Developing the Single Household Hydropower Market for Turbulent

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TU Delft TURBULENT

Executive Summary

This project aims to enlarge the impact of small-scale run-of-the-river hydropower for Turbulent. Turbulent has designed a unique low-head vortex hydropower turbine that creates renewable energy from the flowing of water. To find design opportunities, the company is analysed using stakeholder value mapping, a SWOT analysis, user interviewing, and Business Model Canvases. Independent Power Producers (IPPs) and Single Households are identified as interesting user groups to design for. The insights gained from interviews with IPPs are grouped in a strategic roadmap. The main insights for the IPP market revolve around the topics of partnerships, feasibility and viability studies, certification, manufacturing, and product offering.

For the single household market, a new way of working is proposed, where local contractors do most of the contact with single household clients. A customer journey for both single household clients as well as contractors is made to design a website. This website is used to test the market demand for single household turbines. Potential clients can pre-order a pico turbine (less than 5 kW) on this website (turbulentpico.be). Different price points are tested. It is found that there is enough demand for pico turbines that the design and engineering phase of the pico turbines can be started. It is recommended to start Turbulent Pico as a separate company.

Preface

Dear reader,

In front of you is the result of a 100 day quest to find and design for an opportunity for Turbulent in the hydro market.

After coming across a video from Turbulent on YouTube, I was intrigued by this simple design that turns the energy of flowing water into clean renewable electricity. The company had just recently started and I felt that there was much more untapped potential in this company.

Thus, I called Turbulent and got on the line with Geert Slachmuylders (who would later become my company mentor). I pitched an idea for a platform to crowdfund small-scale run-of-the-river hydropower plants, such as the ones offered by Turbulent. It later turned out that a German start-up had just started with this idea, so we set out to design something different, but it got our thinking started.

I would like to thank the team at Turbulent for offering me the wonderful opportunity to work with you on delivering more clean and renewable energy to the world and taking in some Belgian culture along the way. Thank you Geert Slachmuylders for the great brainstorming and innovative thinking sessions we did. Thank you Maria Elvira for teaching me the sales mindset and your critical look at the innovations proposed. Thank you Andrei Baicu for your help with integrating the prototype website in Turbulent's systems.

I would like to thank Pinar Cankurtaran and Sem Carree for your sharp and bright feedback, helping the project get to a higher level.

Finally, I would like to thank my friends and family for the great support you gave me during the project.

Enjoy reading!

Marijn Bilsen

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1. Introduction

1.1 Company Introduction

Turbulent NV is a Belgian company that was a spin-off from a graduation project on capturing energy from a water vortex. The company was formally started in 2015 by three friends and now has around 15 employees. The company has been making turbines ranging in size between 5 kW and 70 kW. Approximately 20 turbines have been delivered so far. The company is now focussing on turbines ranging from 30 kW to 70 kW. Usual customers are investors that want to install a turbine as an investment and sell electricity, Small-Medium Enterprises (SMEs) that want to save on their electricity bill, or project developers who want to develop a project and sell the whole project to a company nearby. Up until now, the single household market has not been developed, as the profitability is considered too low. However, it has never been deeply studied. That is the aim of this project.

Figure 1: A 15 kW Turbulent turbine

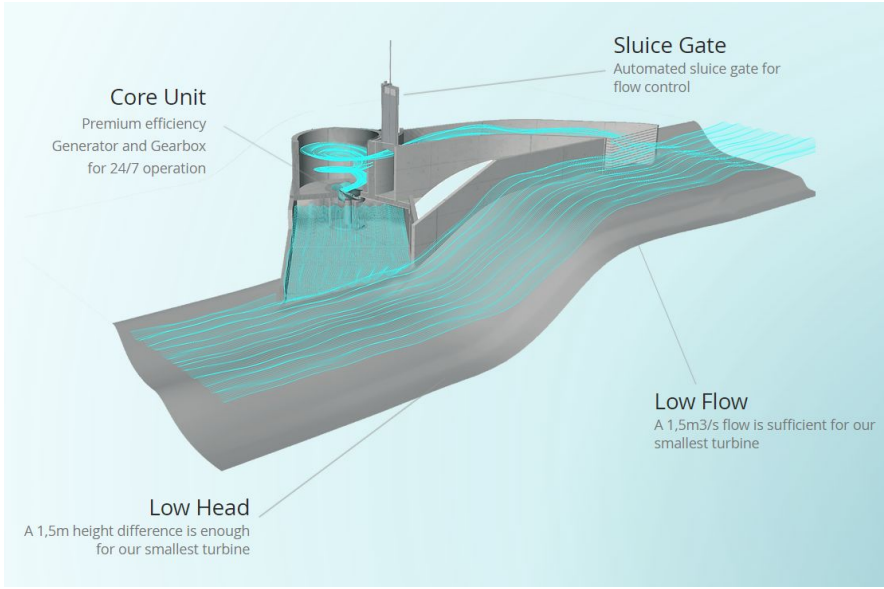


Figure 2: Run-of-the-river vortex turbine

1.2 Project Introduction

Energy is more relevant than ever before. We are seeing growing energy demands, a move towards renewable energy (International Energy Agency [IEA], 2021), rising energy prices (Eurostat, 2022), and a quest for energy independence (European Commision, 2022; Dansk Institut for Internationale Studier, 2022; FTAdviser, 2022). Turbulent is a young company (started in 2015) that has developed technology to extract renewable energy from the flowing of water. Currently, this is done in a range of 15 kW to 70 kW. These are large investments and they power somewhere around 50-100 European households. This project analyses the current status of Turbulent and looks for opportunities to design for. Several opportunities are found. For the Independent Power Producer (IPP) market, the opportunities are summarised in a strategic roadmap. The opportunity that is designed for is found in the single household market. Turbulent does quite often get requests for smaller turbines to power one home. Right now they do not do anything with those leads. This project aims to find out whether this market is worth developing, how this market should be approached, and prototype a part of that strategy. More concretely, this project delivers a website (turbulentpico.be) to test market demand and recommendations on how to approach this market.

1.3 Methodology

The goal of this project is to enlarge the impact of small-scale run-of-the-river hydropower for Turbulent. Thus, the context is first explored. This is done by looking both inwards at Turbulent, and outwards at the (renewable) energy landscape. To understand the complexity of installing hydropower for Turbulent's clients, a stakeholder value map is made. This also helps understand which clients will have an easier time installing hydropower, given the number and type of stakeholders they have to manage. To find out how to use the strengths of Turbulent to cover for the weaknesses and how to turn threats into opportunities, a SWOT analysis is performed. Current and potential clients of Turbulent are interviewed to better understand their needs. The insights from these interviews are used as input for the customer journeys, strategic roadmaps, and website prototype. Business model canvases of the current and future situation are made to get an overview of the (potential) business models.

An overview of the methods used, why they were used, what they were based on, and what their outcomes were can be seen on the next page.

Methodology

Method	Goal	Input	Outcomes
Stakeholder Value Mapping	Finding out the complexity of the process of installing hydropower for our clients. Finding out which are interesting clients to focus on.	Interviews with Turbulent employees. 3 interviews with Turbulent partners	Interesting segments are: Independent Power Producers, Systematic producers, and Single households
SWOT Analysis	Finding out how to use strengths of Turbulent to cover for weaknesses and turn threats into opportunities	Interviews with Turbulent employees. Material from Turbulent	Threats and opportunities to design for
User Interviewing	Understanding the needs and wants of current and future users	3 interviews with Turbulent partners. 13 interviews with potential single household clients, of which 3 with potential contractors for single households	Useful insights for designing
Current Business Model Canvas	Understanding the workings of Turbulent and finding opportunities	Interviews with Turbulent employees. Material from Turbulent	An overview of the current business model of Turbulent and new ideas for improvement
Future Business Model Canvas for Single Households market	Finding opportunities	Interviews with potential single household clients	Features to include in the prototype website
Customer Journey Single Household clients & contractors	Designing the experience a customer has	13 interviews with potential single household clients.	Features to include in the prototype website
Strategic Roadmap for IPP market	Planning innovations	Interviews with 3 Turbulent partners. Interviews with Turbulent employees	Overview of possible innovations that Turbulent can implement to improve their service for IPPs
Strategic Roadmap for single household market	Planning innovations	13 interviews with potential single household clients. Interviews with Turbulent employees	Overview of a strategy how Turbulent Pico can be launched
Website Prototype	Testing assumptions single households	Questions from interested single households. Interviews with interested single households	A tool for assessing the market demand for single household turbines

2. Context

2.1 Stakeholder Value Map

To find out with whom the clients of Turbulent have to collaborate with and select which clients to work with, a stakeholder value map was made.

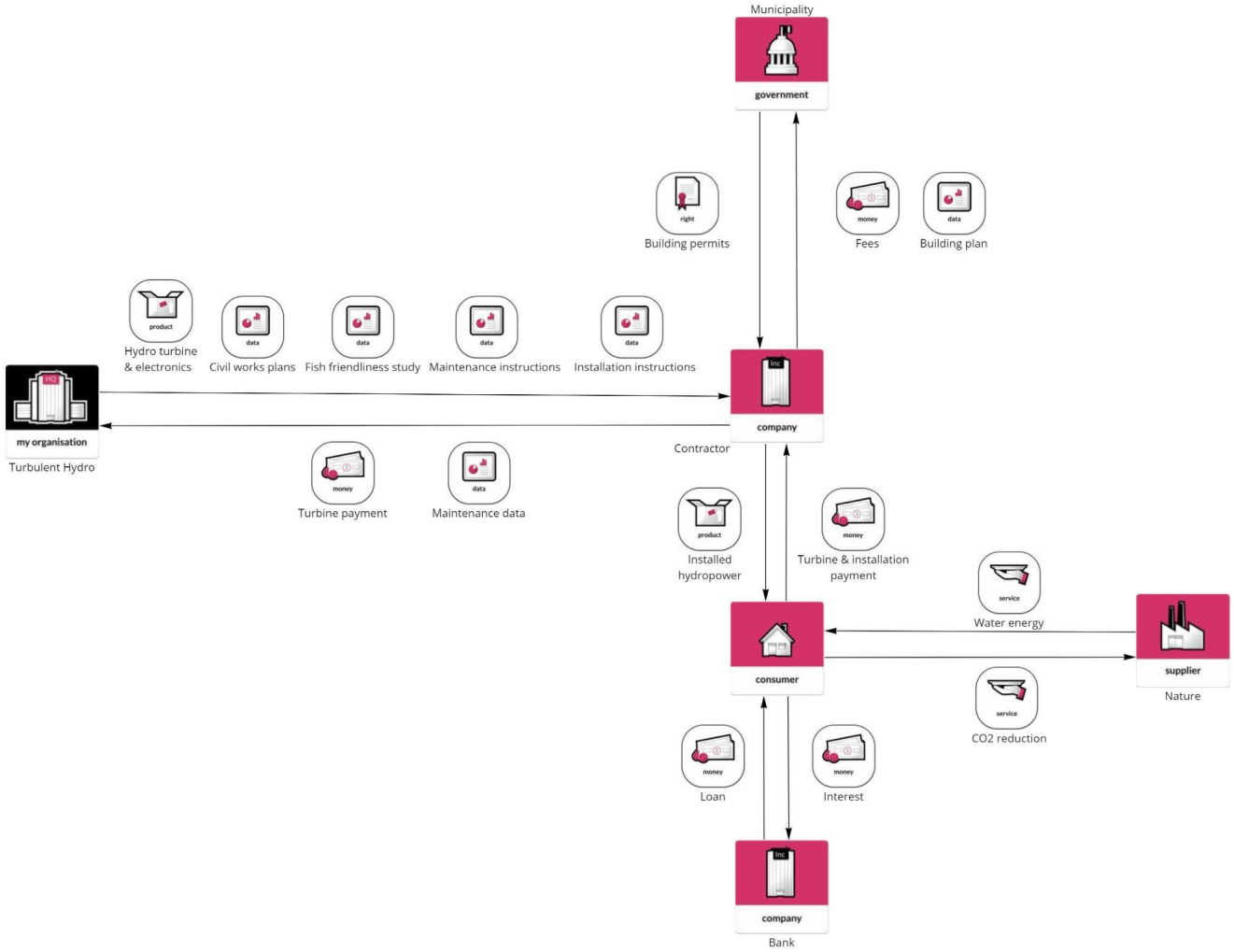
Please look at appendix B for the full stakeholder value map. The full resolution version can be found here: https://miro.com/app/board/uXjVOGUeWEg=/?share_link_id=799959772039

Single Household
For single household clients (the stakeholder value map can be seen on the next page), we see a relatively simple stakeholder structure. The single household client needs to be in contact with a contractor for doing a feasibility study, requesting permits, getting the turbine installed, etc. The contractor is the one doing the most work. The contractor is in contact with the municipality and other relevant agencies for the building permits, environmental permits, and water use permits. The contractor is also in contact with Turbulent to get the right information and buy the turbine. The contractor installs the turbine and commissions it. The single household client might get a loan to finance the turbine, as it is an investment that earns itself back in a few years. The only two stakeholders that a single household client has to work with are the contractor and the bank, both of which have streamlined processes to help the client in a satisfying way.

Small-to-Medium Enterprise (SME)
An SME has to collaborate with more stakeholders. These include the municipality, water authority, subsidisers, network operators, utility companies, contractors, landowners, and banks. This makes the process more complex. Usually, the network operator needs to make a special connection to allow for the turbine to be installed. Contact with the utility company is straightforward. Finding a contractor to do the installation can be a bit of a challenge, as SMEs usually only take the larger turbines (at least larger than 15 kW), which requires trucks and cranes to get installed. Sometimes, the SME owns the land next to the river, but more often this needs to be bought or rented from an external land owner. A bank is also usually involved. Installing a turbine using borrowed money usually decreases the amount a company can borrow for other projects, which can be a disadvantage for SMEs. There are many different stakeholders all with their own interests, making installing a turbine complex for an SME. Therefore, some SMEs prefer having the project developed by a project developer.

Stakeholder Value Map

Single Household

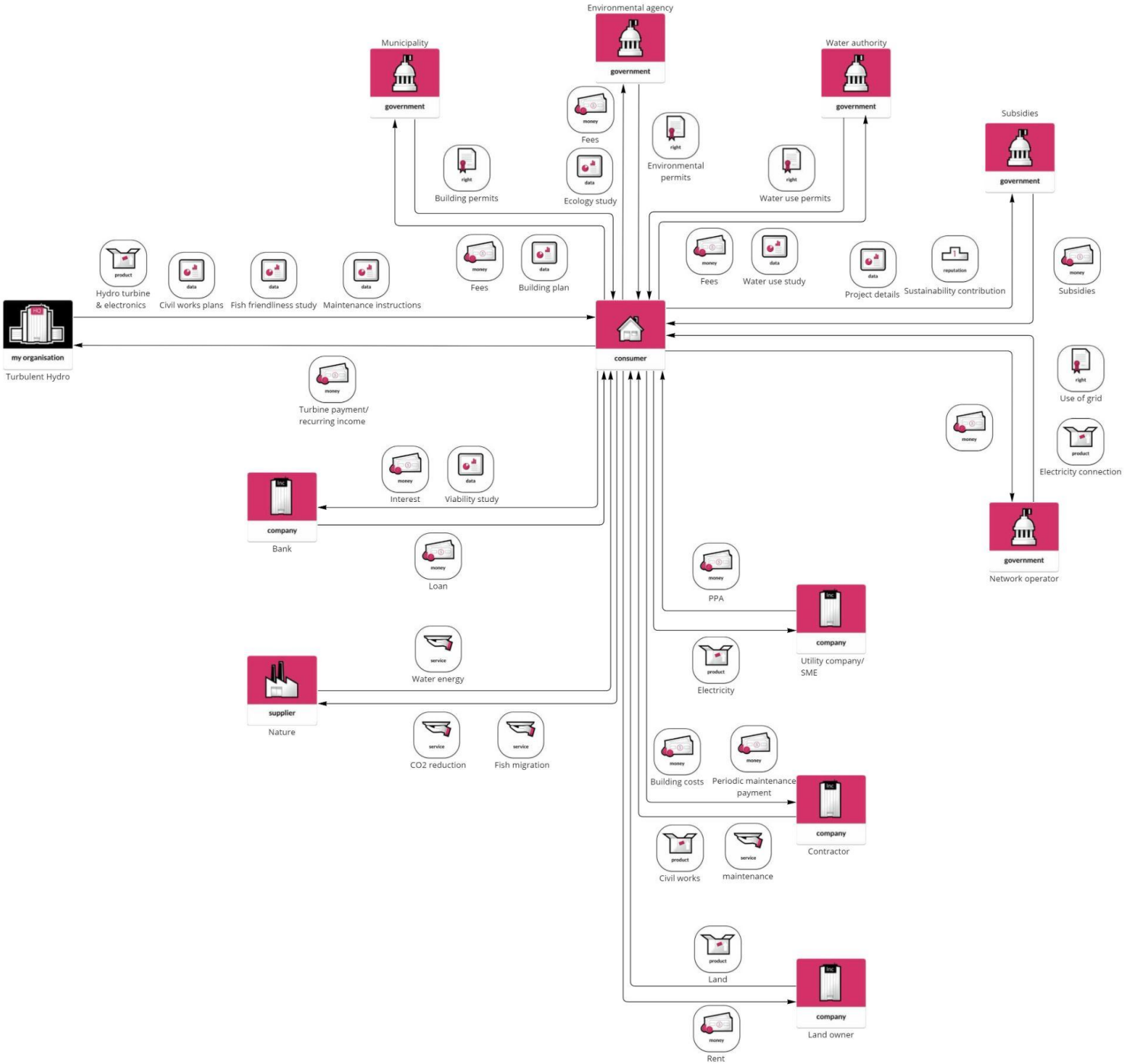


Stakeholder Value Map

Project Developer
A project developer usually creates a working turbine system for an SME. Only when the system is up and running, it is sold to the SME. The stakeholders are very similar to the ones an SME would have to work with if they did the project themselves. A project developer does usually have more credibility in developing hydropower towards a bank or investor, as they do more of these projects. The loan or investment would also be paid back within a short amount of time (usually 1 or 2 years) as the project then gets sold. This allows the project developer to borrow money at a lower interest rate than an SME would get for the same project. An SME does have to pay the project developer a development fee, but as the project risk is in the hands of the project developer, the project is developed using a lower interest rate, and the work of developing the projects is outsourced, it is usually worth the development fee.

Independent Power Producer (IPP)
IPPs (the stakeholder value map can be seen on the next page) create a project, usually with borrowed money and sell electricity over a long period of time to pay back their loan and make a profit. They usually sell their electricity through a power purchase agreement (PPA) to either a utility company or an SME. These PPAs, including a set price of electricity, last for years (e.g. 15 years) and are often required by the bank, as they de-risk the investment. For an SME or utility company, these PPAs are interesting because they know exactly what price they will pay for their electricity and they know that it was generated in a renewable way. IPPs are usually experienced with installing hydropower. They know the local regulations and know the right people to get their project to succeed. Right now we see IPPs that want to do a first pilot project to see exactly how it works. If it is successful, they often have more sites in mind to develop. IPPs think in the long term and usually have a good line of credit. This makes them interesting partners to work with. Their business model is usually sound and they can get enough capital to pay for the Turbulent technology and services.

IPP/Partner


Environmental agency
government
Municipality
government
Water authority
government
Subsidies
government
Fees
Environmental permits
Building permits
Ecology study
Water use permits
Hydro turbine & electronics
Civil works plans
Fish friendliness study
Maintenance instructions
Fees
Building plan
Fees
Water use study
Project details
Sustainability contribution
Subsidies
my organisation
Turbulent Hydro
consumer
Use of grid
Turbine payment/ recurring income
Electricity connection
Interest
Viability study
company
Bank
Loan
government
Network operator
PPA
company
Utility company/ SME
Water energy
Electricity
supplier
Nature
CO2 reduction
Fish migration
Building costs
Periodic maintenance payment
company
Contractor
Civil works
maintenance
Land
company
Land owner
Rent

Stakeholder Value Map

Systematic IPP

With a systematic IPP, multiple turbines are installed along a river or in a certain region. This has big advantages for the economies of scale. The project is usually large enough to involve a consultant. This consultant usually takes care of the contact with authorities. For example, getting the building permits, proving the ecological value, getting the water use rights, and getting subsidies. The IPP is usually responsible for the business side of the project. This means negotiating with the utility company or big enterprise to get a PPA, negotiating with a contractor, negotiating with land owners, and negotiating with banks or investors. The IPP is also in direct contact with Turbulent. These projects sometimes get large enough for local manufacturing to make sense. Especially when the region has lower wages than Belgium, which is the case in many parts of the world (International Labour Organization [ILO], 2022). Local manufacturing then makes for cheaper production costs and it creates local skills and knowledge around the turbines, making repair easier. Sometimes, hydropower sites are granted to IPPs in tenders by governments. Local manufacturing often gives IPPs a better chance of winning a tender. It also prevents having to pay import taxes, which can be significant. Shipping the plans instead of the goods also abolishes transport costs and saves CO2 emissions. Local manufacturing can be very interesting in larger projects.

Government

It depends on the country whether electricity production is a responsibility of the government or of the private sector. Usually, it is a mix of the two. When a government is doing a hydropower project, this makes things much easier. The permitting process still has to take place, but the right people are within the government. Usually, there is a cooperative spirit between different levels of government, making the permitting process more fluent. Funding is also usually not an issue, as states have huge budgets and want to create clean renewable energy for their citizens. Sometimes the utility company is also owned by the government, again making contacts more fluent. If the utility company is private, a collaboration with the government is usually interesting as this is a trustable partner. At this moment we see some interest from governments in Turbulent technology, but it is limited to pilot projects. This is understandable, as the technology is relatively new and needs to prove itself in the long term. Governments can be very interesting partners in the future.

Stakeholder Value Map

Turbulent Development
Turbulent Development does not exist at this time and there are no concrete plans to create it in the near future. However, it is interesting to look into it. Turbulent can manufacture turbines at a low price point and thus offer electricity at low rates. Turbulent can also see in which markets clients are successful, to also enter those markets. This might on the other hand lead to a feeling of competition against Turbulent among clients. This can decrease the goodwill towards Turbulent. It would bring in money in a passive way, allowing Turbulent to innovate more.

Turbulent Development (large scale)
This would bring similar benefits as for a systematic IPP. A consultant for government contacts and local manufacturing would be possible. Turbulent might outcompete its clients, but create a large passive revenue stream for itself.

Conclusion
Developing small-scale hydropower is complex and involves many stakeholders. There are many types of clients that Turbulent can serve, with different needs. Given the complexity of their stakeholder networks, which are the most interesting clients to work with?

2.2 Who to work with?

Single Households in many countries get the advantage of being able to do net-metering. This means that they can sell their electricity to the grid at the same retail price that they buy it for. If net-metering is not available, the feed-in tariffs are usually favourable, to support single households to produce their own electricity. Single households get a high price for their electricity, in Europe usually somewhere around €0.25/kWh (Eurostat, 2022). At the same time, their investment costs are also relatively high, as the capacity they install is limited. This leads to low economies of scale. The cost per installed kW can be around €6000/kW. This could be improved in the future, as the number of turbines sold would increase. On the other hand, the permitting process is simpler and less costly than that of bigger turbines. Single household turbines are often installed in smaller streams, with no fish in them and of little ecological value. This makes getting permits easier. Some even opt for not getting permits, as the stream runs on their own land and has little ecological value. This is not the official way, but rarely prosecuted.

SMEs quite often have a significant power use. It makes sense for them to generate part of their electricity themselves, especially when they are situated next to a flowing river. Net-metering is almost never possible for them. They buy their electricity at prices that are slightly lower than retail prices, however, their feed-in tariffs are at wholesale level (usually €0.06/kWh). They usually need turbines that need an extensive permitting process. This can take up to a year. However, they are on the low end of power production, which makes the costs per installed kW relatively high. Experience from Turbulent states that these projects often do not work, as the ROI for SMEs is usually relatively low and they prefer to invest their money in their core activities which they understand and have higher ROI.

Who to work with?

Project Developers are usually aware of the regulations in their local area and have experience with installing other projects and sometimes with hydropower. They want to develop a project for a specific client and sell the finished project to that client. They know how the permitting process works and look strategically for good sites in connection with companies or organisations that have a high energy need. This increases the ROI of these projects. However, these projects still have many of the problems that the projects with SMEs have, because SMEs are usually the clients of the project developers. Usually, the SMEs are large enough to get relatively inexpensive electricity from the grid. Their electricity use is however not large enough to justify a large turbine. Thus, similar permitting processes and civil works have to be undertaken as with bigger turbines. However, the power production is relatively low (e.g. 15 kW), resulting in a relatively high price per installed kW. This can be around €4500/kW. SMEs do generally not want to do a large upfront investment if the ROI is low. Projects developed by project developers usually do not work, as the proposed clients have better ways to invest their money.

Independent Power Producers (IPPs) develop a project using investment mostly from banks, private investors, or own capital. They have experience with installing hydropower. They stay the owner of the project when it is finished. They earn their ROI by selling electricity to the grid through an electricity company or to a company or organisation through a power purchase agreement (PPA). This can be either an on-site PPA where IPP sells directly to a company next to the turbine or through a virtual PPA where the IPP sells the rights to that renewable electricity to a company that is not near the turbine (see figure 3). PPAs with multiple SMEs can be made. For the SME a PPA has the benefit of predictable, clean, and affordable energy, while not having to do an upfront investment. IPPs look for perfect sites for developing large-scale turbines. These do have the economies of scale in their favour, resulting in low costs per kW. €3000/kW is achievable (Turbulent, 2022). These projects can usually apply for government subsidies to support the development of renewable energy. These come either in the form of grants, but more commonly as an increase in the price of electricity. For example, when the wholesale price of electricity is €0.06/kWh, subsidies will add €0.04/kWh, so that the price received by the IPP is €0.10/kWh. This makes for a profitable business case, which leads to a relatively high ratio of these projects becoming a success.

Who to work with?

