**Rebelo et al., 2018 - Supplementary Data 1 - Business Model Canvas (BMC) description**

In this study, we used the Lean startup method (Blank, 2007) to validate the client segment and value proposition of our product using the Business Model Canvas (BMC) ([Osterwalder & Pigneur, 2013](https://paperpile.com/c/Dr43Ay/SkjY)). The BMC was the instrument we chose to consolidate market information. Each of the nine segments of our business model is discussed below. Overall, our proposed business model can be characterized as customer-driven, as it is built to attend hydroelectric power plants’ needs for a solution to mussels infestation.

**Customer Segments**

We consider freshwater reservoirs as the main systems affected by the mussel invasion. Several economic activities take place in the reservoirs, from artisanal fisheries and aquaculture, to recreation and ecotourism. However, we identified hydroelectric energy generation as the only customer segment for a high-tech disinfestation service.

Some 161 hydroelectric power plants are scattered throughout Brazil. *L. fortunei* infestationhas beenreported at 61 of them (38%). These 61 plants represent 55% of the installed hydroelectric capacity in the country, with approximately 20,000 km² of reservoirs infested according to our survey.

We interviewed a variety of stakeholders who in BMC nomenclature are classified as strategic, technical and economic buyers, and as influencers and saboteurs. And of course, decision makers. The professions and societal players are:

1. **Operations engineer**: Responsible for scheduling and optimization of processes. **Economic buyers and decision maker.**
2. **Maintenance engineer**: Maintenance and monitoring activities. **Influencer**.
3. **Environmental manager**: Environmental licensing and monitoring. **Strategic and technical buyer. May be the decision maker in some cases.**
4. **Head of the legal department**: Defends the company from lawsuits, responsible for compliance with laws and regulation. **Influencer.**
5. **Financial manager:** Responsible for company’s budget and evaluation of economic feasibility of future projects. **May be the economical buyer and decision maker in some situations.**
6. **Community leaders. May be saboteurs if prejudice against GMOs exists.**
7. **Environmental Agency technicians.** **May be influencers or saboteurs depending on their scientific background.**

**Value Propositions**

Interviewing customers, we realized that until very recently, mussels were not perceived as a threat to the hydroelectric power plant business. It was only after two power plants in Santa Catarina (Itá and Machadinho) had to be shut-down because of overheating risk due to heat exchanges clogged with mussels that operation and maintenance engineers began to realize that this small organism could cause substantial damage to the plant. Before that, the mussel was an inconvenience that would lead than to some extra man-hours when the plant was halted for routine maintenance. Conflicts with the environmental agency would arise not from the damages to the biodiversity caused by the mussels, but from the chemicals (mostly chlorine) used to clean up the pipes that are released in the environment. Civil lawsuits lead to a change in this perception as the companies were being accused by society/NGOs as responsible for the infestation, or at least complicit, since they were not doing anything to fight it.

Among the reasons that riverine populations sued included the economic losses (estimated by the Fisheries Institute of São Paulo) due to fish aquaculture cages becoming clogged, the extremely unpleasant odor of decomposing mussels when severe droughts reduction reservoir levels, and small injuries (cuts and bruises) sustained while trying to access the reservoir. The environmental regulatory agency has forced the hydroelectric power plants to take actions and measures to prevent mussels from spread further. Under provisions of the national plan of infestation control, plants are required to a mussel control plan, the lack of which, could lead to loss of the operational license. Even though the risk of lost revenue is theoretical, because most power plants operates below their installed capacity most of the time, maintenance costs have been rising and are now up to USD 500,000 per year. Based on this rationale, we estimated the main value proposition to be delivered to the clients identified for this business are risk and cost reduction and a gain in performance.

1. **Risk reduction:** unexpected operation halts, lawsuits from the riverine population and public attorneys and the loss of the environmental operational license. Loss of revenue.
2. **Cost reduction:** Based on the information (of 1 power plant) that cleaning procedures cost about BRL 80,000 (USD 30,000[[1]](#footnote-1)) a year for each 1,400 MW of installed capacity, we calculated the related costs for all 61 infested hydroelectric plants (55,364 MW) by golden mussel to be BRL 19 million (USD 6.9 million1). According to CTG Brasil estimates, the annual costs associated with the monitoring program, chemicals and products, spare parts and man-hours required to address golden mussel fouling on an annual base is BRL 600,000 (USD 220,0001) for a hydroelectric plant with a medium-to-large installed capacity of 1500 MW in Brazil. This means that, each year, the hydroelectric sector in Brazil spends a range of BRL 19 to 22 million (USD 6.9 - 8 million)1 on the control of the bivalve.
3. **Performance gain:** Based on the number of days a reference hydroelectric power plant’s operations were reported to have been halted for cleaning and maintenance, the energy selling price, the hydroelectric capacity in Brazil (55,364 MW) of the 61 infested HPPs, and the average capacity factor for Brazilian HPPs (55%), we estimated the opportunity cost due to mussel infestation in around BRL 330 million (USD 120 million1) a year.

**Customer Relationship**

Our service is highly technical. We anticipate that sales will require a close and direct relationship with clients. Given the number of HPPs in the country is 161, we believe an in house technical, direct sales team could work closely with clients to explain the product and also support the procurement of the service and be responsible for customer support as well. Based on this assumption, we divided our strategy in to three components: customer acquisition (**get**), customer retention (**keep**) and boosting sales (**grow**):

1. **Get: Direct visits and participation in congresses, conferences and fairs.** Identify events in which strategic, technical and economic buyers (as well as influencers and saboteurs) attend to use as a platform to communicate our service. Create both sales and educational material about GMO.
2. **Keep: Highly technical and attentive customer support.** Work closely with operational and maintenance engineers, as well as environmental engineers, to guarantee a smooth disinfestation service.
3. **Grow. The GM Mussel conference:** our own conference to which we can invite customers and at a single forum, discuss success cases, technical advances and so on. Price reduction of the service: As technology advances, we anticipate the possibility of being able to reduce costs and cut prices. Reducing prices could allow us to pursue other market segments such as aquaculture facilities, municipalities and recreational activities.

