td>Average sales price of coolant (FCFA/L)</td>
<td>Additional cost to produce coolant as percentage of sales price</td>
<td>Percentage of time in Power Optimized Mode (balance of time is in Water Optimized Mode)</td>
<td>Average sales price of electricity (FCFA/kWh)</td>
<td>Percentage of production of electricity that is sold</td>
</tr>
<tr>
<td>Profitable Case – Water Optimized as Coolant</td>
<td>70.0%</td>
<td>0.0%</td>
<td>160.00</td>
<td>0.70</td>
<td>607.00</td>
<td>50.0%</td>
<td>20.0%</td>
<td>113.00</td>
</tr>
<tr>
<td>Mid Value</td>
<td>50.0%</td>
<td>25.0%</td>
<td>80.00</td>
<td>0.70</td>
<td>625.00</td>
<td>50.0%</td>
<td>50.0%</td>
<td>125.00</td>
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<td>0.0%</td>
<td>75.00</td>
<td>0.50</td>
<td>600.00</td>
<td>20.0%</td>
<td>0.0%</td>
<td>75.00</td>
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<tr>
<td>High Value</td>
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<td>50.0%</td>
<td>85.00</td>
<td>0.80</td>
<td>650.00</td>
<td>80.0%</td>
<td>100.0%</td>
<td>150.00</td>
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</table>
## Financial model variables and ranges used in sensitivity analysis.

<table>
<thead>
<tr>
<th></th>
<th>Investments</th>
<th>Investments</th>
<th>Debt</th>
<th>Operations</th>
<th>Ash</th>
<th>Ash</th>
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</thead>
<tbody>
<tr>
<td>Percentage of OP CapEx subsidized</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost of capital (regardless of capital structure)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interest rate</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Period of inactivity in Year 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average price of ash (FCFA/kg)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percentage of production of ash that is sold</td>
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<tr>
<td>Base Case</td>
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<td>8.0%</td>
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<td>85.00</td>
<td>70.0%</td>
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<tr>
<td>Mid Value</td>
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<td>8.0%</td>
<td>8.0%</td>
<td>50.0%</td>
<td>85.00</td>
<td>70.0%</td>
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<tr>
<td>Low Value</td>
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<td>7.2%</td>
<td>7.2%</td>
<td>45.0%</td>
<td>76.5</td>
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<td>8.8%</td>
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<td>93.5</td>
<td>77.0%</td>
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## Financial model variables and ranges used in sensitivity analysis.

<table>
<thead>
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<tbody>
<tr>
<td>Initial year’s water-based product demand as a percentage of maximum demand. Any excess production sold to emptiers.</td>
<td>70.0%</td>
<td>25.0%</td>
<td>80.00</td>
<td>0.70</td>
<td>607.00</td>
<td>50.0%</td>
<td>20.0%</td>
<td>113.00</td>
<td>90.0%</td>
</tr>
<tr>
<td>Percentage of water production that is potable water (balance is coolant)</td>
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<td>25.0%</td>
<td>80.00</td>
<td>0.70</td>
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<td>20.0%</td>
<td>113.00</td>
<td>90.0%</td>
</tr>
<tr>
<td>Average sales price of potable water (FCFA/L)</td>
<td>70.0%</td>
<td>25.0%</td>
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<td>0.70</td>
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<td>50.0%</td>
<td>20.0%</td>
<td>113.00</td>
<td>90.0%</td>
</tr>
<tr>
<td>Average sales price water to the emptiers (FCFA/L)</td>
<td>70.0%</td>
<td>25.0%</td>
<td>80.00</td>
<td>0.70</td>
<td>607.00</td>
<td>50.0%</td>
<td>20.0%</td>
<td>113.00</td>
<td>90.0%</td>
</tr>
<tr>
<td>Average sales price of coolant (FCFA/L)</td>
<td>70.0%</td>
<td>25.0%</td>
<td>80.00</td>
<td>0.70</td>
<td>607.00</td>
<td>50.0%</td>
<td>20.0%</td>
<td>113.00</td>
<td>90.0%</td>
</tr>
<tr>
<td>Additional cost to produce coolant as percentage of sales price</td>
<td>70.0%</td>
<td>25.0%</td>
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<td>0.70</td>
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<td>20.0%</td>
<td>113.00</td>
<td>90.0%</td>
</tr>
<tr>
<td>Percentage of time in Power Optimized Mode (balance of time is in Water Optimized Mode)</td>
<td>70.0%</td>
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<td>80.00</td>
<td>0.70</td>
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<td>50.0%</td>
<td>20.0%</td>
<td>113.00</td>
<td>90.0%</td>
</tr>
<tr>
<td>Average sales price of electricity (FCFA/kWh)</td>
<td>70.0%</td>
<td>25.0%</td>
<td>80.00</td>
<td>0.70</td>
<td>607.00</td>
<td>50.0%</td>
<td>20.0%</td>
<td>113.00</td>
<td>90.0%</td>
</tr>
<tr>
<td>Percentage of production of electricity that is sold</td>
<td>70.0%</td>
<td>25.0%</td>
<td>80.00</td>
<td>0.70</td>
<td>607.00</td>
<td>50.0%</td>
<td>20.0%</td>
<td>113.00</td>
<td>90.0%</td>
</tr>
</tbody>
</table>

### Profitable Case
- Water Optimized as Coolant

### Mid Value

### Low Value
- 63.0%
- 22.5%
- 72
- 0.63
- 546.3
- 45.0%
- 18.0%
- 101.7
- 81.0%

### High Value
- 77.0%
- 27.5%
- 88
- 0.77
- 667.7
- 55.0%
- 22.0%
- 124.3
- 99.0%