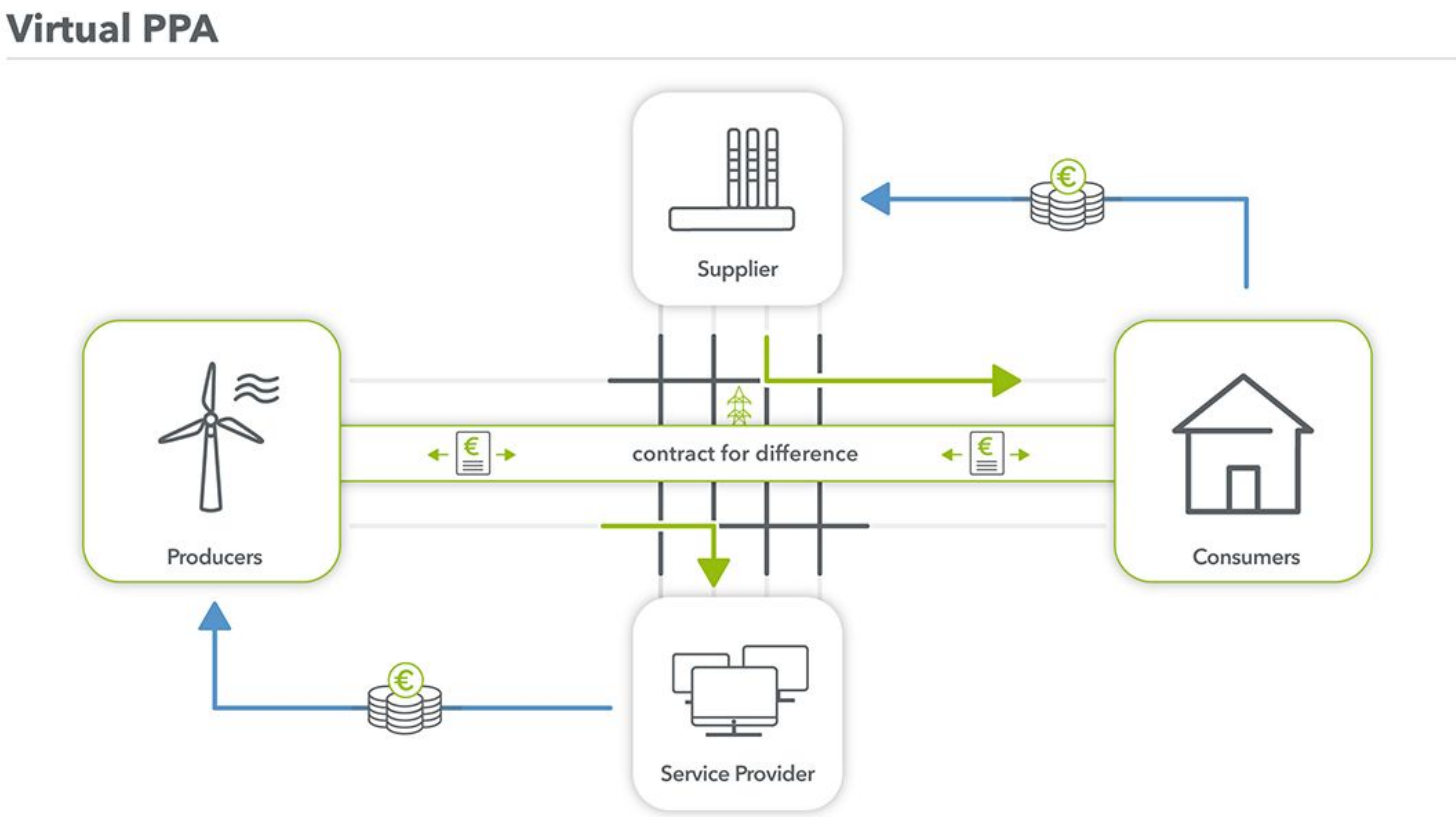


Figure 3: Virtual PPA (Next Kraftwerke, 2020)

Who to work with?

IPP systematic is the most profitable way of installing Turbulent turbines. It has the same characteristics as the process of installing turbines for IPPs, but on a larger scale. It has better economies of scale, allowing for multiple permit applications in one go, large-scale PPAs, good contracts with installers, etc. These projects therefore have a high ROI.

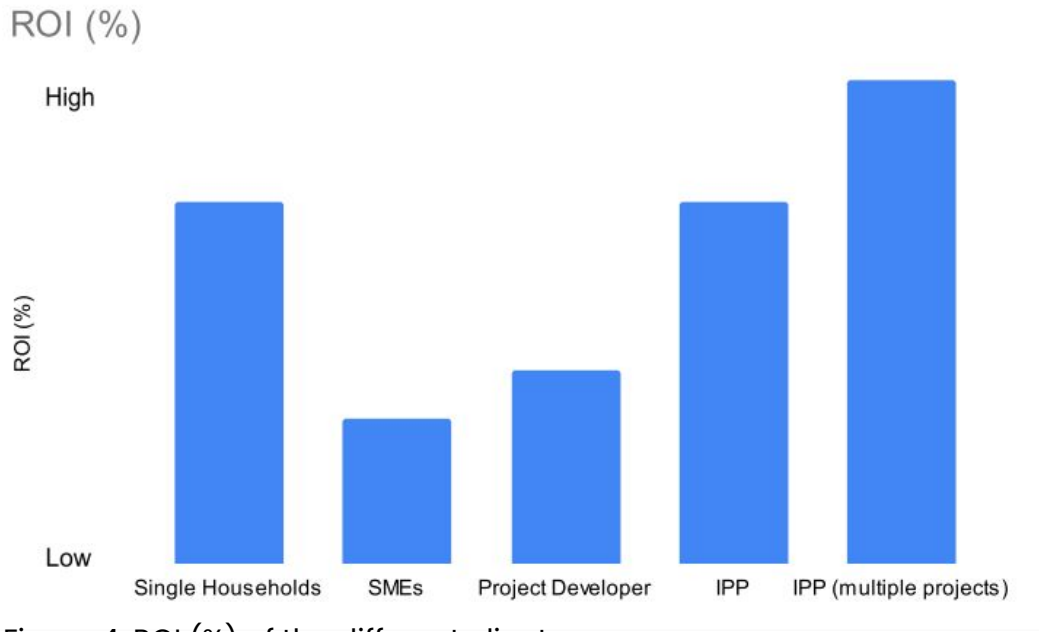


Figure 4: ROI (%) of the different client groups

Conclusion

Interesting clients to work with are single households, IPPs and systematic IPPs. These have good ROIs as displayed in figure 4. Of IPPs and systematic IPPs it is validated that the projects are often successful. The single household market needs are not explored yet and need validation.

2.3 SWOT Analysis

To find opportunities to design for and to get a better understanding of the company, a SWOT analysis of Turbulent was performed.

SWOT Turbulent

1 Strengths

- Applicable in many places
- Needs little civil works
- Strong social media presence
- Fish friendliness
- Cost efficient
- Low maintenance
- Consistent power production

4 Threats

- Kaplan turbines
- Cheap solar/wind energy
- Natural disaster (Mud streams, drought, flooding)
- Copycats

2 Weaknesses

- Permitting often difficult
- Sites often in difficult to reach areas
- High up-front costs
- Young company (possible lack of trust)
- Site specific engineering

3 Opportunities

- Energy Independence
- Rising energy prices
- Move towards sustainable energy (subsidies)
- Standardisation

SWOT Analysis

Strengths

Applicable in many places: The Turbulent technology is relatively compact in size and needs little height difference to work efficiently (at least 1 meter). This makes it usable in many situations. Classic hydropower usually needs big height differences, only found in mountainous terrain. Mountainous terrain is limited to a few places on earth and many of those places are already developed (Moran et al., 2018). These are usually not the places that have a high population density or electricity need, which means spending lots of money and resources on building the infrastructure to get the electricity to where it is needed. With Turbulent technology, electricity can be generated in places that are close to population centres. Only slight height differences are needed, which are commonly found throughout the world.

Needs little civil works: The civil works are simple and straightforward. No dam is required to make the technology work, which significantly decreases the amount of civil work needed. This decreases the project costs and shortens the timeline, increasing the ROI.

Strong social media presence following
Turbulent has a strong presence on social media. Mainly on Youtube through engaging videos. Their 3 best watched video have over 3 million views each, with the most popular one reaching almost 7 million views (June 2022). Through reposting by the World Economic Forum, many more people get to see the Turbulent technology. Turbulent is capable of reaching vast amounts of people through social media.

SWOT Analysis

Fish friendliness
The turbines rotate at a slow speed, which is only slightly lower than that of the water. Thus, any impact with fish will be light, making the turbine very fish-friendly. Fish can swim right through (Turbulent, 2022). Because the turbine does not need a dam, fish can swim up the river unhindered. A dam can be used, but then needs to be complemented with a fish ladder to allow fish to swim up the river. Turbulents' fish-friendly design is unique compared to existing hydropower technologies. This makes getting approval for a project from an environmental agency easier (Scottish Environment Protection Agency, 2015; Wallonie Service Public, 2020).

Cost-efficient
Since the technology is relatively simple, production is inexpensive. Combined with the vast amount of energy that is present in water, the cost per kWh is just somewhere around €0.05/kWh, which is similar to solar energy (Lazard, 2020). This makes Turbulent technology an interesting investment.

Low maintenance
The rotation speed is low which leads to low wear and tear. This results in relatively little maintenance. Once a year, an oil change is needed and in autumn the trash rack will need to be cleaned of twigs and leaves. Generally, keeping the turbine running does not involve much. This makes the maintenance costs low, leading to a good ROI.

Consistent power production
Compared to other renewable energy production methods, hydropower has a very consistent power production. Solar or wind only work when the sun is shining, or the wind is blowing. Rivers also have a regime, but this changes slowly over time and is predictable. Hydropower gives a very good and affordable baseload power (Wasti et al., 2022; Matek & Gawell, 2015).

SWOT Analysis

Weaknesses

Permitting is often difficult
Due to the newness of the technology, most institutions giving permits are somewhat reluctant in allowing the technology to be implemented. This is often observed when new technology is introduced (Wiener, 2004; Ranchordas, 2014). Legislators often first need to see a pilot project in their country to make sure it complies with the regulations of that country. Legislation for hydropower is often made for large-scale hydropower with large dams and a big impact on the environment. This does sometimes lead to overregulation for small hydropower plants, like the ones from Turbulent.

Sites are often in difficult to reach areas
Potential sites can be in areas that are surrounded by forest or carved into a steep valley, making them difficult to reach.

High up-front costs
Before electricity can be produced, many costly things have to be done. The permits need to be granted, the turbine has to be bought, the civil works have to be done, etc. Thus, the up-front costs are high, usually somewhere around €3000-€5000 per installed kW, which translates to €150,000 to €250,000 for a 50 kW turbine. This means that there is a significant risk involved for the investor when installing a turbine, limiting the number of low capital investors.

SWOT Analysis

Young company
Turbulent started out in 2015 and has grown considerably. However, it is still a small company with a new technology that is relatively unproven. Thus, project developers and their stakeholders (e.g. banks or private investors) need to really believe in this technology to invest in it. There is a risk associated with investing in Turbulent technology. Banks are less likely to give loans to SMEs that use innovative technologies (Freel, 2006; van der Zwan, 2014).

Site-specific engineering
Right now, a specific design is made for each site. This increases the engineering costs and lengthens the process of delivering the turbine to the client.

SWOT Analysis

Opportunities

Energy independence
Energy is in high demand at the moment. Energy in Europe is often transported from countries that European countries are not in good relations with or often disagree with (e.g. Russia or Saudi Arabia). It gives those countries power over European countries as they are dependent on their energy (Siddi, 2018). Thus, there is an increasing interest in becoming energy independent as a country or as a continent (European Commision, 2022; Dansk Institut for Internationale Studier, 2022; FTAdviser, 2022). Turbulent can help with extracting energy from flowing water.

Rising energy prices
Energy prices have risen significantly in the last few years (Eurostat, 2022), which leads to a high ROI on Turbulent turbines. The Levelised Cost of Electricity (LCOE) of Turbulent turbines is somewhere around €0.05/kWh (Turbulent, 2022), which is cheaper than electricity from coal or gas. It is similar in LCOE to electricity from solar (Lazard, 2020) and is among the cheapest available energy production methods. The rising energy prices, thus result in rising interest in cheap and sustainable energy production methods, such as that from Turbulent.

Move towards sustainable energy (subsidies)
To combat climate change, there is a worldwide move towards renewables going on (International Energy Agency [IEA], 2021). This is successfully accelerated by subsidies given by governments (Nicolini & Tavoni, 2017). The Turbulent technology does sometimes qualify for these subsidies. However, the subsidies are often aimed at a certain technology, usually solar. There is an opportunity for Turbulent to prove to governments that their technology is at least as good as solar and in some cases even better suited to battle climate changes effectively.

SWOT Analysis

Standardisation

Right now, every turbine is custom-made, which adds to the project costs, decreasing the ROI for the investor and lengthening the project. As a result, investors will be less likely to come back to do another project. At the same time, Turbulent can only do a few projects at once, limiting the growth of the company. Thus, standardisation of the turbines and basins is needed. This will decrease the electric efficiency slightly, but increase the ROI. Standardisation is an excellent way of improving the cost effectiveness, but it may limit the pace of innovation due to the costs of setting up a new production line (Tassey, 2000).

SWOT Analysis

Threats

Kaplan Turbines
Kaplan turbines are another form of hydropower, which operates in a similar head and flow range as Turbulent turbines. These are often also considered by people that want to install a Turbulent turbine. Kaplan turbines are built more with efficiency in mind, while Turbulent turbines are more fish friendly and resilient. Kaplan turbines are a fully developed technology (Polák, 2021), which makes them a serious competitor for Turbulent. Kaplan turbines are however better suited for higher head applications.

Cheap solar/wind energy
Wind and especially solar have seen an incredible drop in LCOE over the past decades. Wind and solar energy are now usually cheaper than energy from fossil fuels (Lazard, 2020). Turbulent hydropower has a similar LCOE as wind and solar. As Turbulent is a relatively new entrant to the energy market, the secure route to invest money into renewable energy is through proven wind or solar. This makes competing against wind and solar challenging. Turbulent hydropower does however have the major advantage that it is consistent in energy output, something that is not the case for wind and solar (Watson, 2019; Woyte et al. 2007).

Natural disaster
The number of natural disasters such as mud streams, droughts or floods will increase as a result of the more extreme weather we get due to climate change (Hallegatte, 2014; Banholzer, 2014). Turbulent turbines will usually be placed right next to a river, where the risk of these is the highest. Mud streams and floods can be designed for, but there remains a risk of a turbine being destroyed by a large mud stream or flooding. Droughts will also likely increase in the future (Hallegatte, 2014), resulting in lower energy production.

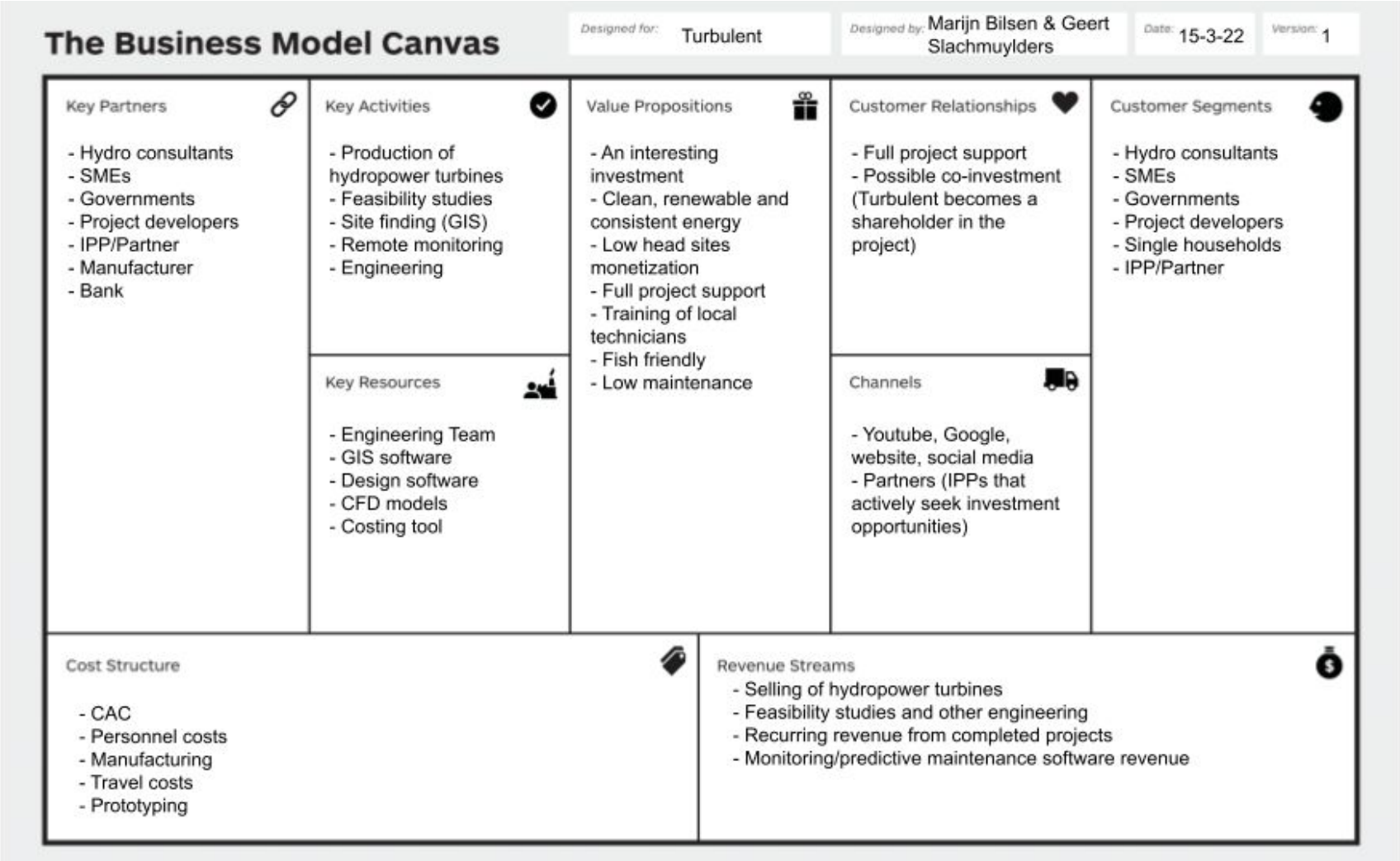
SWOT Analysis

Copycats
Right now people are imitating the vortex technology that Turbulent uses to build just one turbine for themselves. This poses no real threat to Turbulent. However, in the future, companies might start to imitate the technology. Given that they would not have to do much R&D they will probably be able to offer the technology at a lower price point than Turbulent does currently. At the same time, this can be an opportunity for Turbulent to keep on innovating.

SWOT Conclusion
The strengths and opportunities of Turbulent match well. Turbulent can offer a solution that is applicable in many places, needs little civil works, is cost-efficient and low maintenance, which is perfect to combat rising energy prices and to move towards renewables. The threats are significant, but can be designed for by the Turbulent team. The weakness of needing site specific engineering can be overcome by introducing the opportunity of standardisation. The weakness of being a young company with a low trustability record, also offers an opportunity to be innovative and iterate quickly on designs.

2.4 Business Model Canvas

This is a general business model canvas of Turbulent. It was made to get an overview of the current status of Turbulent and to find opportunities to develop for.



Business Model Canvas

In the business model canvas, we see that many stakeholders want to collaborate with Turbulent (as can be seen in the stakeholder value map in chapter 2.1). This makes the business complex. Turbulent is mainly an engineering firm. Usually, a turbine is custom designed to the specific situation (head, flow, amount of debris in the river, fish friendliness regulations, etc.) of the client. The company is also still improving the design of the turbine and system around it. Thus, at this time, there is very little standardisation. This however increases the costs of engineering for a project significantly, which decreases the competitiveness of Turbulent compared to other forms of renewable energy. Standardisation is an expensive undertaking, as the turbines have to be designed, without a client directly paying for the engineering work that needs to be done. This is the main reason why it has not been done yet. However, for the scaling of Turbulent, it is important that the engineers can do more projects in a year and have to work less on making a custom design every time. This can be reached through standardisation.

The manufacturing is outsourced and usually only final assembly and testing are done in-house. The manufacturing of the blades is for example outsourced to a Belgian metal works company. This makes sense for the moment, as the turbine designs are not yet standardised and the scale of production is still too low to set up in-house manufacturing. Currently, Eastern European countries are considered for manufacturing, as the wages and therefore the production costs are lower there.

An interesting new development could be for Turbulent to co-invest in the projects they do to get a long term return on investment on their work. At the same time, all the work on getting permits and making the business agreements with local companies are done by the partner. Turbulent could for example supply their technology in return for a percentage of the profits brought in by the project. To engineer the project and build the turbines, Turbulent could get a loan from a bank that they pay off using the profits from the electricity generated. The technology could also be sold at cost price, where the profit margin is gotten through a share in the profits from the electricity sold. This could be interesting for an IPP, as it lowers the initial investment and onboards the producer of the technology who has all the expertise needed to repair something if it were to break. For Turbulent, it means that a steady stream of income is generated and over the years, more is earned than when the technology would just be sold. The payback time of a project is usually around 4-8 years, However, a project can bring in profits for far longer (30-50 years). When Turbulent gets a share of the profits of a project, instead of selling the technology, the profit is much higher, but spread over many years.

3. User Interviewing

User Interviewing

From the thinking that our clients' problems are our problems, 16 interviews with current and future clients were performed. First, 3 current B2B clients were interviewed through video calls. They are located in Taiwan, the United States, and the Philippines. These are all IPPs and they are all in the process of installing several bigger turbines. 13 potential single household clients were interviewed to test the needs in the single household market. These interviews took place both through video calls and phone calls. The potential clients were mainly located in Europe as this would be the first market that a single household solution would be rolled out for. Their locations are: France 5, Belgium 2, United States 2, Saint Kitts and Nevis 1, Slovakia 1, Sweden 1, United Kingdom 1. The potential single household clients were people that responded to a form for single household turbines on the website of Turbulent. 4 of them were interviewed through a video meeting (usually lasting around 20 minutes), 8 were interviewed through a phone call (usually lasting around 15 minutes).

3.1 User Interviewing - IPPs

Main insights partners (n=3)

For the full interviews, please look at appendix C. These are the main insights:

Learn partners how to do a feasibility study (frequency 3)
When a partner finds a potential site to develop hydropower, they want to know soon whether that site is suitable. Right now, this feasibility study is done by Turbulent using a combination of satellite data, data from a drone, on site measurements, and flow data of the river. This usually takes some time and is out of the control of the partner. The Turbulent team is usually busy with working on several projects. Doing these feasibility studies takes some of their precious time. It does on the other hand generate an income stream. However, it would be good for the partnership and the fluency of the project to learn partners or the contractors of partners to do a feasibility study themselves.

Do co-marketing and branding (frequency 1)
Partners often notice that there is a bit of reluctance from banks or permitters towards the new Turbulent technology. Partners are usually the ones making banks or permitters aware of this new technology. The Turbulent technology is still relatively unknown, as is small-scale run of the river hydropower. Thus, it takes a lot of convincing before a bank will give a loan or a permitter will give a permit. Doing more co-marketing and branding of Turbulent in the local setting of a partner could help with getting the technology more generally accepted. This could include for example brochures in the local language, presence at local renewable energy fairs, or videos in the local language.

User Interviewing - IPPs

Local manufacturing (frequency 2)
Local manufacturing makes many things easier. It usually cuts the production costs, as the wages are most often lower than in Belgium and the scale at which turbines are made offers only minor economies of scale advantages. It also diminishes transport costs significantly as less distance has to be travelled. The turbines are large and heavy objects and as they are round, they are often shipped with a lot of air in their boxes. This makes for relatively high transport costs. Besides, it makes applying to local building codes easier, as the companies making the turbines are usually familiar with that local code. It also abolishes import taxes, as usually only goods are taxed, not the plans behind them. Furthermore, it makes winning tenders simpler. In some countries, potential hydropower sites are tendered by governments. Points can be won for using technology that was made in that country. All in all, local manufacturing has many benefits. It however only becomes viable when multiple turbines are made. Otherwise, it is not worth going through the process of finding a local manufacturer.

Co-invest (frequency 2)
Another part where points can be won in a government tender is if there is foreign investment involved. Co-investing also makes the process of installing a turbine easier for partners as they have to do less convincing of local players in the technology. If Turbulent enters into a good relationship with a (Belgian) bank, private investor, or investment fund, they can show that their technology works well and is viable. If they have won the trust of the bank/investor, they could use that money to invest in many of their own projects. They would not have to convince the bank/investor that this is a viable investment everytime a new turbine is made. For partners, it would be very useful to have a bank/investor that comes through Turbulent invest in a turbine, as it adds legitimacy and trust to the viability of the project. It is also an opportunity for Turbulent to get a long term return on investment on the projects they do, adding to the financial resilience of Turbulent.

User Interviewing - IPPs

Databases of river flows (frequency 1)
Partners are often able to find rivers that have a good flow at the time they measure it. However, they often have to guess how the river behaves at other times of the year. Sometimes a dataset from a nearby measuring station can be obtained. However, this data is often difficult to find and more often, no nearby measuring station is available. Turbulent could develop a tool that looks at the effects of precipitation and melting ice (can be obtained from satellite data) in the catchment area of a river, to predict what the flow regime of a river will be throughout the year. This gives partners a better insight into their potential ROI.

Offer exclusivity (frequency 1)
This is something partners are often interested in. They want to become the sole dealer for Turbulent technology in their region. However, this exclusivity should be rejected, as there is a risk the partner turns out not to be a good partner. It is then the only partner Turbulent can do business with, spoiling the business opportunities in that region. It would also limit competition. Competition is usually a good thing as it pushes partners to do their work to a good standard and at a good price. Therefore, exclusivity should not be offered to partners.

Certification (frequency 1)
Right now, the turbines and their electronics are made to European standards. Standards are different around the world. In the United States for example, the voltage and frequency of the grid are different. This means the technology needs to be certified (in this case by the Department of Energy) to be allowed. Turbulent should arrange this certification, to open up new markets.

User Interviewing - IPPs

Use of GIS tool (frequency 2)
Turbulent has developed a Geographic Information System (GIS) tool to find potential hydropower sites using satellite data. This tool is not very user friendly at this moment and is used internally for feasibility studies. However, it could be very useful for partners to use (a more user friendly version of) this tool to find good hydropower sites.

Viability study (frequency 1)
If the data from the GIS tool about the head, flow, and flow regime of a site is combined with what turbine would make most sense at that location, a preliminary estimate of the viability of a site could be given. This could come in the form of a rough estimate of the ROI or payback time. This makes comparing sites easier for partners.

Share experience from other partners (frequency 1)
Partners are usually the first in their area to start developing hydropower using the Turbulent technology. They often make similar mistakes. Thus, it could be useful for them to share insights. This could go through Turbulent, by sharing lessons learned from other partners with new partners. It could also be through a Turbulent forum that partners can access to share their experiences.