**Channels**

We believe that **direct sales** **team** with be the principal way to deliver our service to our clients: commercial proposals that leads to contracts for the acquisition of disinfestation, maintenance and technical assistance services. Nevertheless, operators rely on **environmental consultancies** to execute many of the activities necessary to comply with regulations of the sector, or other requirements of environmental agencies. We believe they could be an important sales channel for our service.

**Revenue Stream**

Revenue was estimated based on two services:

1. **Stand-alone disinfestation service** (with microencapsulated pre-disinfestation)
2. **Subscription to a disinfestation maintenance** service (that includes infestation monitoring)

The revenue from the business was based on US pricing practices wherein the sales price is derived from its costs. As there currently no service on the market analogous to what we are modeling, that is, there is no delineation of the profit margin by competitors, it became necessary to set a target percentage. Even with a highly innovative service with a relatively small market, the margin was set at 16.5% under lab construction, equipment purchases and installation, and disinfestation service. Each contracting HPP would have its own laboratory for the GMO production and administration. Each year, four additional HPPs would adopt the disinfestation service with the biotechnological tool as a method of golden mussel control in their reservoirs and systems.

In addition to the revenue provided in the model used in economic feasibility analysis, the genetically modified golden mussel may give rise to other related businesses. We imagine, for example, the need to decrease the initial bivalve population in a target reservoir, in order to make our biotechnology more effective. To do this, we could use microencapsulated biocides, a targeted method that relies on the toxic substances bioaccumulation in the bivalve and thus uses a smaller quantity of the chemical.

**Cost Structure**

The Capital expenditure (CAPEX) and Operational expenditure (OPEX) of the disinfestation service were based on Blacher (2012), adjusting the values by an approximation of accumulated inflation in the period 2012-2017 by the Brazilian Consumer Price Index (IPCA), 50%, and were based on a laboratory with a capacity of 100,000,000 seeds (the name given to young mussels with a fixing capacity). Land values were not included in this model, as we assume that the contracting HPP will be responsible for designating an area where the cultivation/support laboratory will be situated.

CAPEX was estimated based on equipment, construction, hydraulic materials and electricity, electrical and hydraulic installations, complementary projects, wastewater treatment, prior environmental report, civil project, environmental permits, and costs of registering the company and obtained necessary authorizations and permits. Total CAPEX investment for each laboratory facility construction was estimated at USD 640,000[[2]](#footnote-2). The depreciation and amortization of investments in infrastructure and equipment were set at 20% per year over five years.

The OPEX, in turn, were divided into: indirect fixed costs (related to compliance of legislation specific to laboratories of this nature), indirect variable costs (referring to telecommunications, marketing, fuel, laboratory maintenance and taxes) and direct variable costs (inputs and consumables). The annual operational costs for running each laboratory facility is estimated to be BRL 8.3 million (USD 3 million)2. Other operational costs include the team responsible for the disinfestation service in each HPP would be composed of 1 higher level technician; 2 technicians; and 2 support technicians.

The Economic Feasibility Study zero mark assumes that all R&D activities are completed. In this way, these costs were not included in this analysis.

**Key Resources**

From the genetically modified mussels themselves to the design of cages, the most important resource to this project is the intellectual property.

The facilities to produce large quantities of embryos, genetically modify and grow them into seeds should also be a key asset.

Last but not least, a R&D team that will continue to work on the development of the service, and a highly technical sales team.

**Key activities**

The main activities necessary for this business includes:

1. **Diagnosis of infestation** (mussel colonies and density in the reservoir) and planning of disinfestation (estimation of number and position of cages distributed over space and time)
2. **Microencapsulated pesticide application**
3. **Production of genetically modified mussel embryos**
4. **Customer support to acquire permits** to use GMO mussel solution
5. **Reservoir and power plant monitoring** of physical, chemical and biological parameters at the reservoir and at the HPP
6. **Disinfestation activities** that includes the handling of mussels, cages, probes and analysis of the data and population dynamics models.

**Key partners**

Disinfestation of a reservoir using GMO mussels is a very specific service, that, we believe, will require custom made materials. We identified 4 materials that would have to be designed specifically for us and could create opportunities for a partnership with a supplier.

1. **Supplier of Fluctuation cages** that will hold the GM Mussels and allow them to release gametes into the reservoir
2. **Supplier of Monitoring probes,** that will hold all the sensors to monitor the quality of the water, overall biodiversity and mussel infestation using environmental DNA
3. **Supplier of Electroporator devices** that will be used to massively transfect mussels
4. **Synthetic DNA supplier** to massively produce DNA constructs to be transfected to mussel embryos.

**References**

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Blank SG. 2007. The four steps to the epiphany: successful strategies for products that win. California: S. G. Blank.

[Osterwalder A., Pigneur Y. 2013. Business Model Generation: A Handbook for Visionaries, Game Changers, and Challengers. John Wiley & Sons.](http://paperpile.com/b/Dr43Ay/SkjY)

1. the contemporary exchange rate in 2012 was USD 1.00 = BRL 2.75 [↑](#footnote-ref-1)
2. the contemporary exchange rate in 2012 was USD 1.00 = BRL 2.75 [↑](#footnote-ref-2)