Conclusion
These are interesting insights that are used to make a strategic roadmap for IPPs found in chapter 4.1

3.2 User Interviewing - Single Household clients

Main insights interviews potential single household clients (n=13)

For the full interviews, please look at appendix C.

Reasons for choosing hydro

- Save on electricity bill (frequency 10)
- Be more sustainable (frequency 8)
- Be more independent of energy from unfriendly countries (e.g. Russia) (frequency 3)
- Be more independent of the local energy grid (frequency 3)
- Use that river that has always been there, of which the energy now goes to waste (frequency 4)
- Because it is better recyclable than solar (frequency 1)

Permits

- Water rights are sometimes in place already from an old water mill
- Ecology study by Turbulent is of high importance
- Most prefer to pay a consultant (can be the same as the contractor) to request the permits for them. (€500 seems reasonable for this) (frequency 9)
- Contractor estimate: requesting permits takes one day and costs around 400 UK pounds
- Permits in France are difficult to get, but there are a lot of existing water rights for old watermills, usually from Napoleonic times or before
- The permitting process in Scotland through the Scottish Environment Protection Agency seems reasonable straightforward
- Some potential clients do not want to request permits, just drop in the turbine and go (frequency 3)

User Interviewing - Single Household clients

Use Case

- Usually on-grid (roughly 70%), some off-grid (roughly 30%)
- Single Households usually just want to power their house (frequency 9)
- Some want to sell to the grid (frequency 4)

Installation

- Most prefer to have the turbine installed by a local contractor and are willing to pay for this (€1500 seems reasonable) (frequency 9)
- Some want to get the installation done by a contractor, to make sure the insurance will cover any potential damages (frequency 1)

Product features

- Basin made of plastic, steel or brick would make sense
- In monumental buildings, brick is usually preferred
- Automatic cleaning as an option
- For older buildings 3-4 kW versions are needed
- The product should be as much plug and play as possible

Maintenance

- Cleaning of leaves would be done by the owners themselves
- Maintenance preferably by the contractor that installed the turbine

User Interviewing - Single Household clients

Technical Support

- Maintenance would preferably come from a local contractor
- Technical support, if a contractor can not fix a problem, would have to come from Turbulent

Business Model

- Pay as you produce could be an interesting option for some single households
- Clients specifically want the Turbulent turbine, not a resold alternative from a competitor, mainly due to better fish friendliness and lower maintenance (6 out of 6)

Clients

- Most potential clients that reached out to Turbulent have some idea of how the technology works. This is probably also the group that is more likely to reach out to Turbulent (frequency 8)
- Some potential clients have no idea about how the technology works. They need a lot of steering (frequency 2)
- Some clients for single household turbines speak on behalf of a city or larger organisation/company. A farm for example (frequency 1)
- Some clients for single household turbines are property developers (frequency 1)

Electricity costs

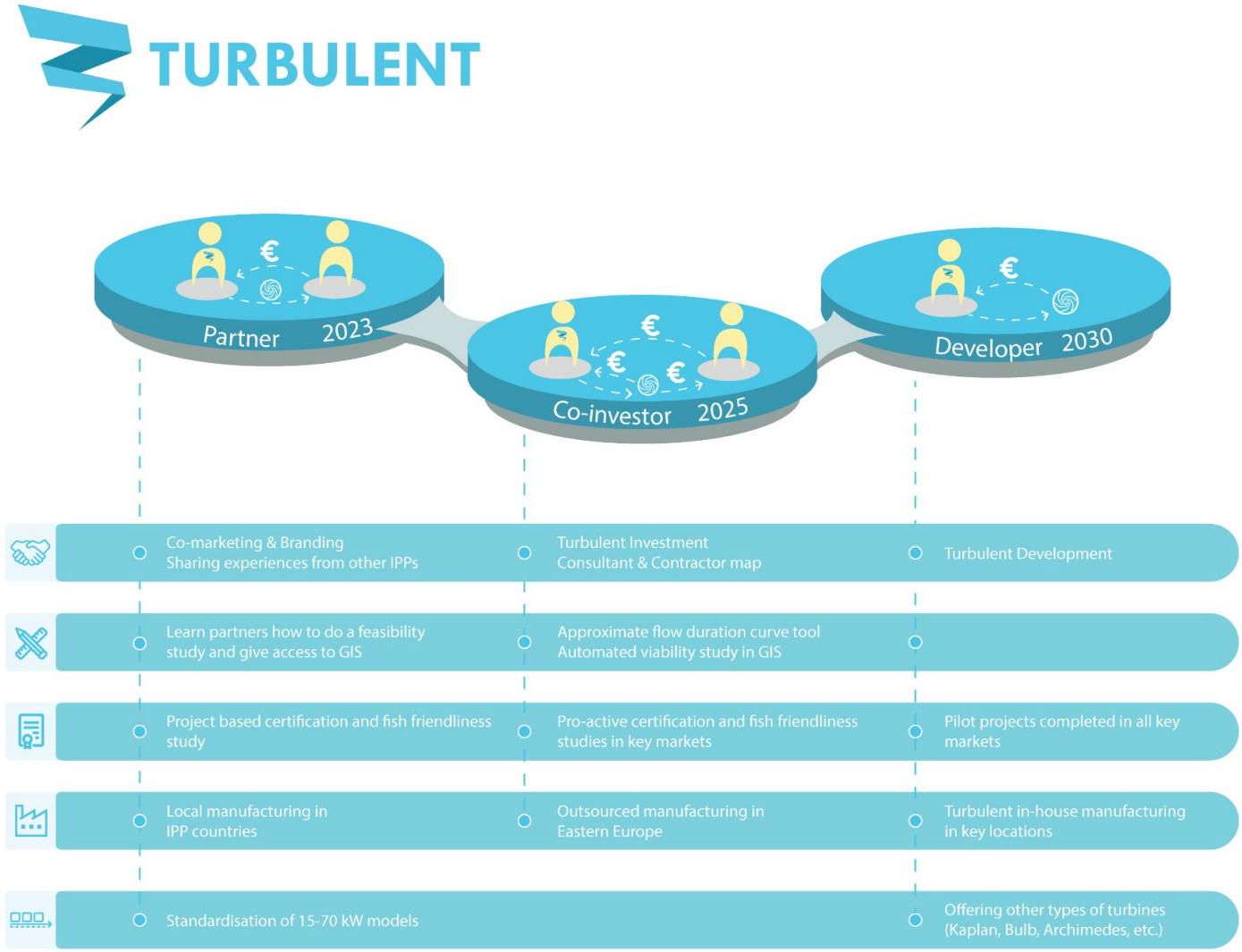
- Electricity costs vary greatly. Usually it is somewhere around €0.20/kWh. The highest electricity cost found is $2.2/kWh on St. Kitts (frequency 1)

The insights from single households are used to develop a new concept to supply them with appropriately sized turbines to power their own houses.

4. Strategy

4.1 IPP Strategic Roadmap

The insights from the interviews with IPPs are used in this roadmap



IPP Strategic Roadmap

Partnerships

Right now, the Turbulent technology is relatively unknown. This poses problems with legislators and investors, as they are reluctant to permit/invest in this new technology they have never heard about. Therefore, there is an opportunity for Turbulent to do co-marketing and branding of their new technology, together with local IPPs. This can be at fairs, innovation events, brochures sent to governmental agencies/investors, etc.

Another opportunity for Turbulent is to share the experiences of IPPs amongst each other. Right now, every IPP is inventing the wheel themselves. This is expected as every country has its own regulations and culture of business. However, some of the experience with getting permits, finding good sites, agreements with power companies, etc. is interchangeable. This could be through a forum, video meetings, or through learnings gathered and communicated by Turbulent in meetings with IPPs.

In the future, it would make sense for Turbulent to share a map or list of contractors and hydro consultants that IPPs have had good experiences with. This makes finding dependable partners easier for IPPs. It also creates an incentive for these contractors and consultants to deliver high quality work.

Turbulent could make the partnership with IPPs even more close, by co-investing in their projects. This gives IPPs more trust in Turbulent, as Turbulent is willing to put its own money in a project. It gives Turbulent a long lasting (30+ years) return on investment, which is over time larger than what they would have gotten if they just sold a turbine. This investment could come from a bank, private investor, or a fund.

If the funding is significant enough, Turbulent could start a new company (Turbulent Development) to start developing its own projects. These projects could be financed by a renewable energy impact fund. Funding could also come from crowdfunding, on a project basis.

IPP Strategic Roadmap

Feasibility and Viability studies

Before an installation is built, the feasibility and viability have to be assessed. Right now, feasibility studies are carried out by Turbulent, which takes some time and this is often named by IPPs as a factor that is limiting their speed of development. They want to do the feasibility studies themselves. It is in the best interest of Turbulent to help their partners speed up their process, so they can pick the most suitable sites and develop profitable hydropower. Thus, partners should be taught how to do feasibility studies themselves. The GIS software developed by Turbulent can also be very useful in finding new sites. This software finds sites that have a large enough drop using satellite data and combines that with known flow duration curves of a certain river. With that information the potential power installed can be estimated for a site. In the future, the cost of installing a turbine on a specific site could be calculated, using a combination of parameters. Examples of parameters to include are: length of the side channel, soil type, digging costs, labour costs, permitting costs, etc. An estimate of a project cost can be given, which can be used to calculate the ROI. This makes assessing the viability of a project more fluent.

In some cases, a flow duration curve is not available, as there is no measuring station on the river. Software can be developed to estimate the flow duration curve using meteorological data from the catchment area of a river. This can help with assessing the feasibility and viability of sites that are on rivers that do not have a measuring station.

Certification

Right now, certification for the electronics and fish friendliness is done for a single project and is partly paid for by the client. This lowers the viability of the project and takes quite some time. When a standardised design is available, it would make more sense to do the certification in key markets proactively. The certification is then paid for by Turbulent, who can spread these costs in a fair way among their clients. To get ecological certification, a real life fish friendliness test is often required. Right now, the fish friendliness is proven using simulations and calculations. Thus, a real life fish friendliness test should be performed in key markets.

IPP Strategic Roadmap

Manufacturing
Right now, the manufacturing is done by a Belgian metal works company and the final assembly is done in-house. As the wages are often lower in countries where IPPs are located and there might be an advantage for winning a hydropower site tender when the turbines are locally made, IPPs sometimes ask for some of the manufacturing to be done locally. As the turbines right now are non-standardised and a manufacturer has to learn how to build a turbine, everytime one is made. It does not matter much where this manufacturer is located and can be in the country of the IPP. Right now, local manufacturing makes sense. However, as the turbine designs become more standardised, it does not make sense anymore to go through the process of finding a new manufacturer and learning them how to build the turbine everytime. Thus, it is better to outsource it to a single party in a low wage country. Eastern Europe seems ideal for this, as the wages are relatively low and cultural and language barriers are also low.
Eventually, bringing the manufacturing back in-house will be the most cost effective. Outsourcing the manufacturing, means that the manufacturer is making a profit. This is worth it as Turbulent does not have to set up manufacturing. However, if the scale of manufacturing becomes large enough, it makes sense for Turbulent to take the manufacturing back in-house. In this way, Turbulent will not have to pay a profit margin to the manufacturer.

Product offering
Right now, the turbines are custom designed for every client. Design improvements are made every time. These engineering costs are charged to the client. It increases the overall project costs and thus decreases the viability for the client and only a few projects can be handled at the same time. Standardisation is needed, to lower the cost for the client and increase the number of projects that can be delivered yearly. Sometimes, IPPs have several sites that can be developed. For some sites with a low head, a Turbulent vortex turbine is well suited. However, if the head is more than 5 metres, other turbines are better suited. For example, a Kaplan or Bulb turbine, or an Archimedes Screw. Right now, these clients have to do business for their low head sites with Turbulent, and for their higher head sites with other parties. It would be most efficient for them to do business with just one party: Turbulent. These other turbine types are relatively well explored and documented. Thus, introducing them to the Turbulent catalogue, will require relatively little R&D.

4.2 Design Focus

Turbulent is focussing its business on clients that buy turbines of between 30 and 70 kW. These can approximately power between 30 and 150 European homes, depending on their electricity use. However, more turbine sizes are possible. Some of them are worth developing, some are not. Here is an overview:

1-5 kW turbines: These are projects that power single homes or farms. Turbulent can not offer a competitive price at the moment, as every project right now is a custom project. These single household clients want Turbulent to install the turbine. This is not worth the effort and not scalable if this is done by Turbulent. However, many leads come for this type of turbine. Turbines from competitors are available for this type of customer, however, they are not found and Turbulent is (due to strong marketing and reach) → set up a separate company that upsells small turbines of competitors in combination with a (paid) course on how to install this kind of turbine. This course can be taken by people that want to install the turbine themselves (DIY) or by contractors that want to offer to install turbines to their clients. Turbulent needs to keep track of the contractors that have completed this course and communicate them as "Turbulent Certified" contractors. Installing by Turbulent Certified contractors should be favoured, as these contractors will not just install 1 turbine, but multiple turbines. Turbulent does not have the time to answer all questions asked by DIYers and this lowers the number of questions asked to Turbulent. In the future, Turbulent may want to develop their own 2-5 kW turbine when the economies of scale are right.

5-30 kW turbines: These are larger projects that need engineering, consultancy, permits, etc. This is a lot of work. However, the amount of electricity produced is still quite low. This makes these projects not so viable. Clients for these types of projects are usually SMEs or small project developers who will sell their project to an SME. For an SME, relatively low viability is a major problem as they can often invest their money in one of their core processes that is much more viable (i.e. a farmer buying new farming equipment). These projects often fail when it becomes clear that the costs are high and the financial gains or not that high. Therefore, Turbulent should for the foreseeable future avoid this market. When the costs of Turbulent projects lower due to scaling, this market range might become interesting again.

Design Focus

30-70 kW turbines: Sweet spot for Turbulent turbines. The financial gains are interesting here and worth the time and effort of going through engineering, consultancy, permits, etc. The technology of Turbulent is better suited for low head 30-70 kW projects than that of competitors. The viability is good, especially when multiple of these projects are installed behind each other. In the future, more standardisation is needed to get the costs of site specific engineering down. This will allow Turbulent to offer a more competitive price to its customers and gain a greater market share, while increasing its profits.

70-200 kW turbines: Competitors have better alternatives for these kinds of projects. For example Kaplan or Bulb turbines. These turbines are better suited for these projects and this is a developed market with significant competition. Turbines using the Turbulent technology would be bulky, difficult to transport, expensive, etc. Therefore, Turbulent should not focus on this market now. In the future, Turbulent may start offering different types of turbines, including Kaplan or Bulb turbines.

200+ kW turbines: Many of the sites where it is technically feasible and financially viable to develop large-scale hydro have already been developed, especially in the Western world (Moran et al., 2018). In the developing world (mainly Africa, South America and Asia) there are chances for large-scale hydropower. Often these involve building a large dam to create a pressure difference and stock up water to be able to adjust electricity production. Damming a river does have a profound negative ecological effect (stopping fish migration), can lead to water scarcity further along the river, and may lead to methane and carbon release from slush that precipitates in the basin (Miller et al. 2017). This goes against the values of Turbulent. Furthermore, the market for large scale hydropower is highly developed and has a lot of competition. Turbulent can offer few sustainable competitive advantages and thus, Turbulent should avoid this market for the foreseeable future.

Design Focus

Conclusions:

- Turbulent should focus on 30-70 kW turbines
- Standardisation is needed for the 30-70 kW turbines
- Find out how to increase 30-70 kW turbine development for IPPs/Partners
- Develop a system specifically for the single household market
- Develop a network of Turbulent Certified contractors
- Develop education for Turbulent Certified contractors

Given that developing the B2B market is currently the main focus of Turbulent, they are understandably somewhat reluctant with letting me interview and test with all their IPPs and partners, and being part of business development. At the same time, the amount of B2B partners to test with is relatively small and their time is limited. However, the B2C market is not developed at all at the moment. Daily, potential clients contact Turbulent to find out whether a single household version of a turbine is available and what this would cost. There is demand for a single household turbine and turbines of the 5 kW size have been successfully built in the past. Smaller turbines are perfectly feasible. However, the question is: can this market be turned into a profitable market? This can really bring something new to the company. Thus, the focus of this thesis will be on developing the B2C market.

Design Focus

At first, the idea was to upsell turbines from competitors to the single household clients. Turbines from competitors are available for this type of customer, however, they are not found and Turbulent is (due to strong marketing and reach). The idea was to set up a separate company that upsells small turbines of competitors in combination with a (paid) course on how to install this kind of turbine. This course could be taken by people that want to install the turbine themselves (DIY) or by contractors that want to offer to install turbines to their clients. It was tested with several potential single household clients through interviews whether they would be open to buying a turbine from another company. Several competitors were considered and the most common type of turbine found was the axial-flow propeller turbine. Multiple of them were of low quality. Powerspout from New Zealand does however have a seemingly good quality axial-flow propeller turbine. The Powerspout LH was proposed to several potential single household clients. However, none of them were interested, naming concerns with fish friendliness, the turbine clogging up, and the maintenance being high. This is due to the high rotation speed of the propeller and the small openings that the water passes through. They wanted to have a slow rotating vortex turbine from Turbulent. Thus, the plan to upsell turbines from competitors was cancelled.

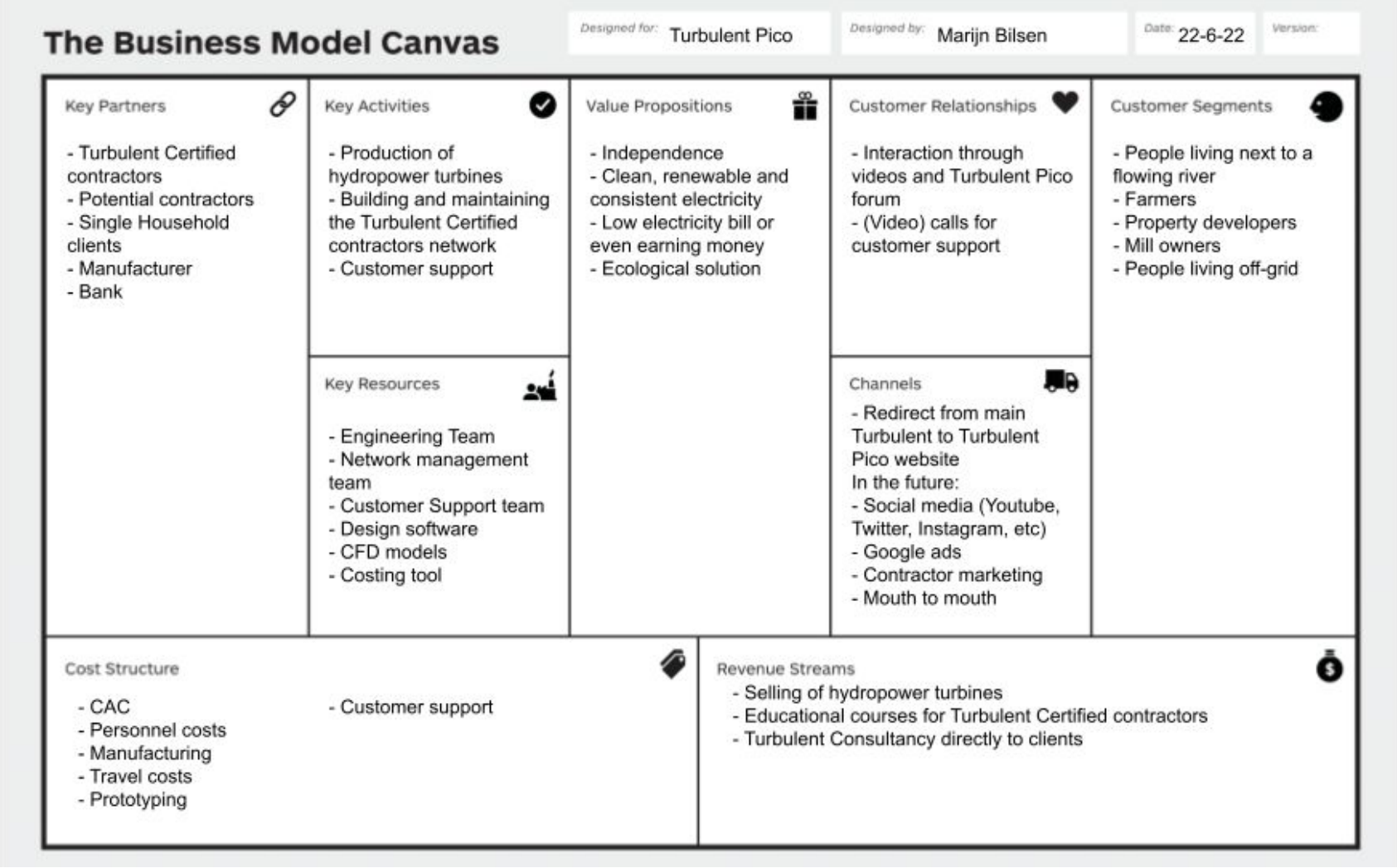
The new plan was to have Turbulent develop a single household turbine using a similar design as is used for the bigger turbines. The single household branche was named Turbulent Pico. This would be sold through a webshop to single household clients. These clients would get the turbine, electronics, plans for the basin structure, and an installation manual. With that they would either do the installation themselves, or find a local contractor to do the installation. After installing a Turbulent turbine, contractors would then be able to apply for becoming a Turbulent Certified contractor. They would have to show the project they did and have a meeting with Turbulent to prove that they are capable installers. This bottom up approach was tested with various single household clients. Several of them were willing to install the turbine themselves. These were people that had some technical skill. However, some of the people that wanted to install the turbine themselves, would not do it due to insurance reasons. About 30% of the people suggested working with a contractor that they have previous experience with. However, the majority of people would prefer Turbulent to appoint contractors to work with. Therefore, we should be open to clients suggesting their own contractor. However, most clients prefer to work with Turbulent Certified contractors.

Design Focus

Thus, the final concept is to have a website where potential single household clients can find out roughly if their site would be suitable for Turbulent Pico technology. Then, clients can look for the best Turbulent Certified contractors near them. The Turbulent Certified contractor will then do the process of assessing the feasibility and viability of the site, requesting the right permits, purchasing the turbine from Turbulent Pico, and installing and commissioning the turbine.

4.3 Business Model Canvas Turbulent Pico

This business model canvas was made to get and communicate the essence of the Turbulent Pico business case.



Business Model Canvas Turbulent Pico

The key partners for Turbulent Pico are relatively simple. Turbulent Pico mainly works with potential and Turbulent Certified contractors. It also of course works with single household clients for technical support. However, single household clients will be mostly supported by the Turbulent Certified contractors. This network of Turbulent Certified contractors will be the most important asset of Turbulent Pico. The Turbulent Certified contractors know their local area, what the permitting rules are, how marketing can be done effectively, etc. They are the face of Turbulent Pico throughout the world. Thus, great care has to be taken in selecting good contractors and educating them to a high standard. They do the feasibility studies, building of the casing, installation of the turbine, and the commissioning of the project. They also order the turbine and electronics from Turbulent. To become a Turbulent Certified contractor, an educational course will be set up to teach the contractors to install and commission the turbine correctly. This will be online and involve video meetings with Turbulent Pico educators. Contractors will be asked to do a first pilot project and show how they have installed the turbine. If this is done according to the installation manual and the quality of the project is good, they are granted the Turbulent Certified contractor status and they are added as such on turbulentpico.be. The education comes at a fee, to cover the costs made by Turbulent Pico. Given that on average around 10 contact hours are needed to train Turbulent Pico contractors, the costs for the education will cost around €1000. This fee also acts as a proof of commitment. If a contractor is willing to pay this amount, they are likely planning to install at least a few turbines. It prevents every other contractor from taking part in the course and then deciding that they will not install any turbines.

Turbulent Pico interaction directly with single household clients will be mainly in marketing, customer satisfaction studies, the forum on the website, and customer support when something is broken. At the start there might be some consultancy directly from Turbulent Pico to single household clients, to support them in finding the right contractors and doing the feasibility studies, before the Turbulent Certified contractor network is in operation.

Business Model Canvas Turbulent Pico

Main customer segments for the Turbulent Pico turbine are: all single households that live next to a flowing river or stream. Within this group, requests often come from farmers, as quite often there is a stream of water flowing somewhere on their land and they use a lot of electricity to run their farm. Another group that often shows interest in pico turbines are water mill owners. These are usually old water mills that are attached to a house or are on a property of a single household. These old water mills are usually built between the 12th and 20th century. Especially in Europe, water rights for indefinite time have often been granted, usually during Napoleonic times. These water rights are still valid today, which makes the permitting process for installing a Turbulent Pico turbine much simpler.
Property owners also occasionally are interested in pico hydro solutions, as their clients are often interested in buildings that use little energy or produce their own energy. Especially in the current energy market with high electricity prices, this is something that home buyers are looking at. Thus, it is interesting for project developers to build houses that supply their own electricity, for example through pico hydropower.
People living off grid are also often interested in a pico hydro solution. They need to supply their own electricity and usually work with a battery system. Compared to other renewables such as wind and solar power, the battery system can be much smaller. This is because the electricity generated from hydropower is much more consistent compared to wind or solar. When a nearby stream or river is available, pico hydropower often makes more sense than wind or solar power.

5. Design

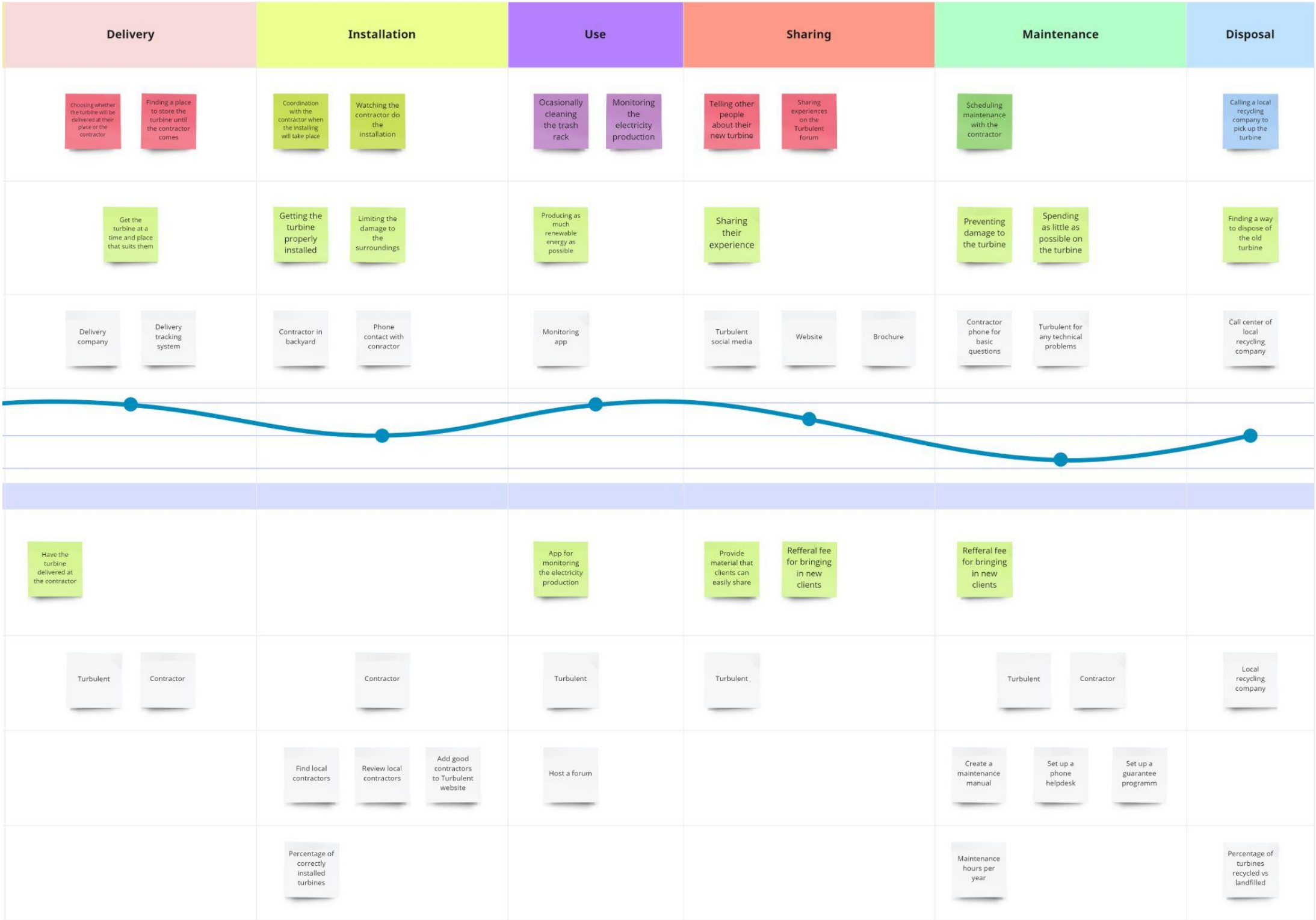
5.1 Customer Journey

To better understand and design the customer journey, two customer journey maps have been made. One for the customer journey of the single household client, and one for that of a contractor. These can be seen in the next pages or in high resolution at: https://miro.com/app/board/uXjVOw3i2HQ=/?share_link_id=745344181942

From these customer journeys it was learned that contractors can do a part of the marketing, adjusting their marketing to local standards. It was also learned that on the website, assessing the financial needs to be as simple as possible, an overview of available contractors should be given in the form of a map, and that when it is known, an overview of the permitting process (cost and time) per country/region should be given. The turbine ordering and delivery should go through the contractor, to make a carefree experience for the single household client. The Turbulent Certified contractor network is key to the success of Turbulent Pico. Thus, the business opportunities for contractors should be clearly pointed out. The process of learning them how to install the turbines should be easy to understand with an easy installation manual, online course material, and online video meetings with people from Turbulent. Also after they have become Turbulent Certified Contractors, the contact with Turbulent must be straightforward. There is also an opportunity for Turbulent to design a system that sends notes to contractors and possibly also single household clients, about when maintenance is due. This assures that maintenance is done in time, which keeps the turbines running in a good condition.

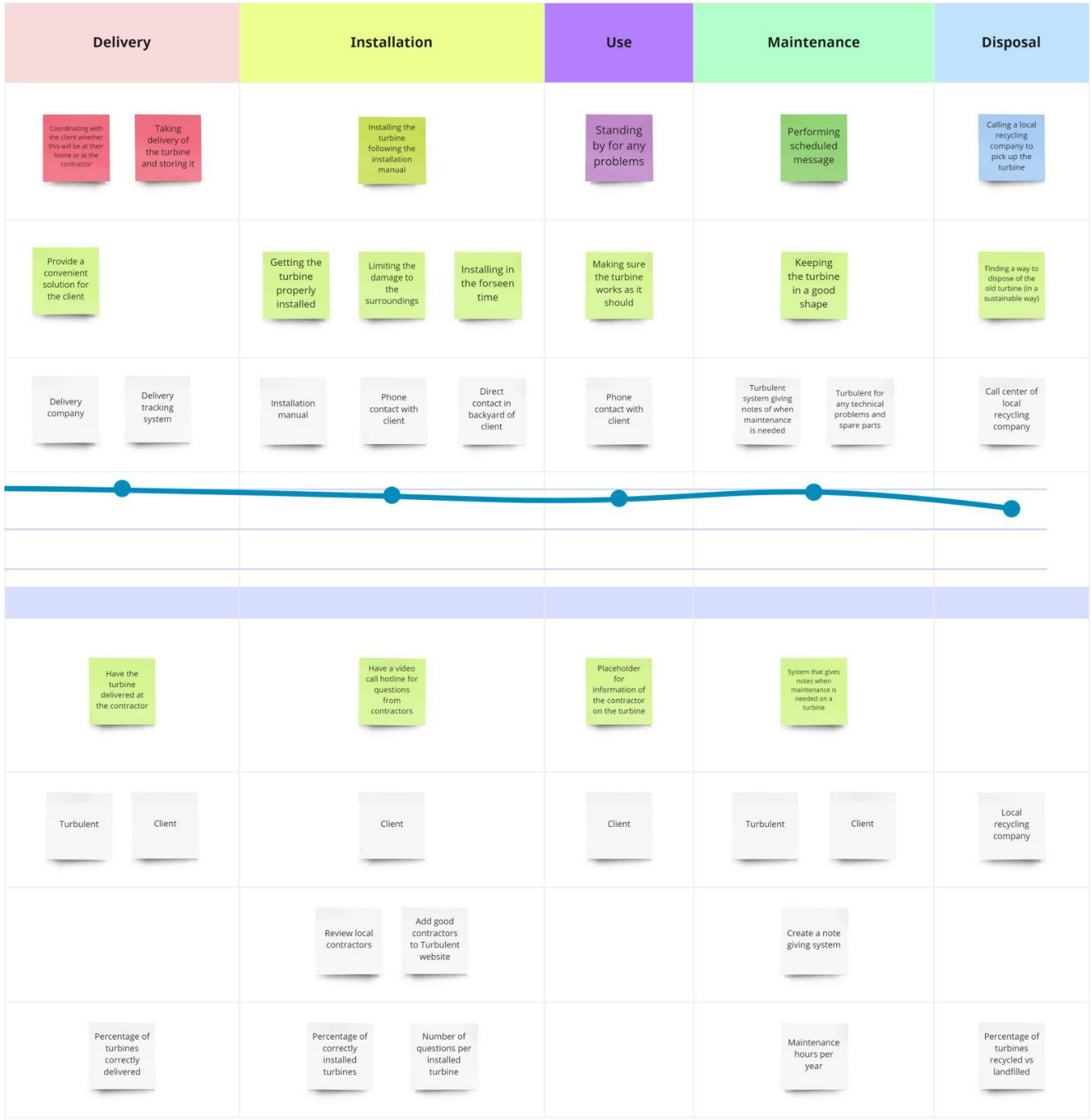
Single Households

Journey Steps	Awareness	Consideration	Decision	Order
Customer Actions	Hear from friends See an online ad	Compare renewable energy options (solar, hydro, wind) Assess financial savings Get a quotation from local contractors Asses effort needed to keep the turbine running Discuss options with friends Finding a contractor	Pay the contractor to apply for permits	Give the contractor the go ahead to buy the turbine
Customer Goals	No goals at this point	Cut electricity bill Do good for the environment Use that untapped resource that was always there Gain energy independence Order effortlessly	Know whether installing a turbine is allowed	Pick the right turbine easily together with the contractor
Touchpoint	Word of mouth Social media Website	Calling contractor Website Feasibility study by contractor	Person from the contractor doing measurements Phone call with contractor	Website calculators Advice from contractor
Customer Feeling	😀 😐 😕			
Backstage				
Opportunities	Engaging ads Marketing by local contractors Become part of local grant programms	Make assessing the financials as simple as possible Supply an overview of contractors Allow clients to supply their project details. Have local contractors react to that and make a quote	Give an overview of what the usual permitting time and costs are in different regions	Make an easy portal for contractors to order the turbine
Process ownership	Turbulent Contractor	Turbulent Contractor	Contractor	Turbulent Contractor
Organisational activities	Create marketing material Create a website	Create calculators for clients to see their savings Create a map of contractors Give the option to add contractors yourself		Process manufacturing Process fulfillment
KPIs	Number of people reached	Website visits Conversion percentage	Percentage of succesful permit applications	Number of sales Conversion percentage


Delivery
Installation
Use
Sharing
Maintenance
Disposal
Choosing whether the turbine will be delivered at their place or the contractor
Finding a place to store the turbine until the contractor comes
Coordination with the contractor when the installing will take place
Watching the contractor do the installation
Ocasionally cleaning the trash rack
Monitoring the electricity production
Telling other people about their new turbine
Sharing experiences on the Turbulent forum
Scheduling maintenance with the contractor
Calling a local recycling company to pick up the turbine
Get the turbine at a time and place that suits them
Getting the turbine properly installed
Limiting the damage to the surroundings
Producing as much renewable energy as possible
Sharing their experience
Preventing damage to the turbine
Spending as little as possible on the turbine
Finding a way to dispose of the old turbine
Delivery company
Delivery tracking system
Contractor in backyard
Phone contact with conractor
Monitoring app
Turbulent social media
Website
Brochure
Contractor phone for basic questions
Turbulent for any technical problems
Call center of local recycling company
Have the turbine delivered at the contractor
App for monitoring the electricity production
Provide material that clients can easily share
Refferal fee for bringing in new clients
Refferal fee for bringing in new clients
Turbulent
Contractor
Contractor
Turbulent
Turbulent
Turbulent
Contractor
Local recycling company
Find local contractors
Review local contractors
Add good contractors to Turbulent website
Host a forum
Create a maintenance manual
Set up a phone helpdesk
Set up a guarantee programm
Percentage of correctly installed turbines
Maintenance hours per year
Percentage of turbines recycled vs landfilled

Contractors

Journey Steps	Awareness	Consideration	Decision
Customer Actions	Respond to a question from a customer Respond to an opportunity offered by Turbulent	Download the installation manual Quoting the turbine installment Assessing the potential for more turbine installments in the area	Agree to install the turbine Order the turbine for the client
Customer Goals	Finding out what Turbulent Pico turbines are	Finding out whether it is worth my time What can I quote for the installation works? Are there other clients that want something similar?	Setting up a profitable new business activity Making the process easy for the client
Touchpoint	Word of mouth Website Phone call with Turbulent Turbulent stand at a fair	Word of mouth Website Installation manual Phone call with Turbulent	Phone call with Turbulent
Customer Feeling			
Backstage			
Opportunities	Showecase of the business opportunities for contractors to install turbines	Brochure with financial opportunities Supply an overview of competitors Easy to understand installation manual	Have sales people from Turbulent visit contractors
Process ownership	Turbulent Client	Turbulent Client	Turbulent
Organisational activities	Create a brochure with business opportunities for contractors Appoint someone to be in contact with contractors	Create easy to understand manual	Convince contractors that this an interesting opportunity
KPIs	Number of contractors reached	Percentage of contacted contractors that converts to a Turbulent installer	Conversion percentage


Delivery
Installation
Use
Maintenance
Disposal
Coordinating with the client whether this will be at their home or at the contractor
Taking delivery of the turbine and storing it
Installing the turbine following the installation manual
Standing by for any problems
Performing scheduled message
Calling a local recycling company to pick up the turbine
Provide a convenient solution for the client
Getting the turbine properly installed
Limiting the damage to the surroundings
Installing in the forseen time
Making sure the turbine works as it should
Keeping the turbine in a good shape
Finding a way to dispose of the old turbine (in a sustainable way)
Delivery company
Delivery tracking system
Installation manual
Phone contact with client
Direct contact in backyard of client
Phone contact with client
Turbulent system giving notes of when maintenance is needed
Turbulent for any technical problems and spare parts
Call center of local recycling company
Have the turbine delivered at the contractor
Have a video call hotline for questions from contractors
Placeholder for information of the contractor on the turbine
System that gives notes when maintenance is needed on a turbine
Turbulent
Client
Client
Client
Turbulent
Client
Local recycling company
Review local contractors
Add good contractors to Turbulent website
Create a note giving system
Percentage of turbines correctly delivered
Percentage of correctly installed turbines
Number of questions per installed turbine
Maintenance hours per year
Percentage of turbines recycled vs landfilled

5.2 Website Prototype

To test the single household market, a website has been made (see turbulentpico.be or the following pages and appendix D). The goal of this website is to find out to what extent potential single household clients are likely to convert into actual Turbulent clients. The website is geared at single households who are interested in installing a small turbine (between 1 and 5 kW).

On the website, potential single household clients can get an idea of what the process of installing a pico turbine looks like, see what the benefits of these turbines are, get a rough idea of what kind of power is in their river/stream, which turbine would best suit their electricity need, and what their financial payback time would be (the three most asked questions by potential single household clients). They can also find a more extensive overview of the installation process, learn how to measure the head and flow of their site if they want to do it themselves, find Turbulent Certified contractors near them (at this moment there are no Turbulent Certified contractors), and pre-order the turbine that they are interested in. They can also get support by using the support form, sending an email or through a phone call.

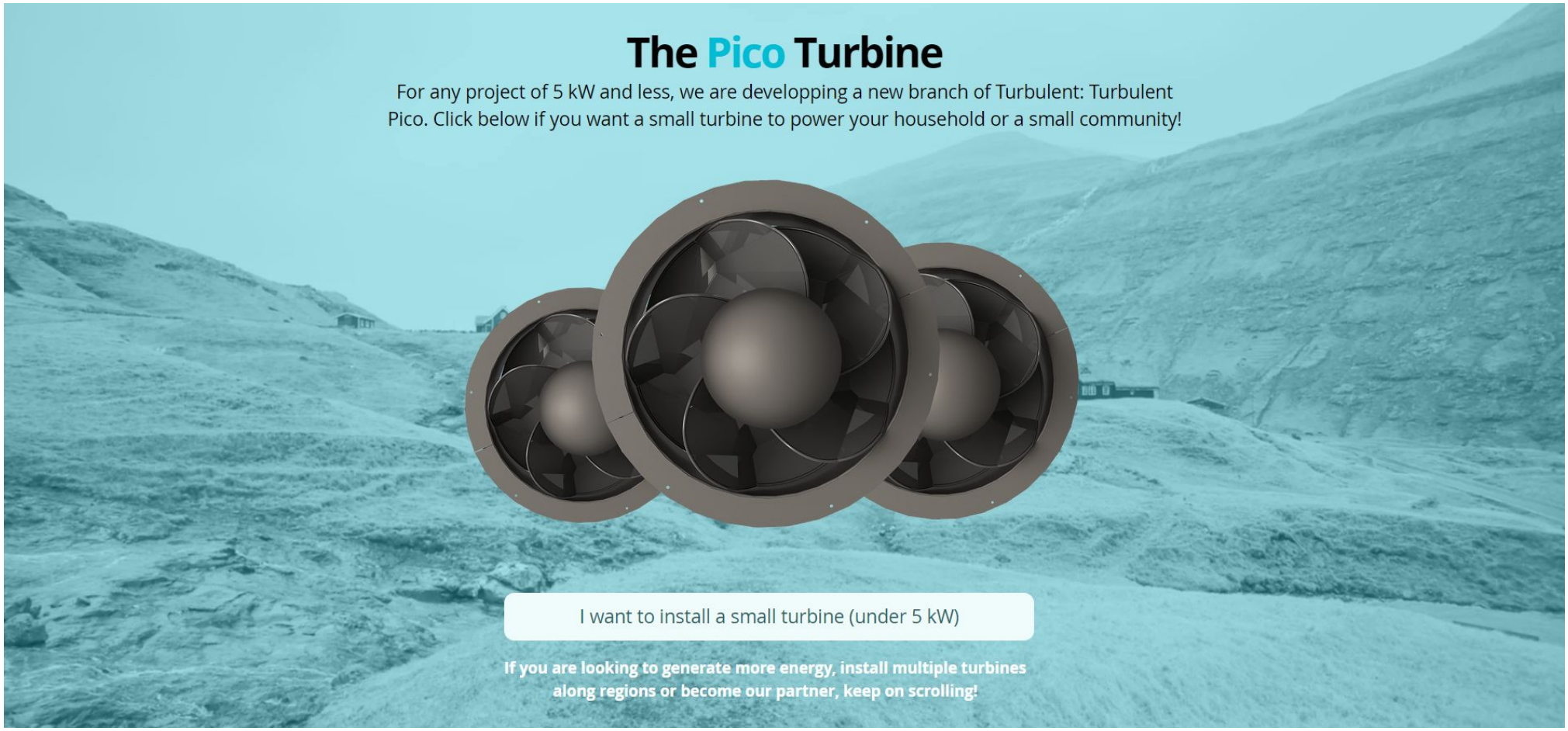
Forum
A forum is included (see appendix D) to allow (potential) Turbulent Pico clients to share experiences and learn from each other. It is expected that mainly the Do It Yourself (DIY) community will start using this forum to share experiences and ask questions on how to install the turbine and about any modifications that they have done. If people start modifying their turbine or basin or anything surrounding the project, this can offer useful insights into users' needs and can be used to design on. Questions that people ask can also show a lack of information on a certain topic or a gap in the service. Thus, the forum can be a valuable resource for improving the product and service. Due to technical problems at the website hosting service, the forum has not been tested.

Website Prototype

The website for Turbulent Pico is featured on the homepage of the website of Turbulent (turbulent.be) . This is done to redirect potential single household clients to the right section and away from the main company website. On the main website, they are not the targeted client. Potential single household clients do many simple inquiries, which is logical as they are not at all involved in the field of hydropower. These potential clients generally get an email stating that at this moment there is no turbine available for their needs and their questions are usually not answered. This is because the capacity within the Turbulent sales team is limited, and single households are considered not worth spending much time on, as these projects usually do not go through. This is due to high prices that Turbulent has to ask as they do not have a standardised turbine model. It is probably also due to the low service level experienced by potential single household clients, as they would have to do the whole permitting process and installation themselves. However, with Turbulent Pico this will change as contractors will guide clients through the process.

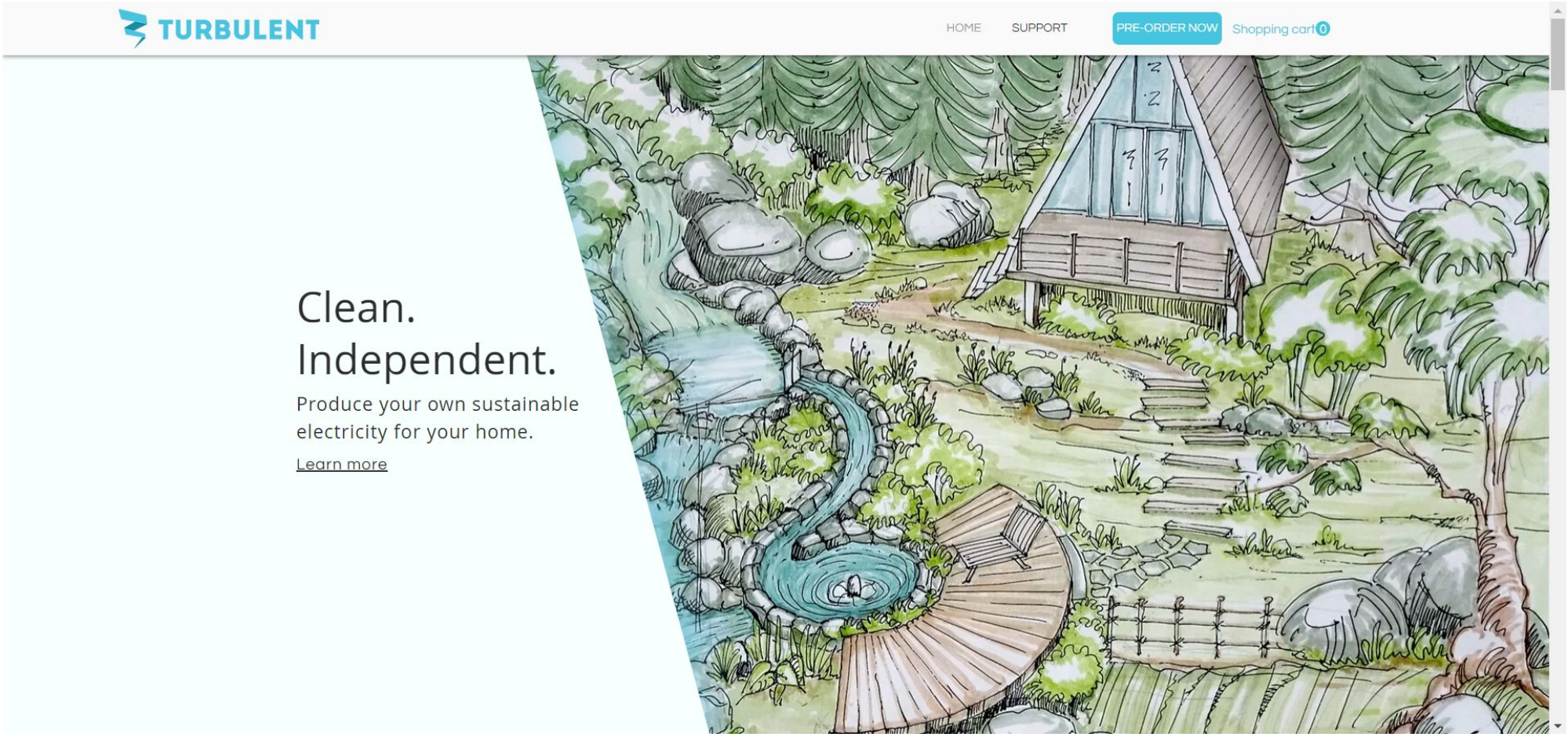
To see if this concept would work for potential single household clients, a prototype is made in the form of a website. This website (turbulentpico.be) informs potential single households clients of the process of installing a turbine, stated above. However, at this moment the Turbulent Certified contractor network is not yet developed and thus the single household clients are not yet able to contact a Turbulent Certified contractor. However, in anticipation of the Turbulent Certified contractor network, single household clients can already pre-order a turbine. Pre-ordering is free. The prices that the turbines will eventually cost are shown as the target price. These prices are varied from time to time, to test different price points.

Website Prototype



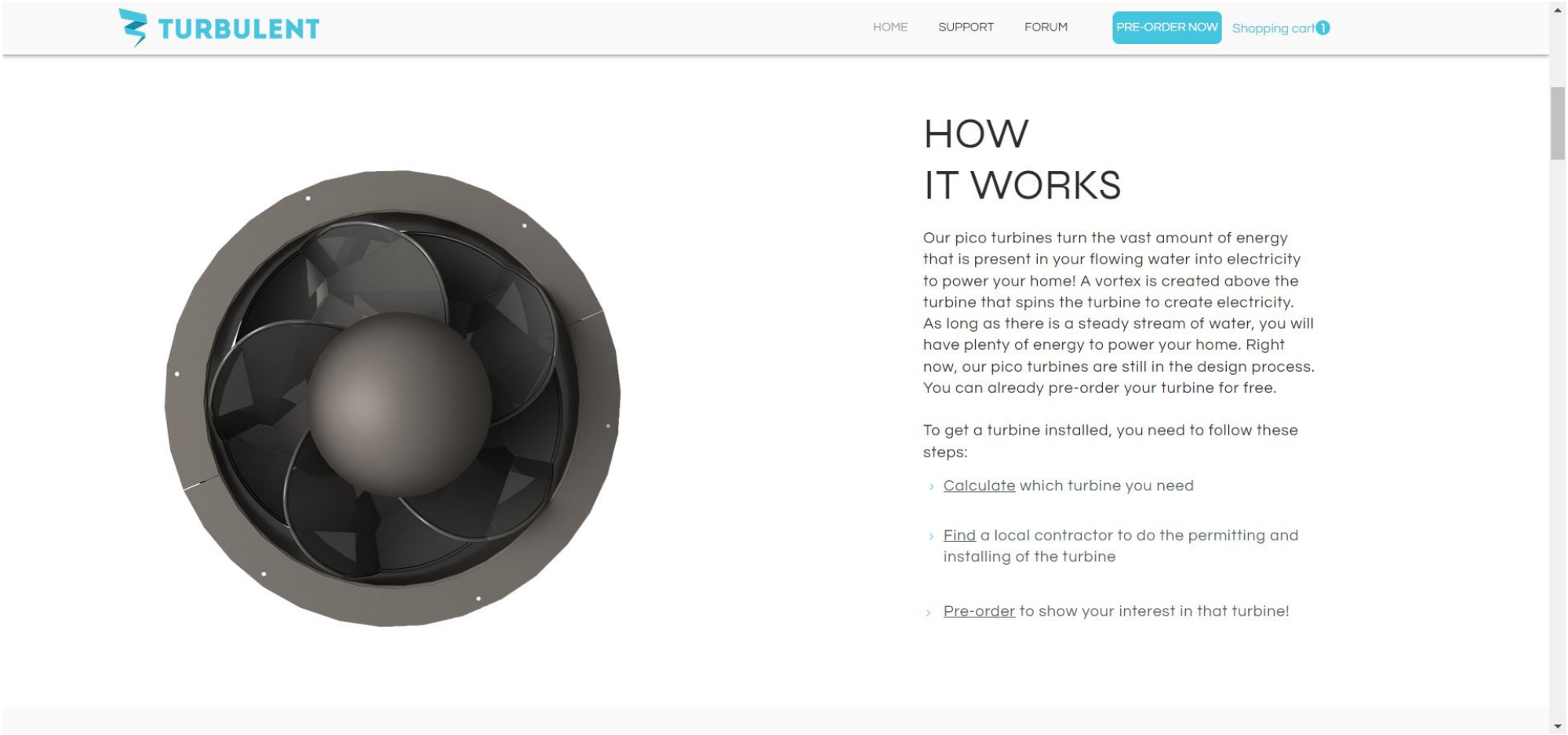
Page on the homepage of turbulent.be that sends single household clients to turbulentpico.be

Website Prototype



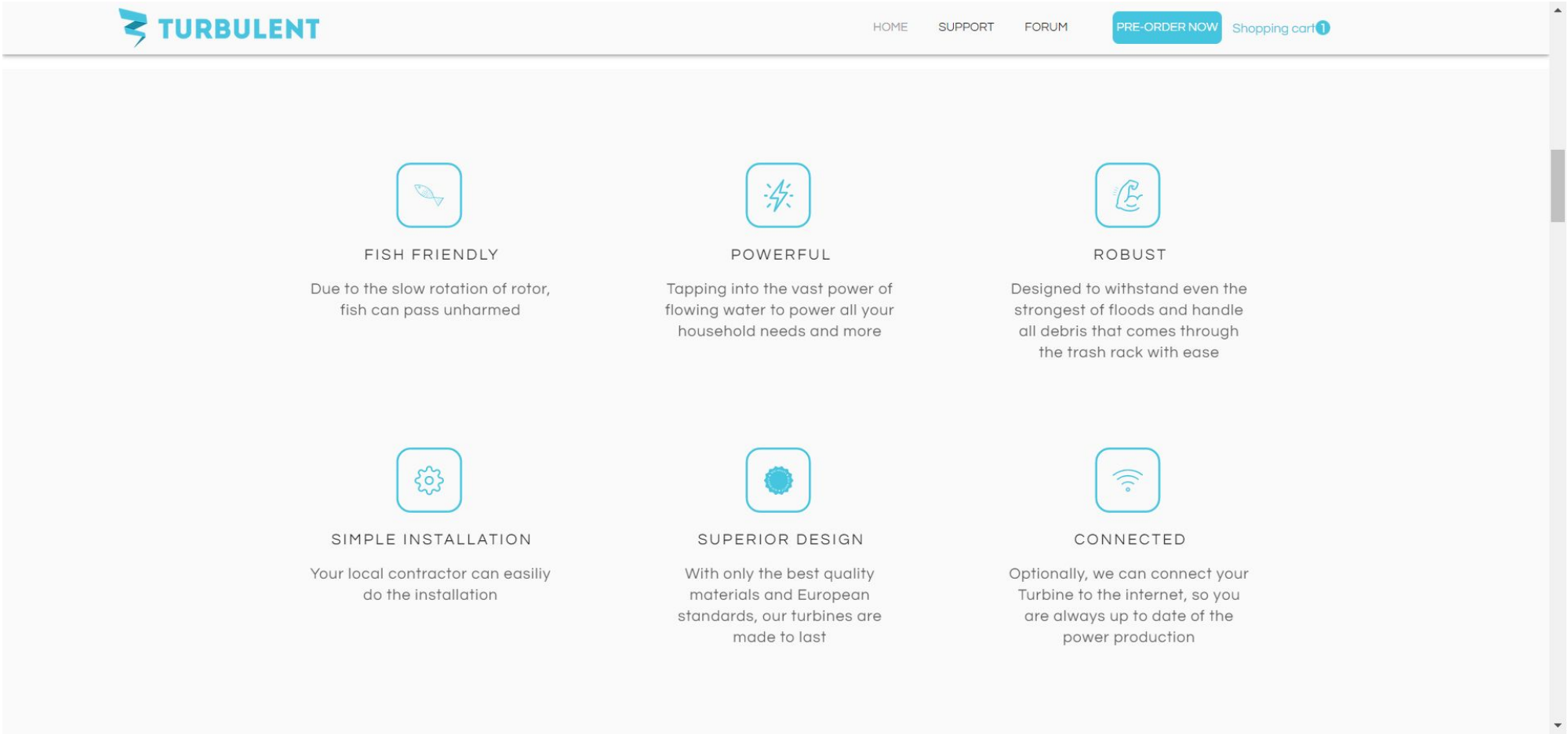
Homepage with an idyllic use case scenario for a Turbulent Pico turbine in a remote house in a forest (image by Turbulent). It grasps the attention of the website visitors.

Website Prototype



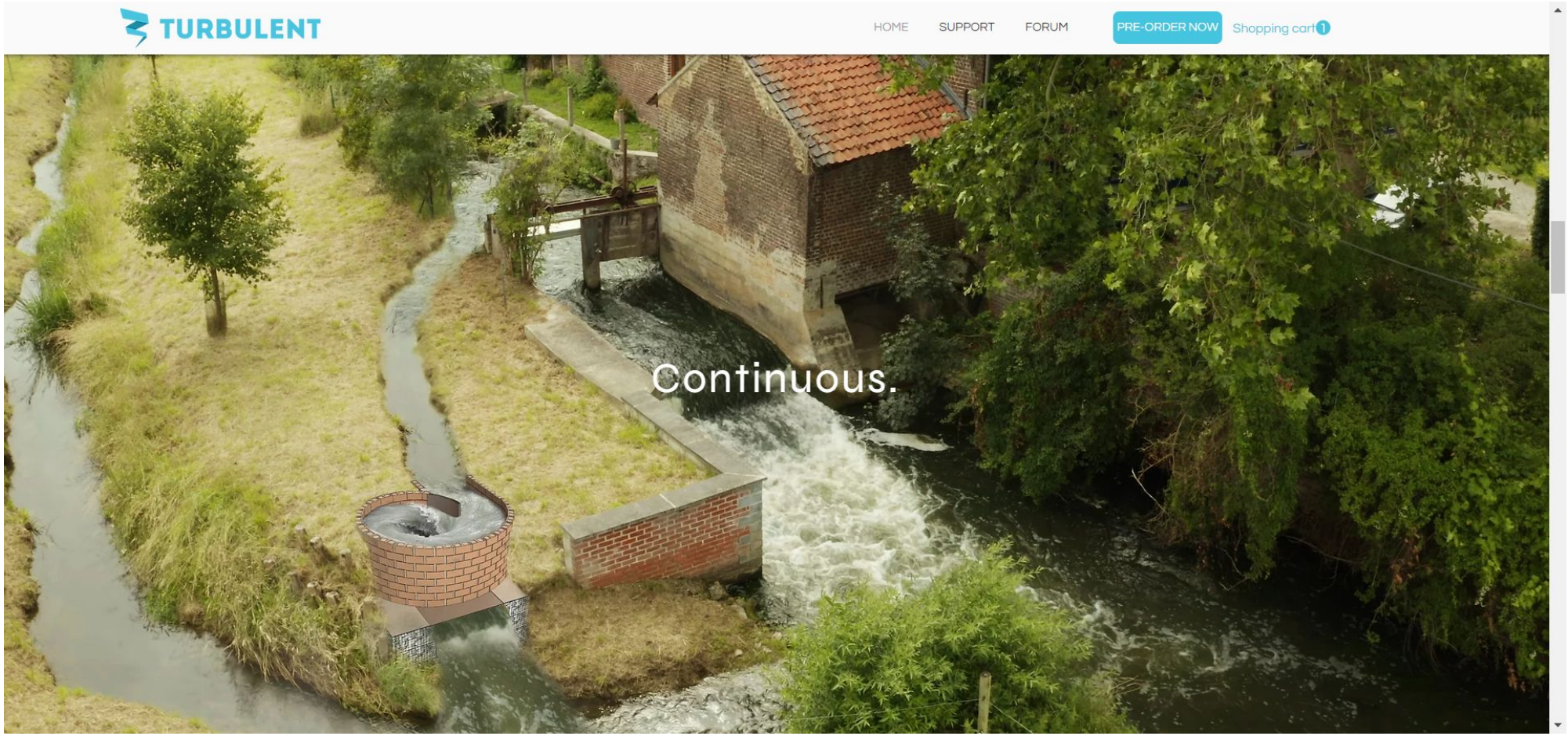
A short explanation of how the process of installing a turbine works

Website Prototype



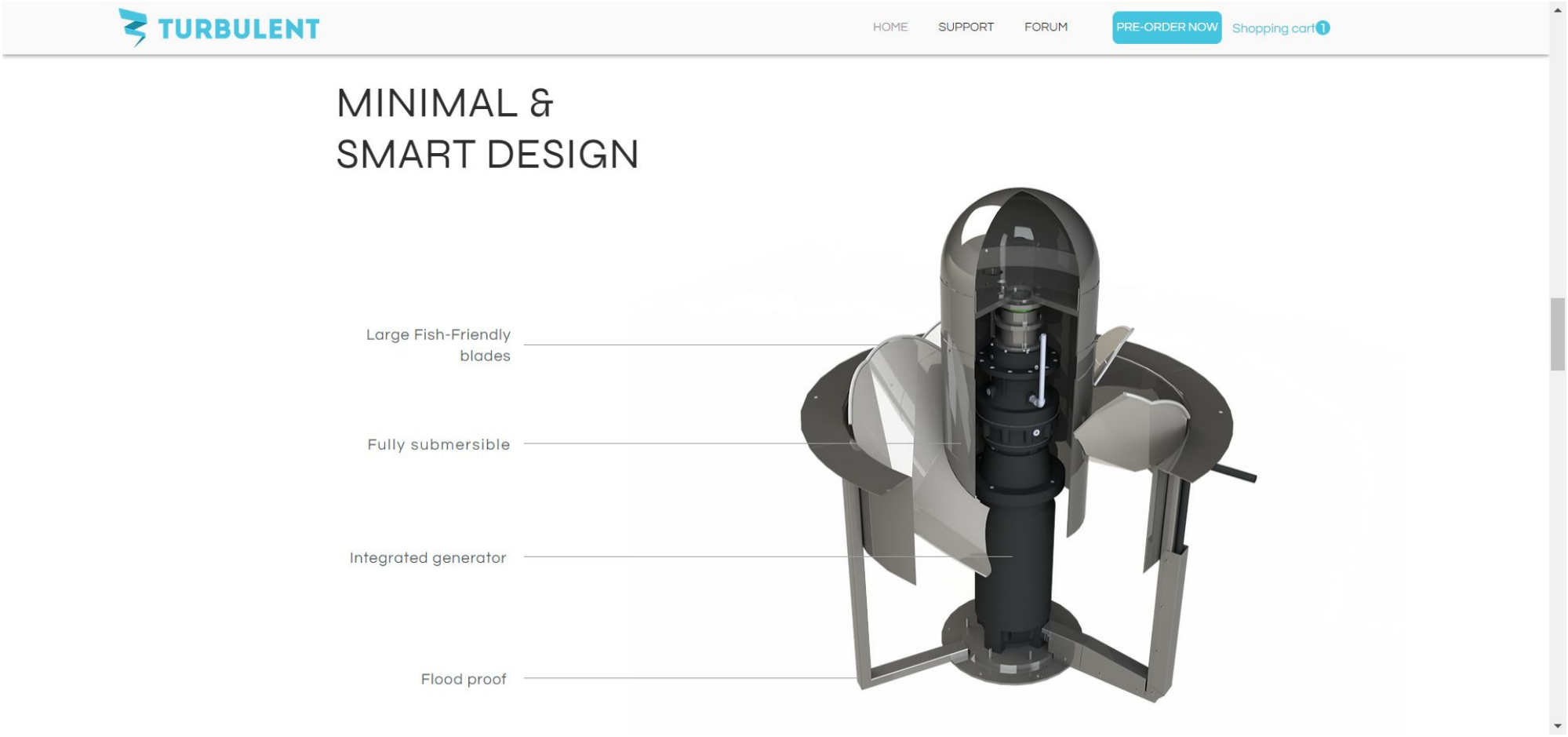
A number of benefits to the single household turbines

Website Prototype



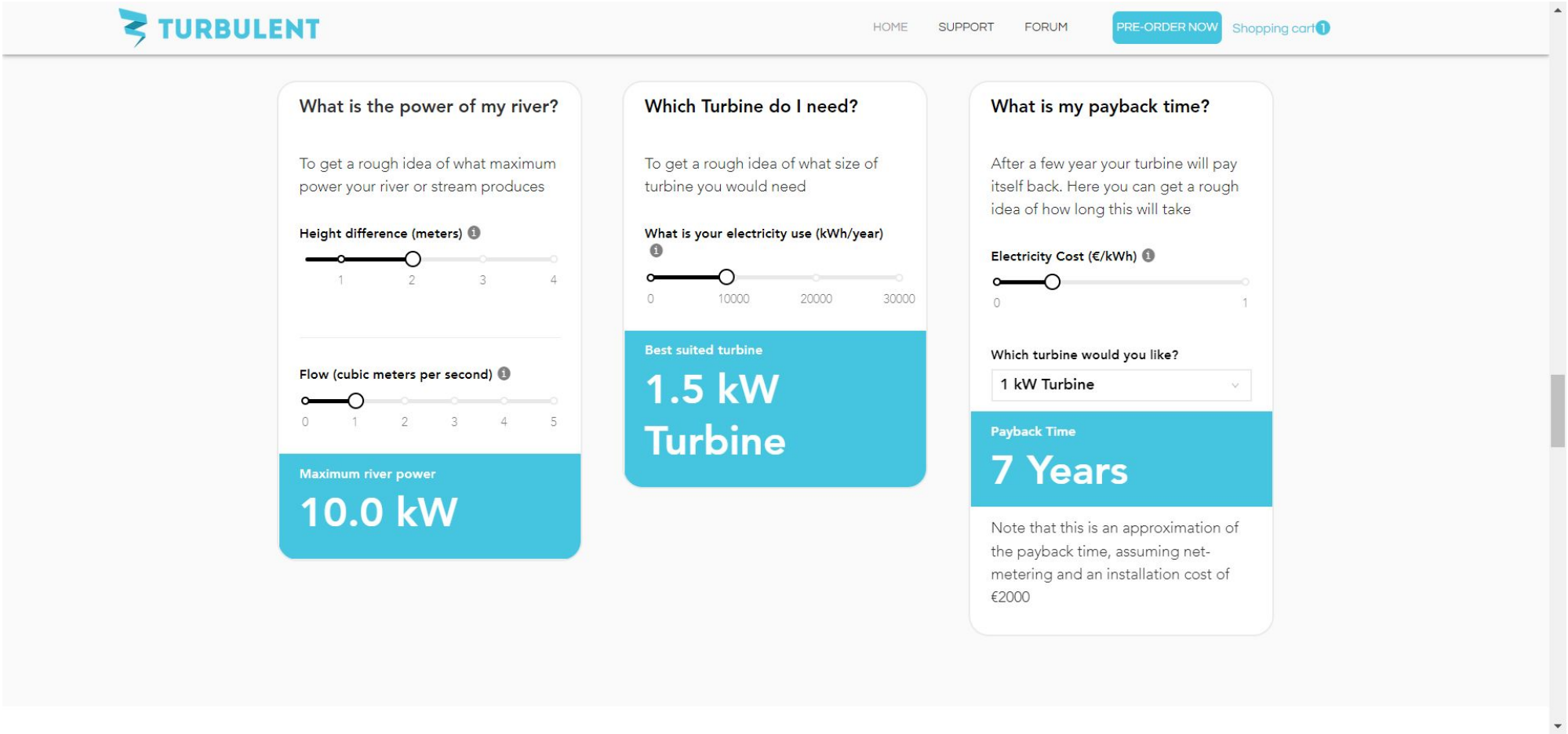
A showcase of what a pico turbine could look like (image by Turbulent)

Website Prototype



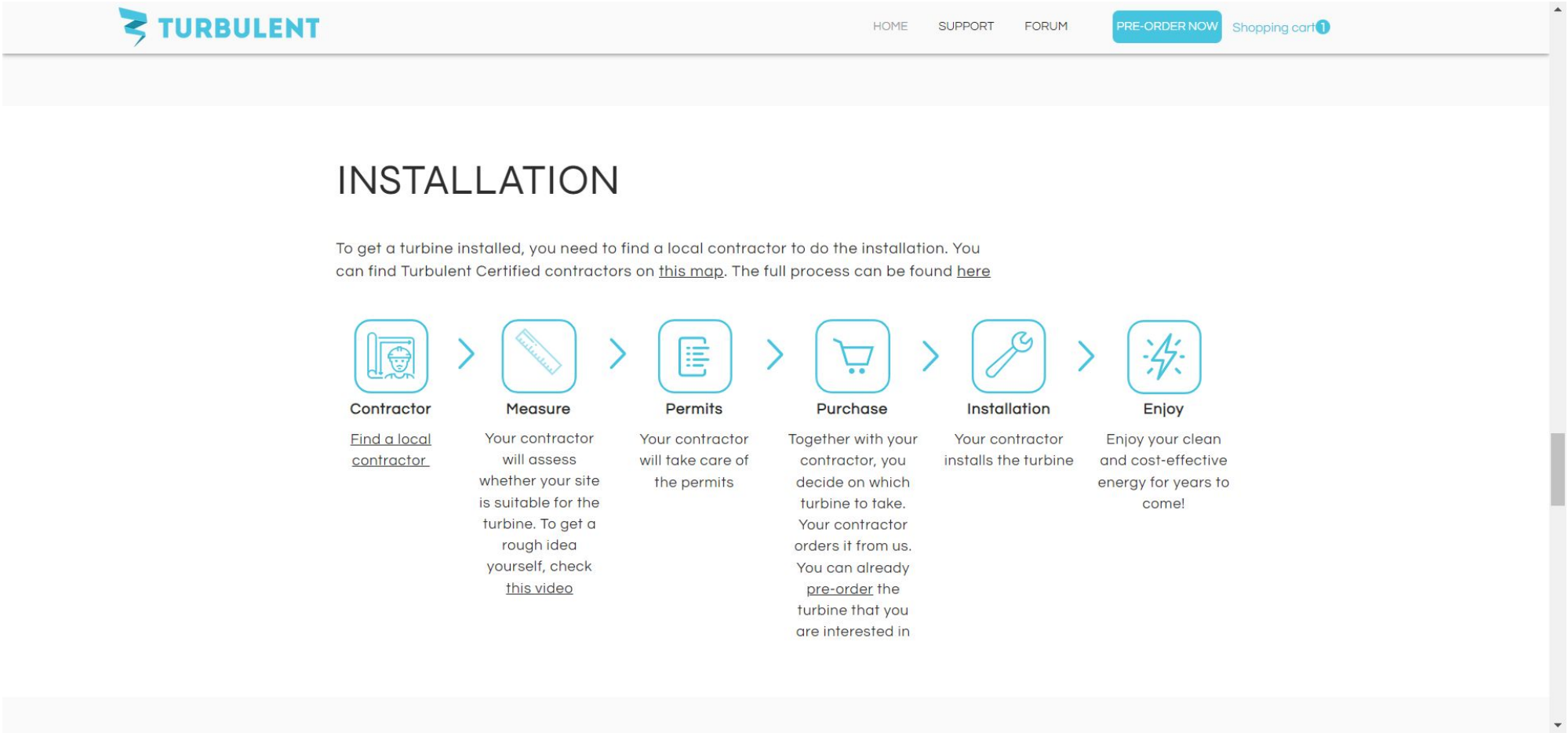
Some of the product features

Website Prototype



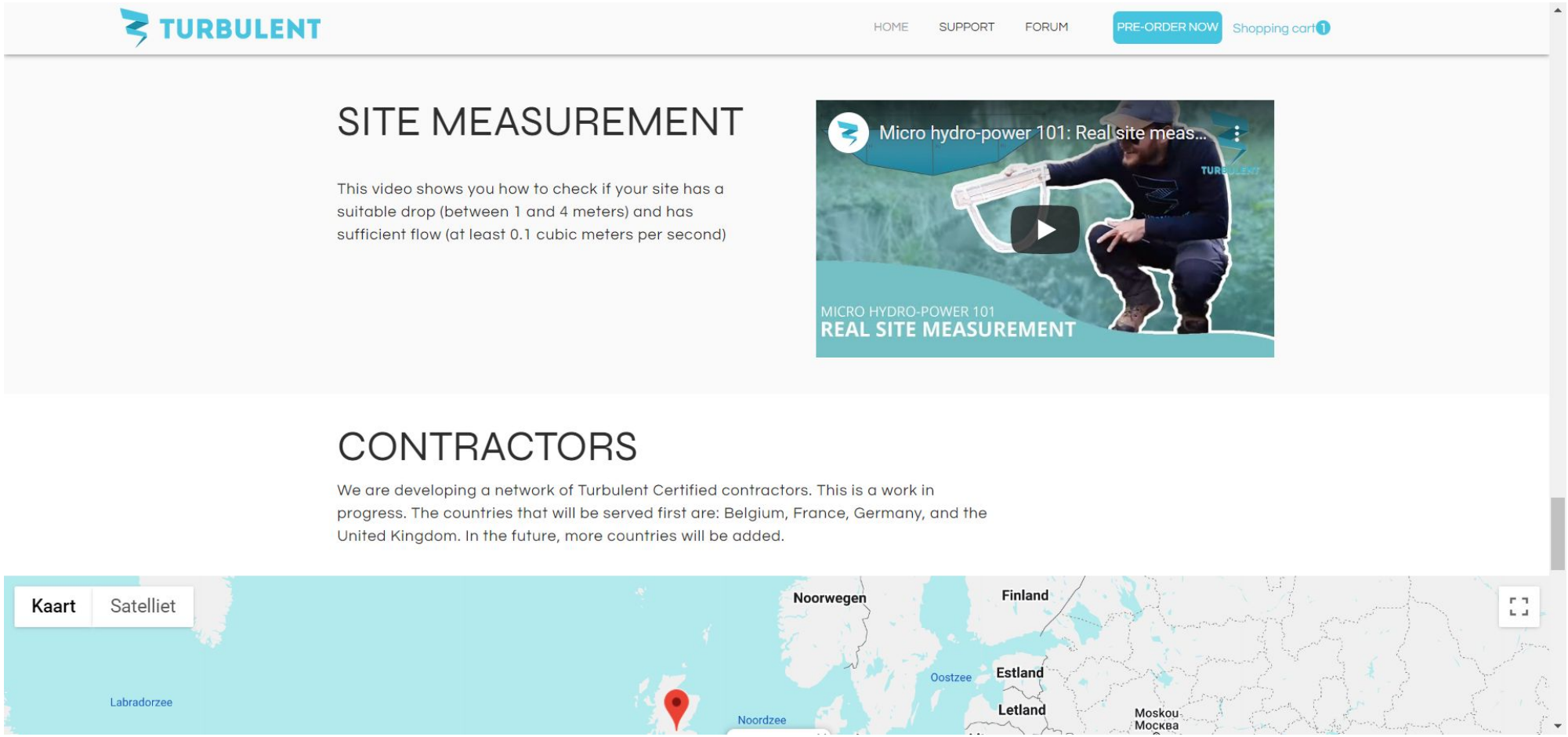
3 calculators with which the potential clients can find out how much power their river produces, which turbine size would fit them and how long it will take to earn their turbine back. These are the 3 most asked questions by single household clients.

Website Prototype



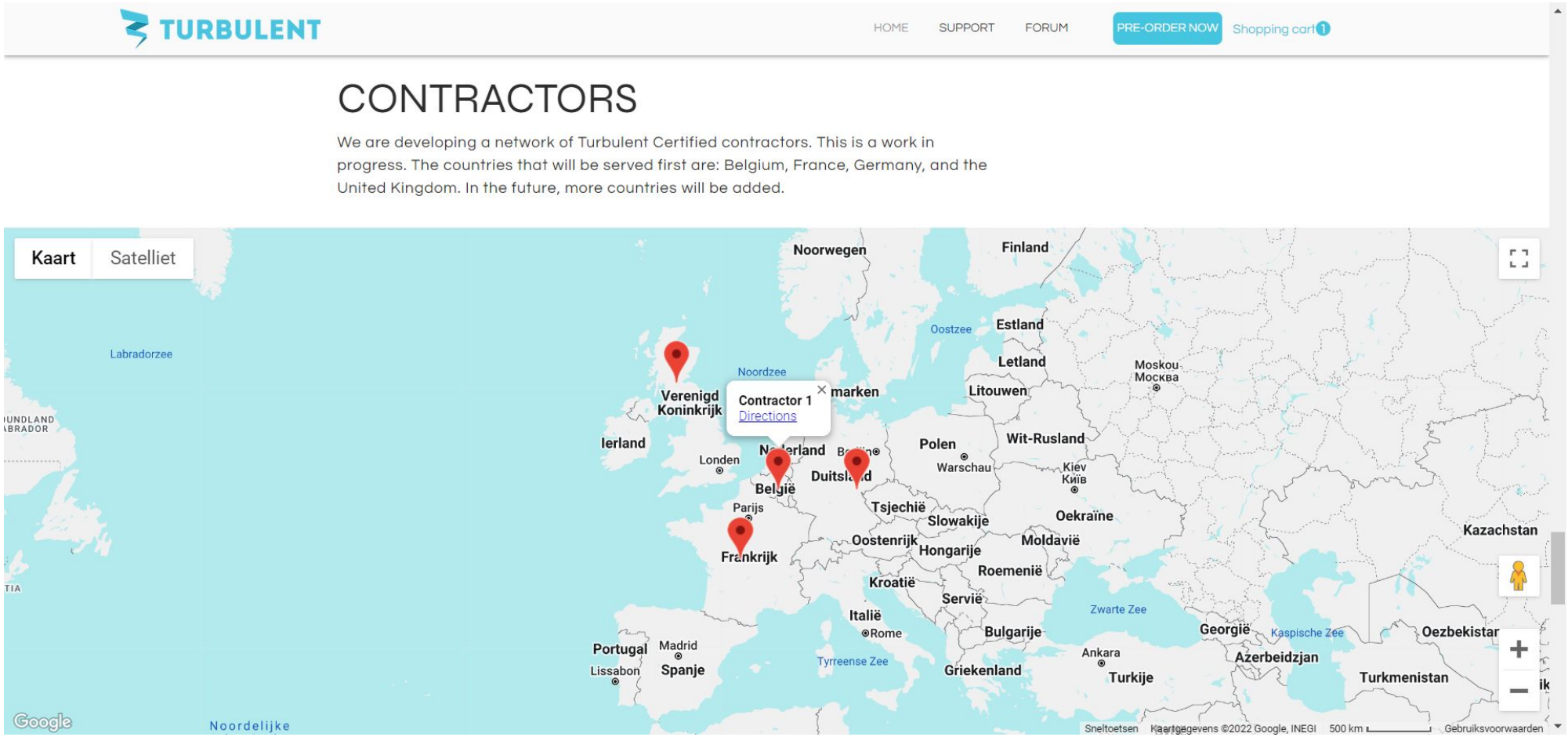
An explanation of how the process of installing a turbine works

Website Prototype



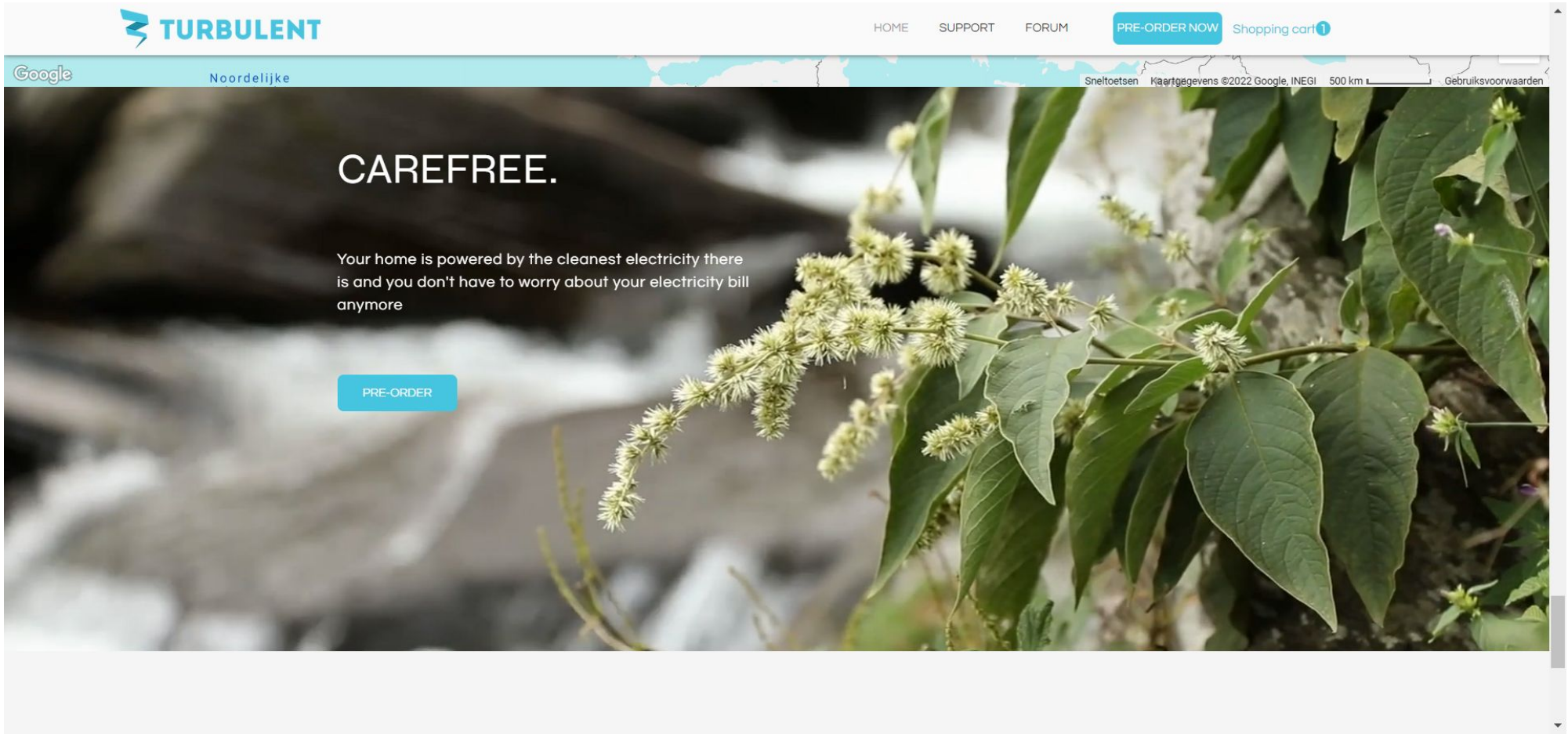
An explanation video on how to measure a site's head and flow (that is needed for calculating the power of the river). Often, clients want to measure this first themselves before hiring a contractor.

Website Prototype



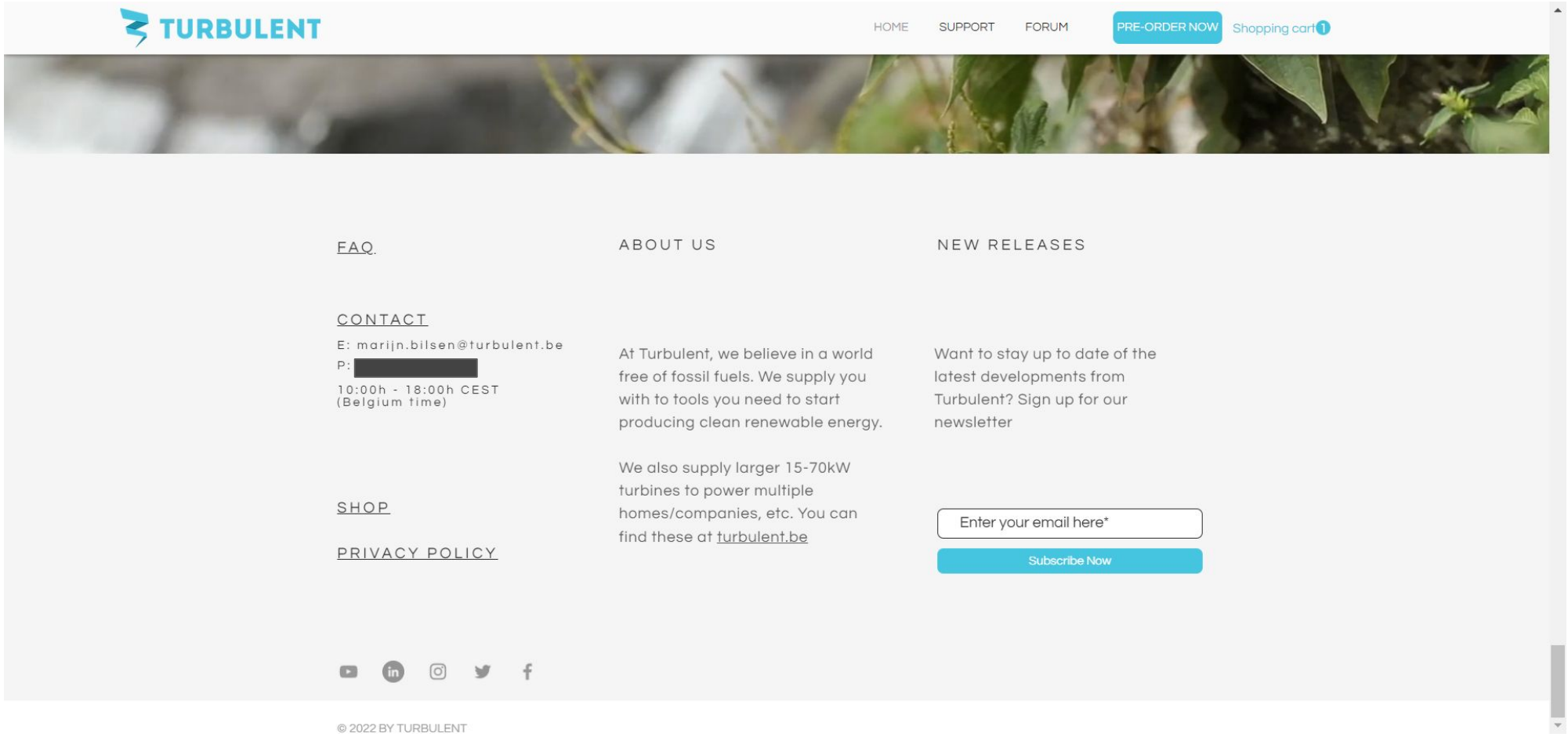
A map of Turbulent Certified contractors. Potential clients can here find a contractor near them.

Website Prototype



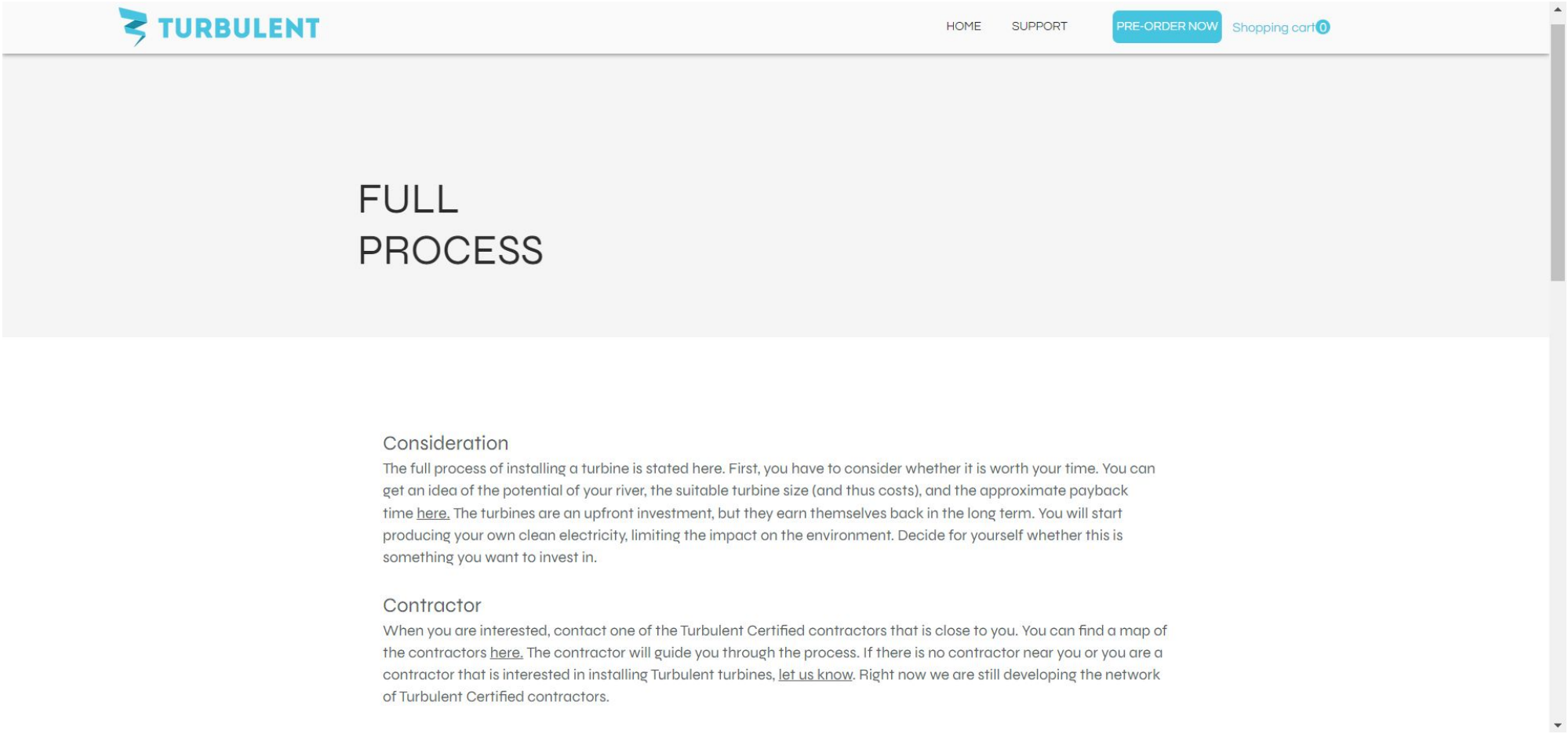
A call to action to pre-order the turbine

Website Prototype



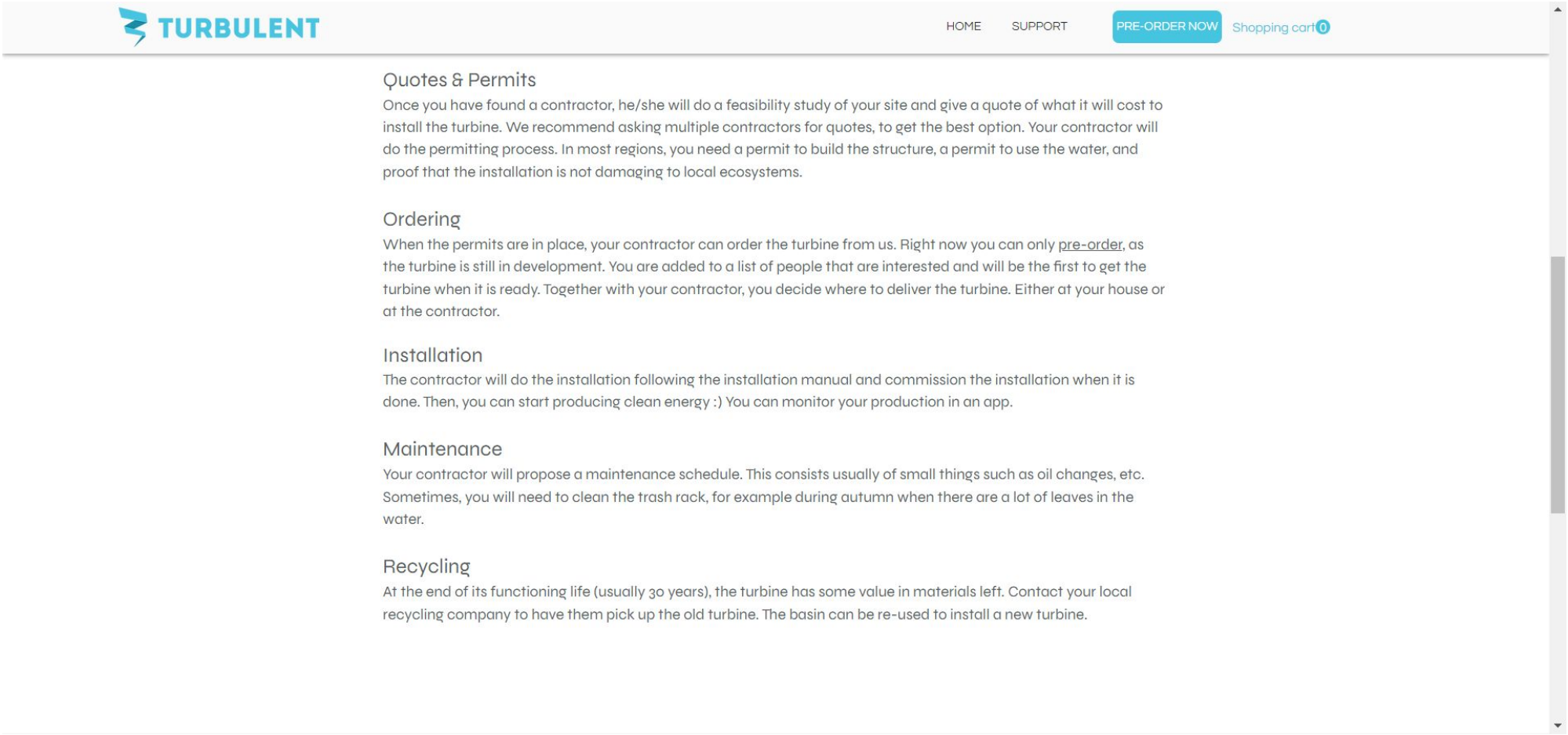
Contact details, a short “about us” and an option to subscribe to the newsletter

Website Prototype



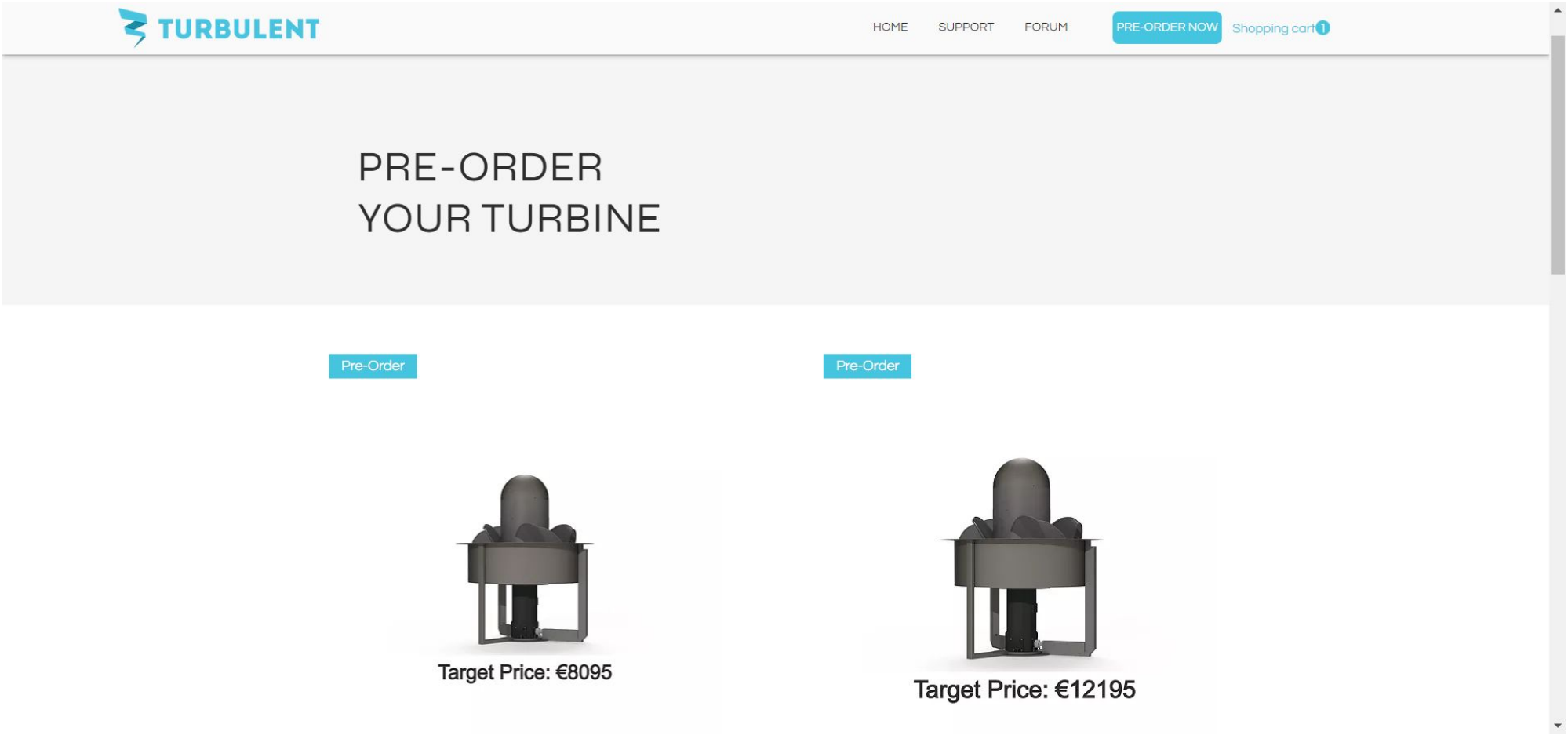
A more elaborate version of the process of installing a turbine

Website Prototype



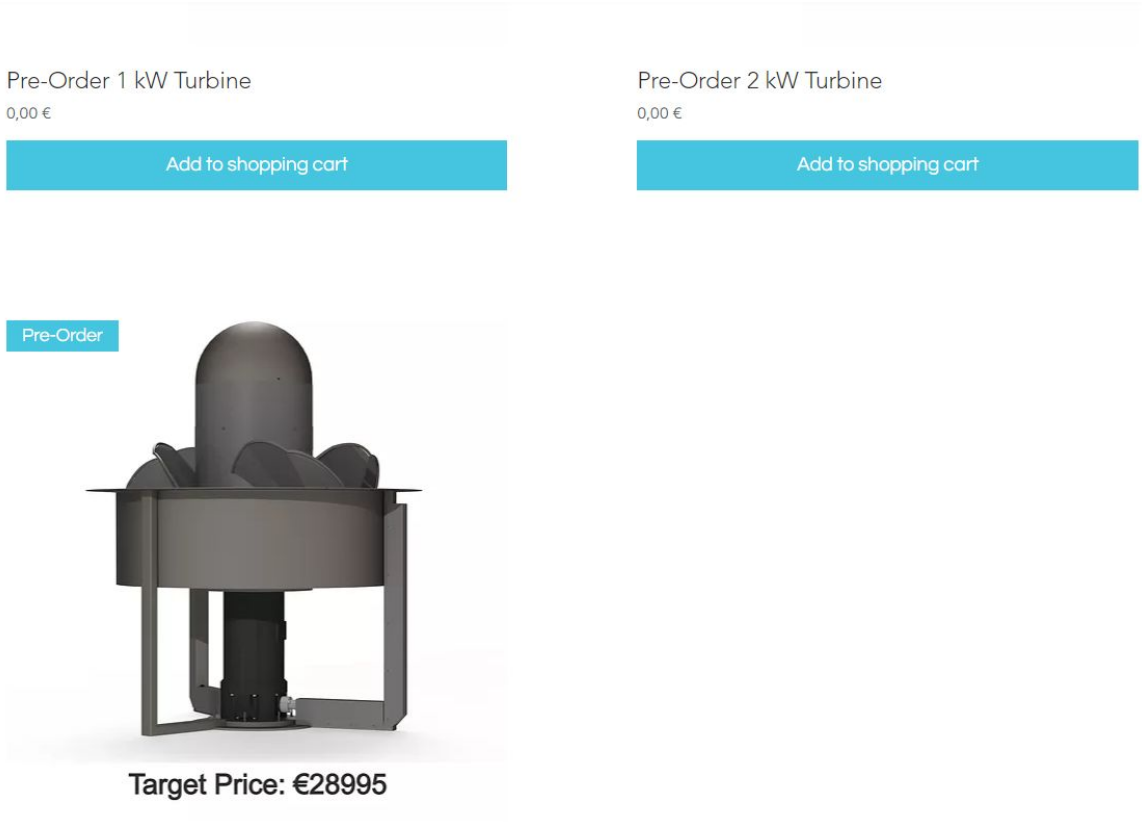
A more elaborate version of the process of installing a turbine

Website Prototype



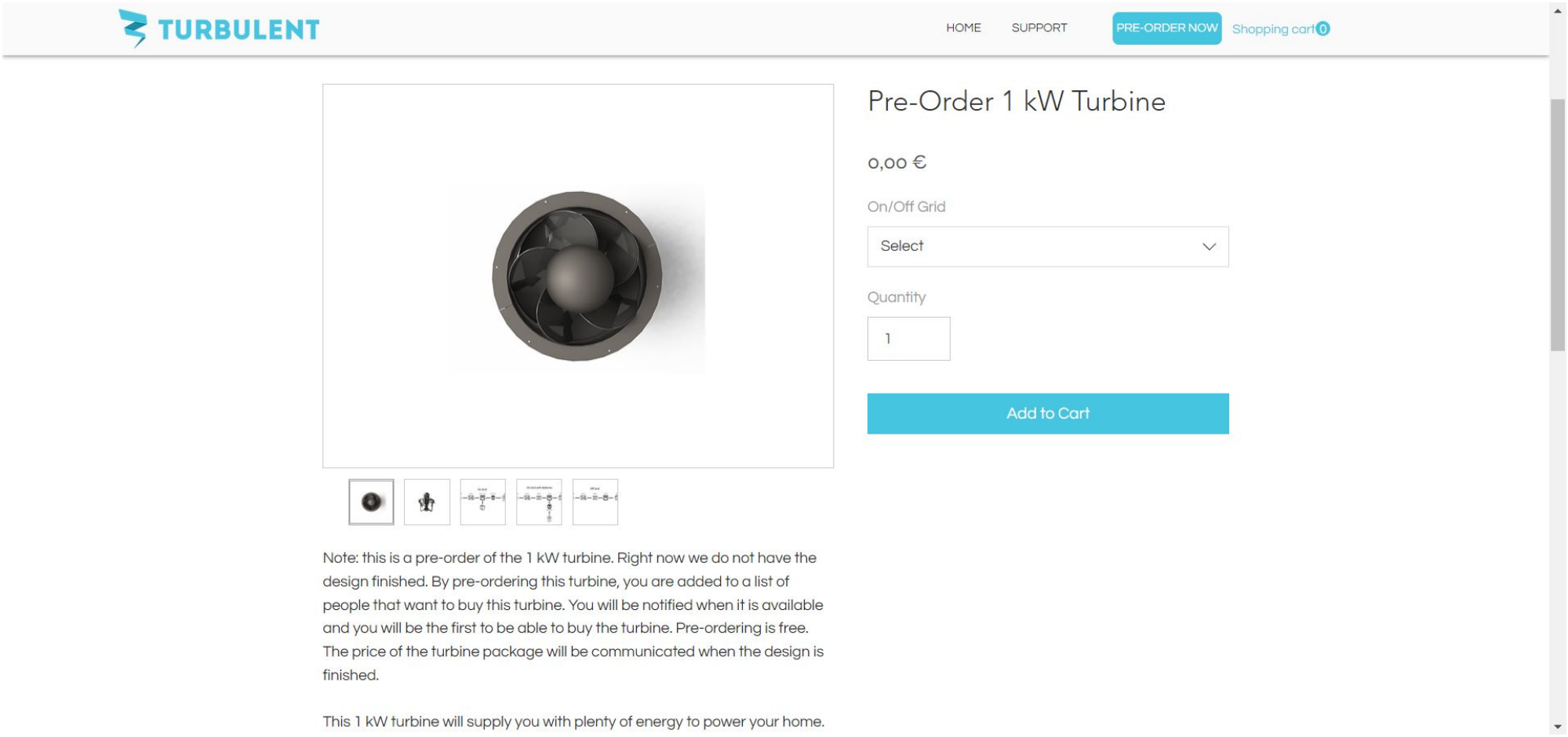
The pre-order page where potential clients can compare the different options

Website Prototype



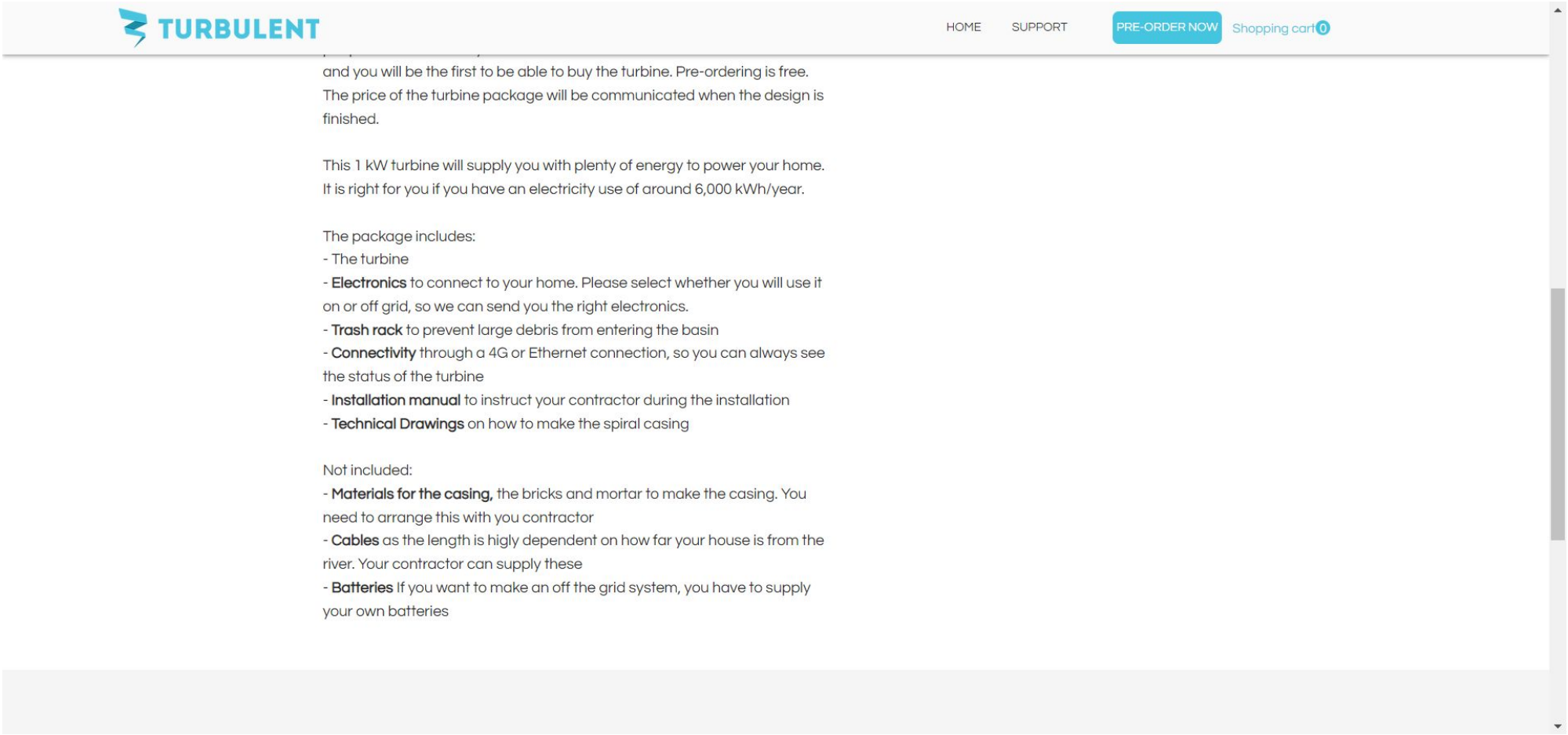
The pre-order page where potential clients can compare the different options

Website Prototype



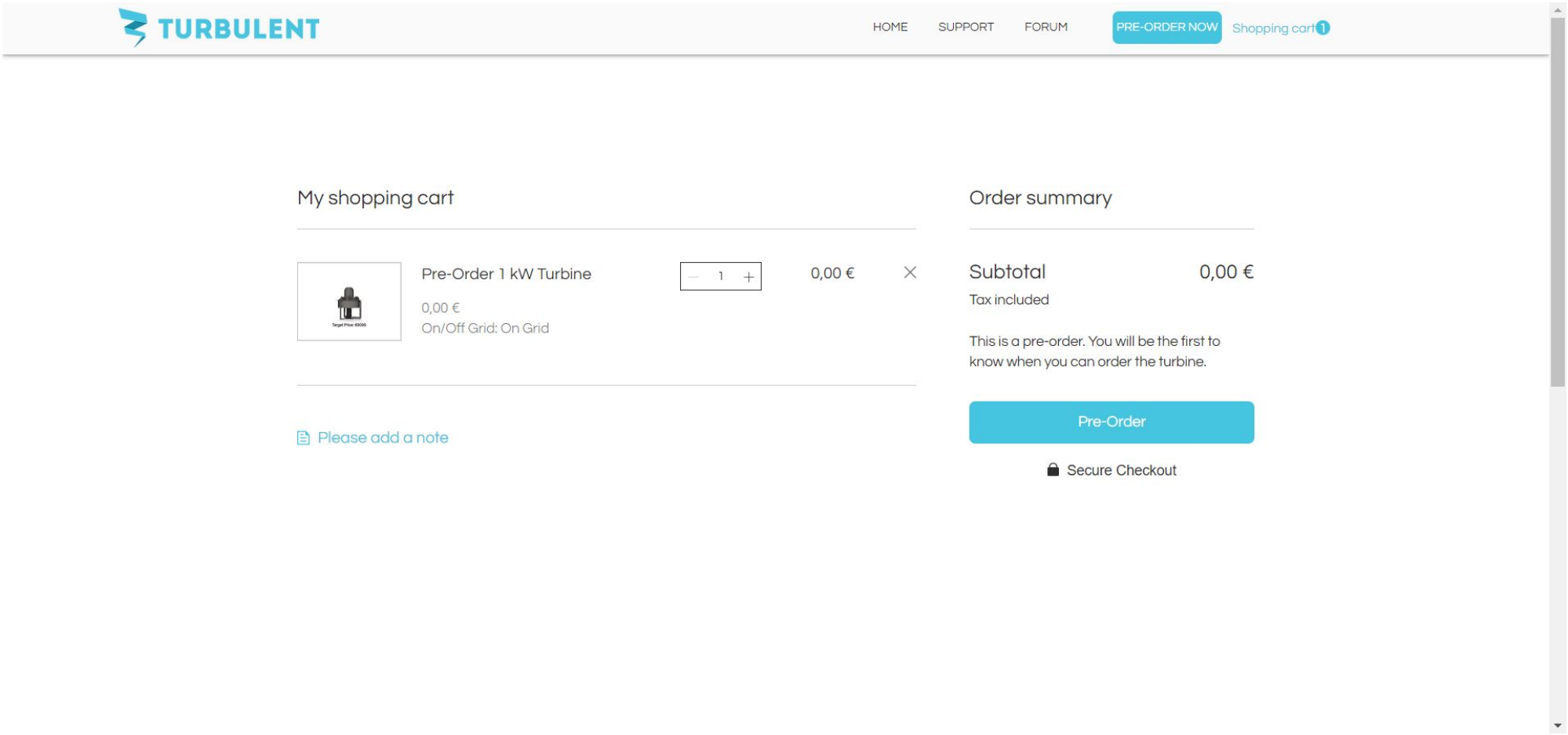
The information that potential clients get when clicking on a pre-order

Website Prototype



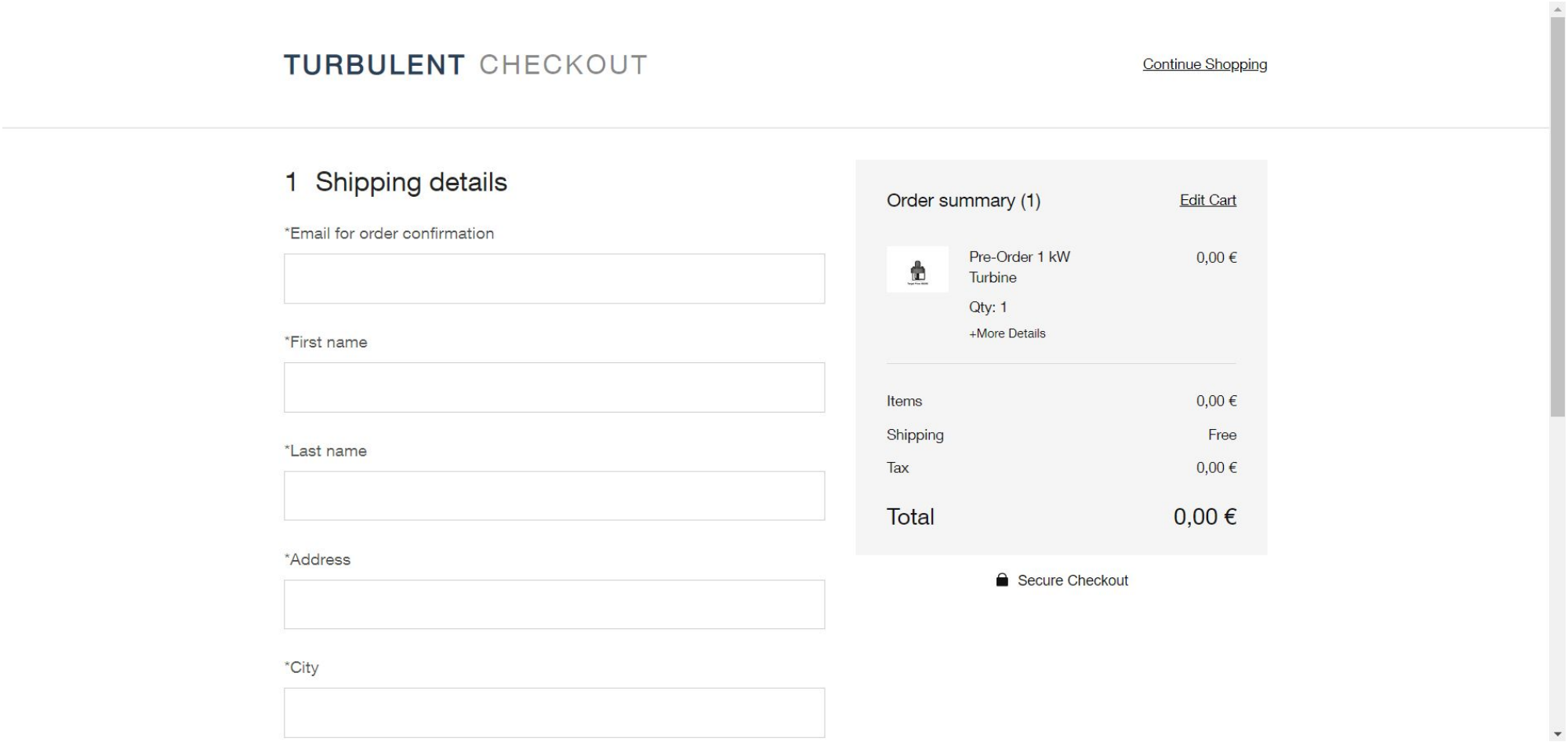
The information that potential clients get when clicking on a pre-order

Website Prototype



Turbulent Pico shopping cart

Website Prototype



Turbulent Pico checkout

6. Results

6.1 Results & Discussion

Different scenarios were tested to find out what price point seems reasonable to potential single household clients. The website was kept the same, but the turbine prices were changed. The prices in scenario 1 were based on an estimate that the production cost of these small turbines would be around €3000 per kW, leaving an approximately 100% gross profit margin. In scenario 2, the prices were increased by 25% to test if that would influence potential clients significantly. In scenario 3, no prices were shown, to test to what extent potential single household clients were influenced by the prices shown.

	Scenario 1	Scenario 2	Scenario 3
1 kW turbine price	€6295	€8095	Not shown
2 kW turbine price	€12195	€15195	Not shown
5 kW turbine price	€28995	€36195	Not shown

Results & Discussion

Scenario 1
Between June 15th (date when turbulentpico.be was linked on turbulent.be) and July 8th (date when the turbine prices were changed):
424 unique visitors
14 pre-orders (6 times 5 kW, 2 times 2 kW, 6 times 1 kW)
Conversion rate: 3.3%

25 newsletter subscribers
18 support requests

Scenario 2
Between July 9th (date when the prices were increased 25%) and July 25th (date when the prices were removed)
363 unique visitors
10 pre-orders (5 times 5 kW, 4 times 2 kW, 1 time 1 kW)
Conversion rate: 2.8%

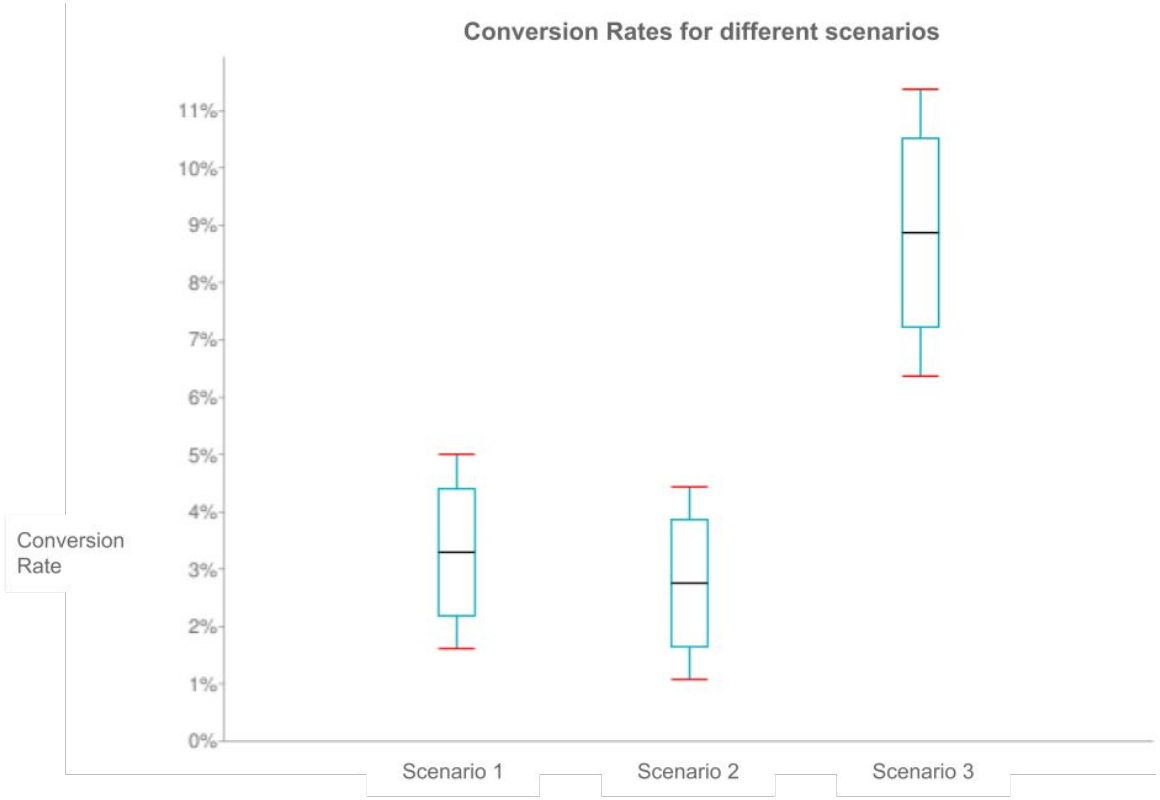
41 newsletter subscribers
11 support requests

Scenario 3
Between July 26th and August 15th (end of the measuring period)
496 unique visitors
44 pre-orders (29 times kW, 9 times 2 kW, 6 times 1 kW)
Conversion rate: 8.9%

61 newsletter subscribers
24 support requests

Results & Discussion

Figure 5: Conversion rates for different scenarios



In figure 5, it can be seen that the conversion rate in scenario 2 is slightly lower than that of scenario 1 (2.8% versus 3.3% respectively). This suggests that increasing the prices of the turbines by 25% decreases the conversion rate. A/B tests were used to compare the results of the different scenarios.

The decrease in conversion rate between scenario 1 and 2 is not significant (p=.654). This may point out that increased prices do not discourage clients from pre-ordering. However, more data is needed to give a definitive answer. A significant increase of 169% in conversion rate is seen when the prices are removed (p<.001). This indicates that showing the prices deters many of the people interested in a single household turbine. This is not a problem, as the turbines are sometimes incorrectly seen as “free energy” machines, where their cost is so low that the energy is basically “free”. It is good to inform this group of “free energy” dreamers that an upfront investment is needed.

Results & Discussion

The conversion percentages of 3.3% and 2.8% for scenario 1 and 2 respectively are good. FirstPageSage (2020) found that the average conversion rate for B2B solar energy companies from unique visitors on their websites to a qualified lead was 1.8%. Here they define a qualified lead as an event where the customer makes contact with the company, for example through downloading a report, joining a mailing list or requesting a sales call. Ruler Analytics (2022) found conversion rates of 1.7% in B2B Tech and 2.0% in B2C Ecommerce. IRP Commerce (2022) found that the average conversion rate in the electrical & commercial equipment market in July 2022 was 1.30%. It has to be noted that IRP Commerce calculates the conversion rate as the ratio between the number of sales versus the number of website sessions (instead of unique visitors). When using this same method of calculating the conversion rates, these would be 2.4% for scenario 1 and 2.0% for scenario 2.
In all of these instances, the conversion rates found on turbulentpico.be are higher than average. However, it should be considered that on turbulentpico.be, pre-orders are seen as conversion. Whether pre-orders turn into actual orders is highly dependent on the situation. With turbulentpico.be, there are a few factors increasing and decreasing the number of people that pre-order compared to the number of people that are actually interested in buying a turbine. A potential client does have to fill in their contact details and shipping address, but the act of pre-ordering is free. Thus, the potential client does not make a hard commitment to actually buying the product when it becomes available. One can always change their mind later. This may increase the number of people that pre-order without having a genuine intent of actually ordering the turbine when the finished product is available. It might also be the case that people that pre-order now will have found another solution to fulfil their energy need, by the time the turbines are available. On the other hand, the contractor network that is talked about on the website is still non-existent. Some people have sent requests to share the contact details of contractors they assumed Turbulent would have. They wanted to make a plan on when to install the turbines. When told that there are no Turbulent Certified contractors yet, these people would not pre-order, because they want to have a solution now.

Results & Discussion

The Turbulent Pico product and service are only prototypes and ideas right now. Potential clients notice this (the product pictures are clearly just renders) and it may discourage them from pre-ordering, especially for such a large expense. The whole process would also go differently when the finished product is available. The contractor would come to take a look if the site is suitable for a Turbulent Pico turbine, and then a quote would be made for the costs of the installation. The contractor would then order the turbine from Turbulent. Now, people are asked to do a pre-order without knowing the exact cost of installation and whether it is feasible at all to install a turbine at their site. This may deter potential clients from pre-ordering. Besides, Turbulent Pico has no reputation at this moment, and people can not rely on experience from others with this new company. Online true innovators will pre-order a turbine now. Therefore, the pre-order can be seen as an indication of the number of actual orders. The conversion rate with the actual product and service might be a bit higher, but this can not be said with certainty.

Several contractors (6) have shown interest in becoming a Turbulent Certified contractor, without searching for them actively. They say that they would need a good installation manual and would do a pilot project to learn how to install a turbine. Then, they would feel confident installing a turbine at someone's home. It seems that finding contractors would not be very difficult.

Assuming that the conversion rates during scenario 1 and 2 are representative for the conversion rates when the turbines are available, a revenue of €485,980 would have been earned in 42 days. This would equate to a yearly revenue of roughly €4.2 million. This is without any specific marketing for Turbulent Pico. All website traffic comes through turbulent.be. With specific marketing for Turbulent Pico, the revenue could be increased.

6.2 Recommendations

An engineering study to find out at what cost the turbines can be made is needed. This will give an insight into whether the turbines can be sold profitably. At a first glance, it seems possible to produce turbines at a production cost of €2000-3000/kW. This would leave a gross profit margin of more than 100%, which would likely be able to cover the associated costs. However, this €2000-3000/kW production cost is at the moment only an educated guess by Turbulent engineers and a proper study into the production cost and cost associated with setting up the company needs to be done.

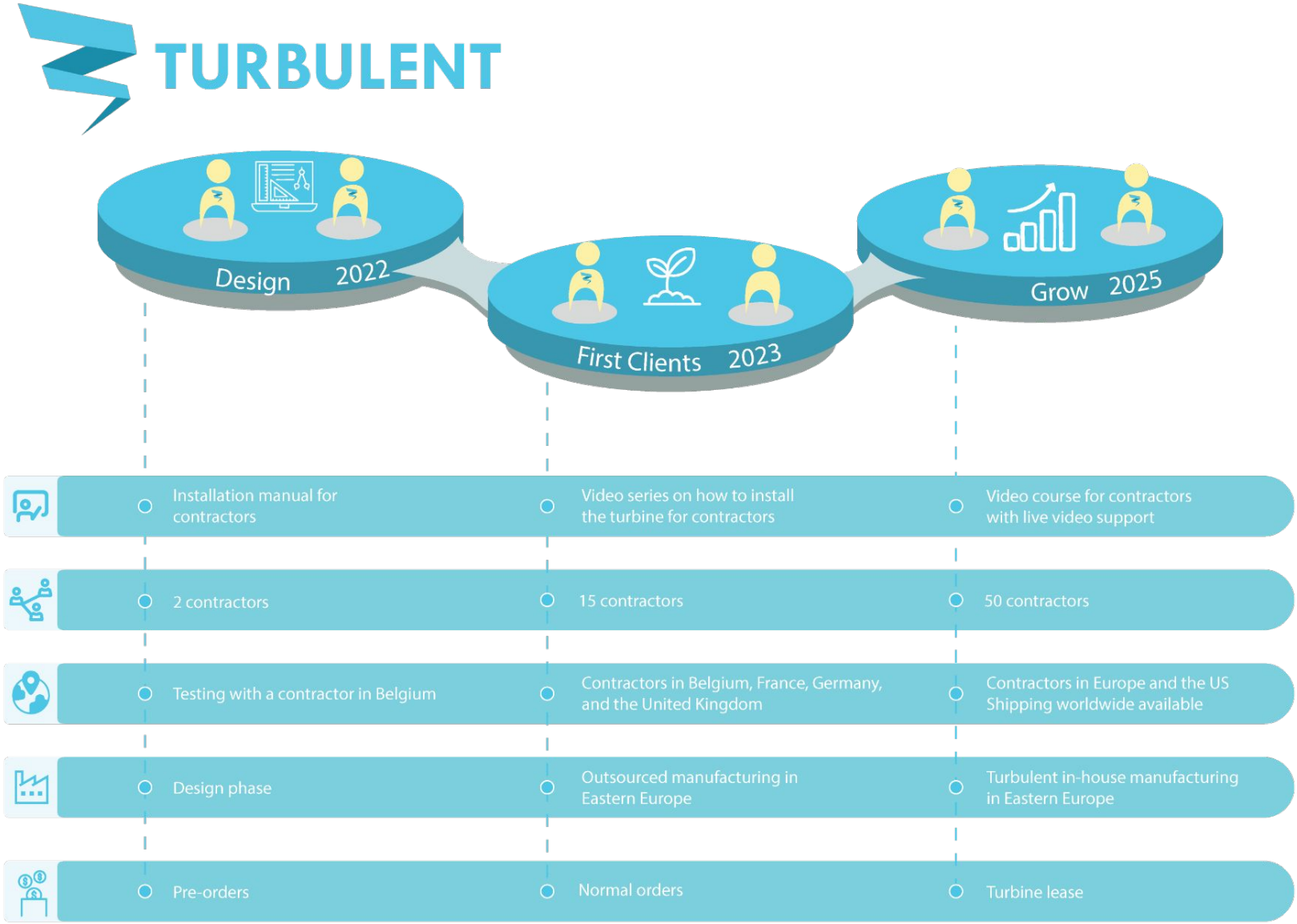
New company
Launch Turbulent Pico as a separate company. Turbulent Pico will be a B2B2C company, which is very different from the B2B company that Turbulent currently is. Turbulent Pico will mainly manage a network of contractors that will be in direct contact with consumers. The product needs to be as simple and user friendly as possible

Turbulent Pico may serve as a testbed for the larger installations. Given that the investment costs for the pico turbines (1-5 kW) are much lower than those of the bigger turbines (30-70 kW), implementing innovations is much cheaper. The forum where users can share their questions, modifications, needs, etc. may lead to some useful product and service innovations.

It should be an option for people to buy a turbine and install it on their own. Several people have asked if it is possible to just buy the equipment (turbine, electronics, etc.) and install everything themselves using the installation manual. After these people have successfully installed a turbine themselves, they could be given the option to become a Turbulent contractor.

6.3 Roadmap Single Household Market

The insights gained during single household client interviewing and testing of the website prototype are used to make a roadmap for the single household market



Roadmap Single Household Market

Education
The contractors that reached out to find how to become a Turbulent Certified contractor felt confident that if they would be supplied with a clear installation manual, they would be able to do the installation. They would most often first prefer to install a turbine at their own home first, before installing one at a client's house. This would be the preferred method in the first horizon, combined with calling back and forth, and teaching the contractors physically how to install the turbine. When the contractors are spread over multiple countries, in addition to the installation manual, a video series should be recorded showing the installation. Eventually, this video series can be turned into a video course with live video call support.

Contractor Network
Before rolling out a full contractor network, it should be tested on a small scale. At the start, just 2 contractors seems adequate. When the contractor network becomes available in 4 countries (Belgium, France, UK, and Germany), at least 15 contractors are needed to serve the demand in these countries. Eventually, at least 50 contractors are needed worldwide to serve the demand. Contractors will be actively searched for in countries with high Turbulent Pico turbine demands, mainly in Europe and the US. A worldwide shipping option should also become available. In this case, the turbine is shipped with an installation manual. Clients that feel confident installing the turbine themselves are served in this way. Clients that are in countries without a Turbulent Certified contractor can also find their own local contractor to do the installation. This can be the first touchpoint for such a contractor with Turbulent Pico, and may lead to them becoming a Turbulent Certified Contractor.

Manufacturing
When production volumes are still low, it makes more sense to outsource the manufacturing. This is due to the high upfront costs that building a factory brings with it. However, when production is of a large enough scale, it makes sense to do that upfront investment and set up an in-house factory. In this way, there is no external manufacturing company that takes part of the profit anymore. Eastern Europe seems an ideal factory location, as wages are low, but most countries are in the European Union, simplifying shipping and importing.

Roadmap Single Household Market

Revenue Model

To get some money in to start the manufacturing of the pico turbines, the first turbines will be sold as pre-orders. In these pre-orders, the full amount has to be paid upfront, after which the turbine is delivered a few months later. When the production is up and running, normal orders will become available. Here, the contractor advises the single household client on which turbine to pick. The contractor orders the turbine from Turbulent Pico, which is delivered from stock. By 2025 a lease model will also become available for the pico turbines. Turbulent Pico will have built up credibility by then, allowing them to get larger loans from banks. These loans will be used to pay for the production costs of the pico turbines. These are leased to single household clients, who pay a monthly fee to Turbulent Pico, which is lower than their current electricity bill. Leasing is more expensive in the long term than just buying the turbine for single household clients, but it lowers the threshold for them, as no large investment is needed. They can start saving on their energy bill now, instead of in a few years when they have enough money to buy the turbine. For Turbulent it means that they can get more clients and earn more money per turbine. A win-win scenario.

6.4 Conclusion

The conversion rates for Turbulent Pico are good. There is enough demand from the single household market and there a multiple ideas to get Turbulent Pico off the ground, summarised in the single household roadmap. Now, an engineering study has to be done to calculate the exact production cost. Given a gross profit margin of 100% and a selling price per kW of €6,850 (the average selling price tested in scenario 1 and 2), the maximum production costs of the different turbine types can be seen below.

Turbine type	1 kW	2 kW	5 kW
Maximum production cost	€3245	€6850	€17125

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Appendix A: Graduation Brief

DESIGN FOR our future

TU Delft

IDE Master Graduation

Project team, Procedural checks and personal Project brief

This document contains the agreements made between student and supervisory team about the student's IDE Master Graduation Project. This document can also include the involvement of an external organisation, however, it does not cover any legal employment relationship that the student and the client (might) agree upon. Next to that, this document facilitates the required procedural checks. In this document:

- The student defines the team, what he/she is going to do/deliver and how that will come about.
- SSC E&SA (Shared Service Center, Education & Student Affairs) reports on the student's registration and study progress.
- IDE's Board of Examiners confirms if the student is allowed to start the Graduation Project.

USE ADOBE ACROBAT READER TO OPEN, EDIT AND SAVE THIS DOCUMENT

Download again and reopen in case you tried other software, such as Preview (Mac) or a webbrowser.

STUDENT DATA & MASTER PROGRAMME

Save this form according the format "IDE Master Graduation Project Brief_familyname_firstname_studentnumber_dd-mm-yyyy".
Complete all blue parts of the form and include the approved Project Brief in your Graduation Report as Appendix 1 !

family name: Bilsen 5557
initials: M M given name: Marijn
student number: [redacted]
street & no.:
zipcode & city:
country:
phone:
email:

Your master programme (only select the options that apply to you):

IDE master(s): ( ) IPD ( ) DfI (★) SPD
2nd non-IDE master:
individual programme: - - (give date of approval)
honours programme: ( ) Honours Programme Master
specialisation / annotation: ( ) Medisign ( ) Tech. in Sustainable Design ( ) Entrepeneurship

SUPERVISORY TEAM **

Fill in the required data for the supervisory team members. Please check the instructions on the right !

** chair: Pinar Cankurtaran dept. / section: DOS - MCR
** mentor: Sem Carree dept. / section: DOS - MOD
2nd mentor: Geert Slachmuylders
organisation: Turbulent Hydro
city: Leuven country: Belgium

comments (optional)

Chair should request the IDE Board of Examiners for approval of a non-IDE mentor, including a motivation letter and c.v..

Second mentor only applies in case the assignment is hosted by an external organisation.

Ensure a heterogeneous team. In case you wish to include two team members from the same section, please explain why.

Appendix A: Graduation Brief

TU Delft

Procedural Checks - IDE Master Graduation

APPROVAL PROJECT BRIEF
To be filled in by the chair of the supervisory team.

chair Pinar Cankurtaran date 02 - 03 - 2022 signature Pinar Cankurtaran Digitally signed by Pinar Cankurtaran Date: 2022.03.02 11:55:04 +01'00'

CHECK STUDY PROGRESS
To be filled in by the SSC E&SA (Shared Service Center, Education & Student Affairs), after approval of the project brief by the Chair.
The study progress will be checked for a 2nd time just before the green light meeting.

Master electives no. of EC accumulated in total: 27 EC
Of which, taking the conditional requirements into account, can be part of the exam programme 27 EC
List of electives obtained before the third semester without approval of the BoE

★ YES all 1st year master courses passed
NO missing 1st year master courses are:

name K. Veldman date 08 - 03 - 2022 signature Kristin Veldman Digitally signed by Kristin Veldman Date: 2022.03.08 10:33:25 +01'00'

FORMAL APPROVAL GRADUATION PROJECT
To be filled in by the Board of Examiners of IDE TU Delft. Please check the supervisory team and study the parts of the brief marked **.
Next, please assess, (dis)approve and sign this Project Brief, by using the criteria below.

- Does the project fit within the (MSc)-programme of the student (taking into account, if described, the activities done next to the obligatory MSc specific courses)?
- Is the level of the project challenging enough for a MSc IDE graduating student?
- Is the project expected to be doable within 100 working days/20 weeks ?
- Does the composition of the supervisory team comply with the regulations and fit the assignment ?

Content: ★ APPROVED NOT APPROVED
Procedure: ★ APPROVED NOT APPROVED
comments

name Monique von Morgen date 15 - 03 - 2022 signature

Initials & Name M M Bilsen 5557 Student number 4463854
Title of Project Enlarging the impact of small scale hydropower

Appendix A: Graduation Brief

Personal Project Brief - IDE Master Graduation

TU Delft

Enlarging the impact of small scale hydropower — project title

Please state the title of your graduation project (above) and the start date and end date (below). Keep the title compact and simple. Do not use abbreviations. The remainder of this document allows you to define and clarify your graduation project.

start date 01 - 03 - 2022 — 23 - 08 - 2022 end date

INTRODUCTION **

Please describe, the context of your project, and address the main stakeholders (interests) within this context in a concise yet complete manner. Who are involved, what do they value and how do they currently operate within the given context? What are the main opportunities and limitations you are currently aware of (cultural- and social norms, resources (time, money,...), technology, ...).

In a world that is moving towards renewable energy and has increasing (electric) energy demands (REN21, 2021; IEA 2021), the need for renewable energy is greater than ever before. We need to move from fossil fuels to renewables to prevent the acceleration of the greenhouse effect. Recently, amidst rising political tensions, energy independence is becoming of renewed interest in Europe (Euronews, 2022).

Turbulent Hydro (a Belgian scale-up founded in 2015, with around 20 employees) has developed a small scale run of the river hydropower plant (see figure 1). It gives cheap and sustainable electrical energy. It often gives cheaper and more consistent energy than solar panels for example, in a much smaller footprint (Turbulent, 2020). However, the impact of small scale hydro is still quite low. The power installed has increased, but this could be accelerated much further. Right now, people want to invest in this technology, but don't have the site to develop it. Or site owners do not have the investment, but want to use the energy of the river. Municipalities, Water Authorities, or local governments often need to permit the building of such a hydropower plant. Electricity buyers (e.g. local communities, energy companies, factories) need to be on board, as well as grid operators. Local contractors need to know how to build a correct concrete casting. In short, many stakeholders are involved. This makes installing a hydropower plant a complex process.

Clients right now include non-profits, individual households, project developers, etc. The emphasis of completed projects has mainly been on smaller installations for clients with a strong intrinsic motivation for installing clean and reliable electric power, eventhough the technology of Turbulent Hydro was relatively new (innovators). Now that the technology has proven itself, it is time to move towards larger scale implementation of Turbulent's turbines and reach early adopters, and groups thereafter.

Euronews. (2022, February 25). Europe's reliance on Russian fossil fuels may push it towards energy independence, says Germany. https://www.euronews.com/green/2022/02/25/europe-s-reliance-on-russian-fossil-fuels-may-push-it-towards-energy-independence-says-ger

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Appendix A: Graduation Brief

introduction (continued): space for images

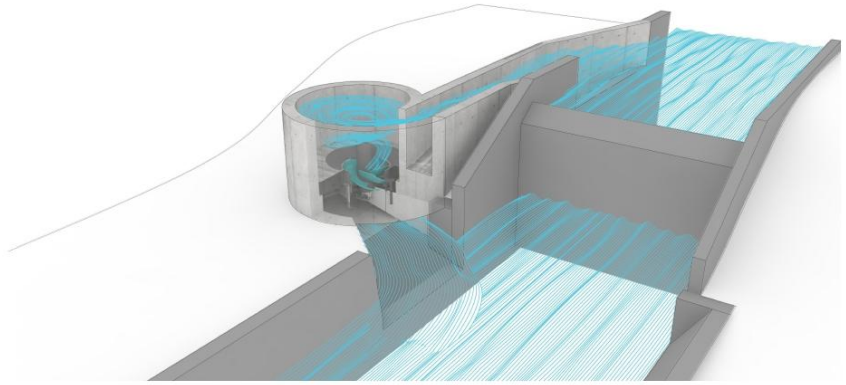


image / figure 1: Overview of a hydropower plant by Turbulent Hydro

image / figure 2: One of the early projects installed by Turbulent Hydro

Appendix A: Graduation Brief

Personal Project Brief - IDE Master Graduation

TU Delft

PROBLEM DEFINITION **

Limit and define the scope and solution space of your project to one that is manageable within one Master Graduation Project of 30 EC (= 20 full time weeks or 100 working days) and clearly indicate what issue(s) should be addressed in this project.

In my opinion, the small scale hydropower plants of Turbulent Hydro are not currently having the impact on society they would be able to have. The power installed is relatively low and the scaling of the company seems to be somewhat slow. The technology works and has been proven. Now it needs to be rolled out on a larger scale. There seems to be little industry around installing small scale hydropower.

Based on the principles of impact investing (Chen, 2022), impact is here defined as a mix of the following:
Environmental impact (Tons of CO2 saved)
Power installed (Watts)

Having a greater impact should lead to higher financial gains for Turbulent Hydro, enabling it to grow sustainably and at a higher pace. Especially since profits are coupled to the power installed, which is coupled to the environmental impact.

At this moment, Turbulent Hydro serves 3 types of projects: single households, project based and systematic (multiple turbines). They want to create more focus. It is unclear which type of project is the most strategic to choose.

Major bottlenecks right now are: 1) high amount of overhead costs. Too much specific engineering is needed for every project. 2) 70% of the leads are for small (single household) projects. However, right now those are not profitable. 3) Getting the right permits can be challenging, especially in Europe. 4) Financing the projects can be difficult. 5) Bringing the right people together is complex

Chen, J. (2022, February 24). Impact Investing Definition. Investopedia. Retrieved 28 February 2022, from https://www.investopedia.com/terms/i/impact-investing.asp

ASSIGNMENT **

State in 2 or 3 sentences what you are going to research, design, create and / or generate, that will solve (part of) the issue(s) pointed out in "problem definition". Then illustrate this assignment by indicating what kind of solution you expect and / or aim to deliver, for instance: a product, a product-service combination, a strategy illustrated through product or product-service combination ideas, ... In case of a Specialisation and/or Annotation, make sure the assignment reflects this/these.

Find out what is limiting the scaling of Turbulent Hydro and deliver a roadmap on how to tackle those problems and prototype some of those solutions. Make a strategic choice about which type of project to focus on. The goal is to increase the impact of small scale hydropower.

Make a roadmap of a future vision. Develop prototypes of possible products/services that would help Turbulent Hydro in making more impact. Perform interviews, creative sessions, stakeholder (value) mapping, SWOT analysis, Trend Analysis, make a business model canvas and look critically at the value proposition. Take learning from the solar/windpower industry on how to bring this product to market. Assess the market potential and business plans of the 3 types of projects. Choose the most strategic type of project type. Do suggestions for the commercialisation of the prototypes.

Possible products/services could be:
- A crowdfunding platform to connect crowdfunders and hydropower site owners
- A tool for site owners to fill in the parameters of their site and get the optimal turbine and construction
- An investment fund to finance the installation of hydropower turbines

Initials & Name M M Bilsen 5557 Student number 4463854

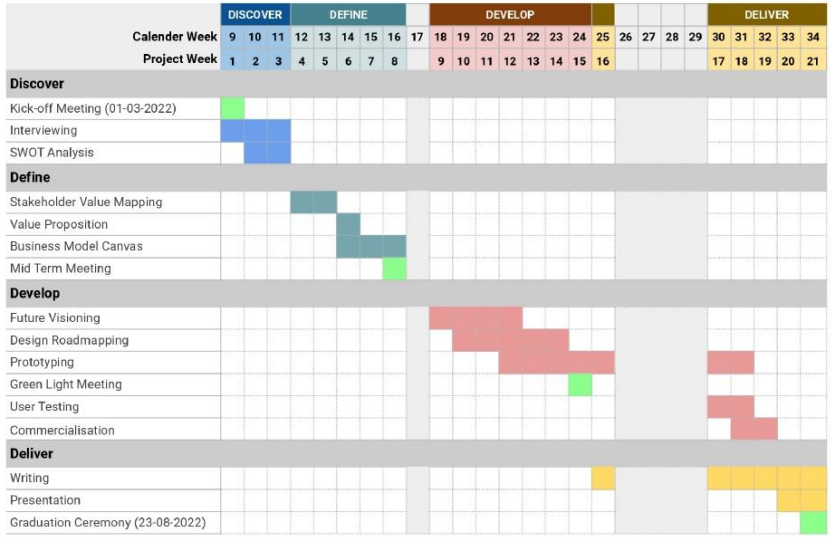
Title of Project Enlarging the impact of small scale hydropower

Appendix A: Graduation Brief

PLANNING AND APPROACH **

Include a Gantt Chart (replace the example below - more examples can be found in Manual 2) that shows the different phases of your project, deliverables you have in mind, meetings, and how you plan to spend your time. Please note that all activities should fit within the given net time of 30 EC = 20 full time weeks or 100 working days, and your planning should include a kick-off meeting, mid-term meeting, green light meeting and graduation ceremony. Illustrate your Gantt Chart by, for instance, explaining your approach, and please indicate periods of part-time activities and/or periods of not spending time on your graduation project, if any, for instance because of holidays or parallel activities.

start date 1 - 3 - 2022 23 - 8 - 2022 end date



The double diamond design process will be followed. First, the context will be explored by talking to the major stakeholders. Those include for example people at Turbulent Hydro, clients, potential clients, clients that cancelled their orders. The goal is to find out what pains exist when developing a small scale hydropower plant. I will also look at the strengths, weaknesses, opportunities, and threats of Turbulent.

During the define phase, I will define the problems around installing small scale hydro. I will do this by looking at the values of the different stakeholders, and creating and revising a value proposition and business model for Turbulent.

During the develop phase, I'll create a future vision and make a design roadmap. I'll prototype some of the solutions that are part of this future vision.

During the deliver phase, I will mainly focus on prototyping and writing/presenting the thesis.

Calendar weeks 17 and 26-29 will be spent as breaks.

Appendix A: Graduation Brief

MOTIVATION AND PERSONAL AMBITIONS

Explain why you set up this project, what competences you want to prove and learn. For example: acquired competences from your MSc programme, the elective semester, extra-curricular activities (etc.) and point out the competences you have yet developed. Optionally, describe which personal learning ambitions you explicitly want to address in this project, on top of the learning objectives of the Graduation Project, such as: in depth knowledge a on specific subject, broadening your competences or experimenting with a specific tool and/or methodology, ... Stick to no more than five ambitions.

As we all know, we have a climate crisis to solve. I would like to make a difference in that, especially when it also makes great economic sense. I think that the renewable energy sector is a sector that offers that. I find Turbulent Hydro a very interesting player in that market, as it is a scale-up that offers a new solution with some desirable benefits.

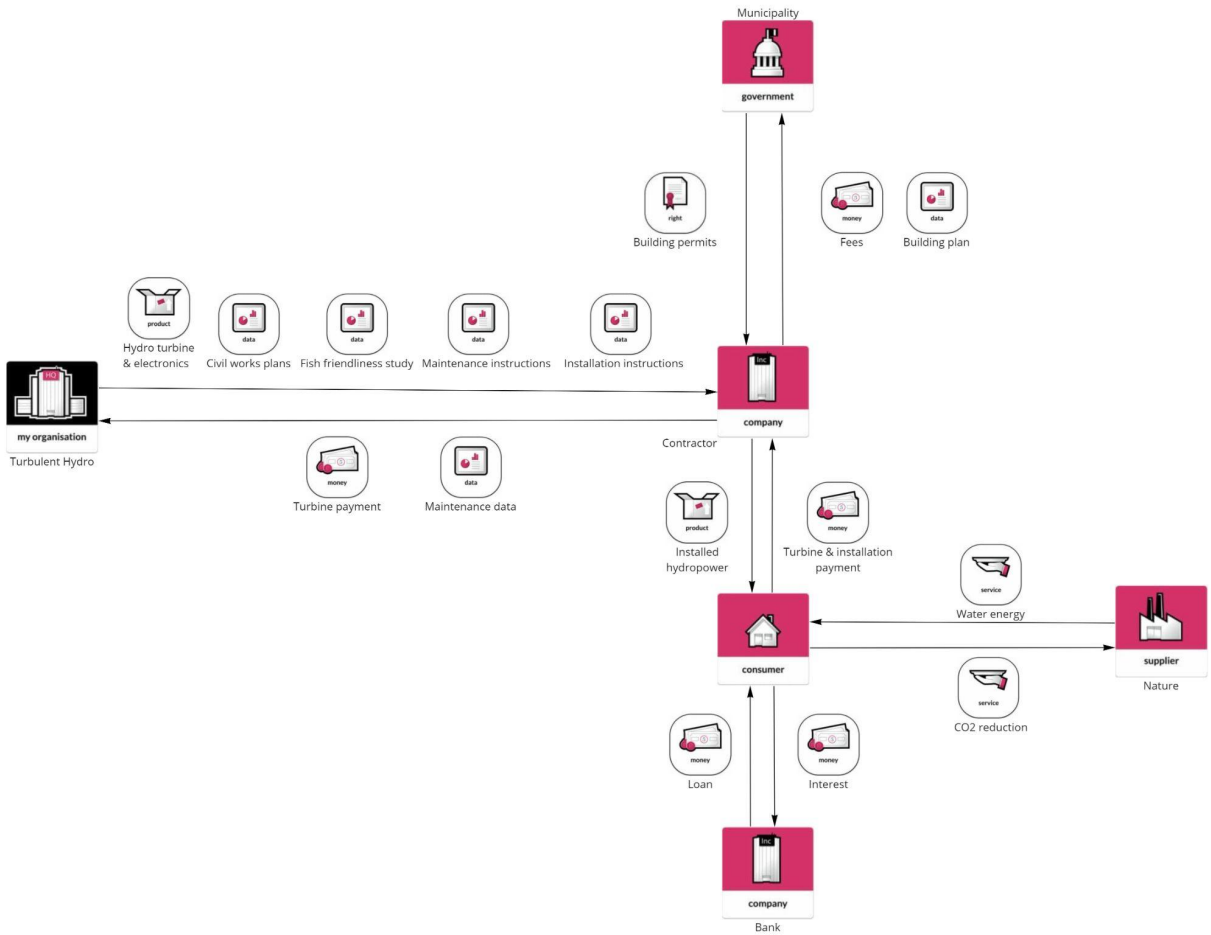
To learn about how to create broad value for and get people onboard in a project, I want to learn about Stakeholder Value Mapping. To make strategic decisions in what type of product to focus on, I want to become better at making Business Model Canvasses and become better at New Product Economics. To become better at Future Visioning and steering a company in a sensible strategic direction, I want to learn more about Design Roadmapping. To implement strategic decisions, I want to become better at prototyping new solutions. Furthermore, I want to learn more about the renewable energy sector and about project development. This might be something I want to work in after graduation.

FINAL COMMENTS

In case your project brief needs final comments, please add any information you think is relevant.

Appendix B: Stakeholder Value Map

For a high resolution version see: https://miro.com/app/board/uXjVOGUeWEg=/?share_link_id=757558813398



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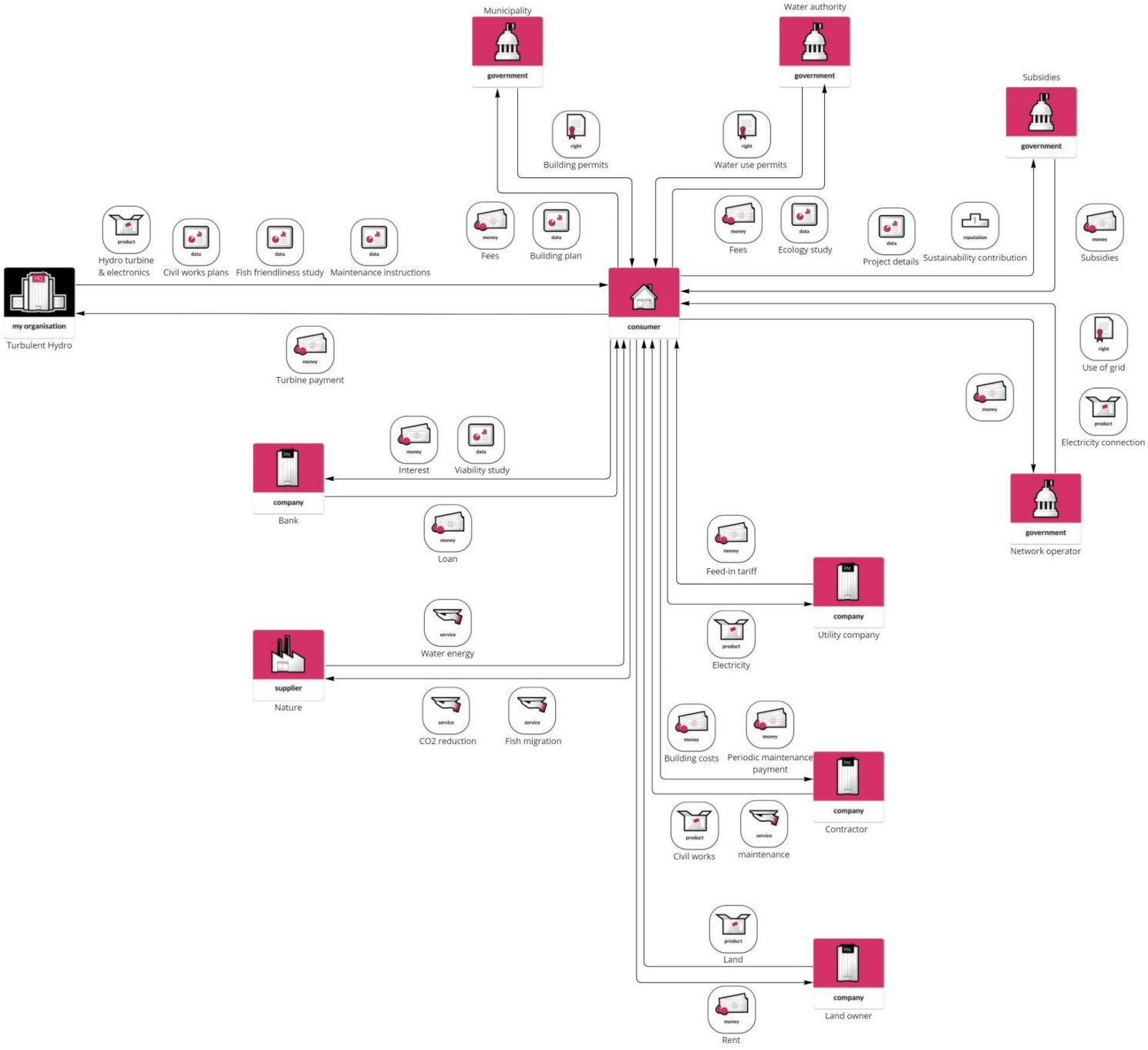
Municipality
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Water authority
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Subsidies
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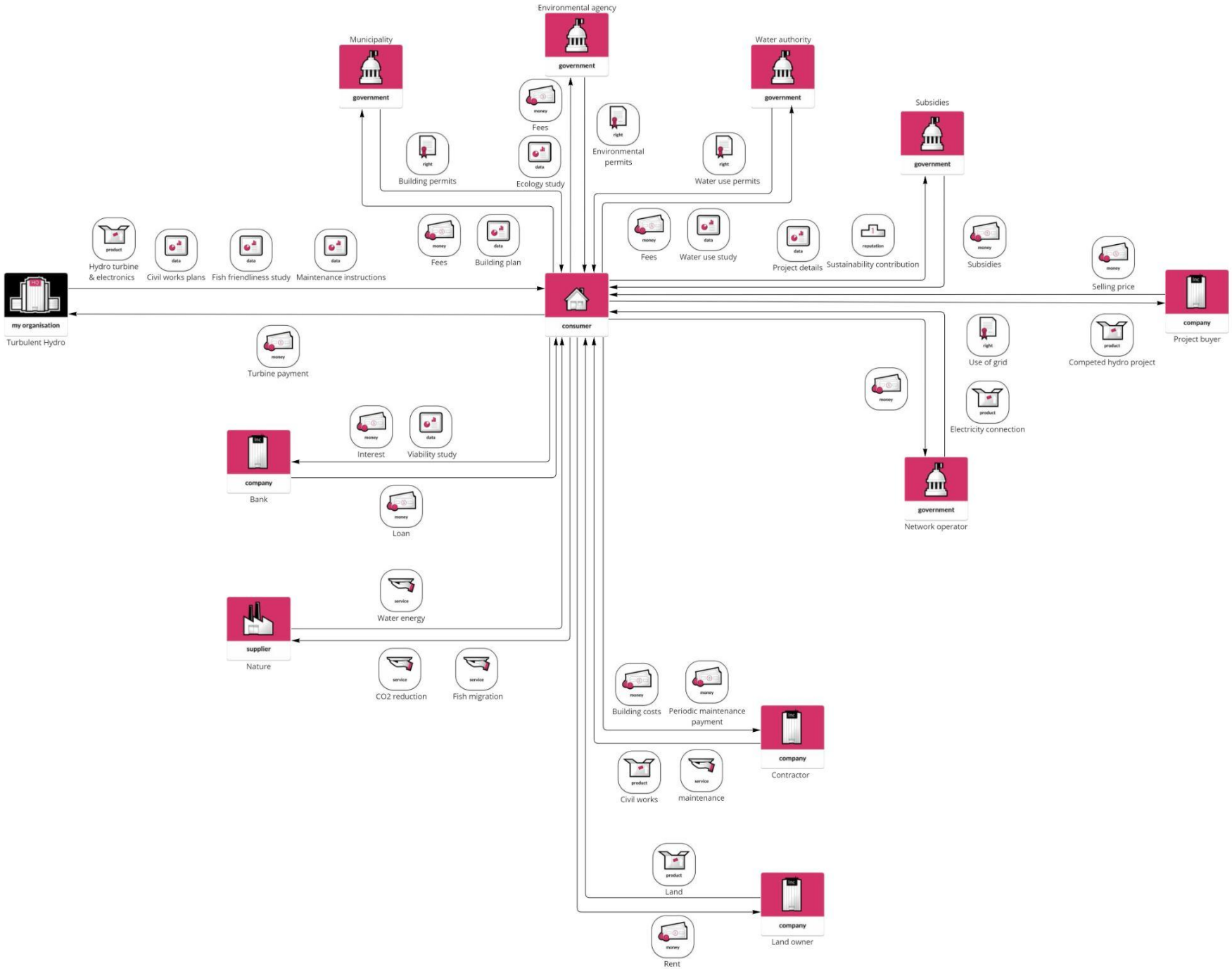
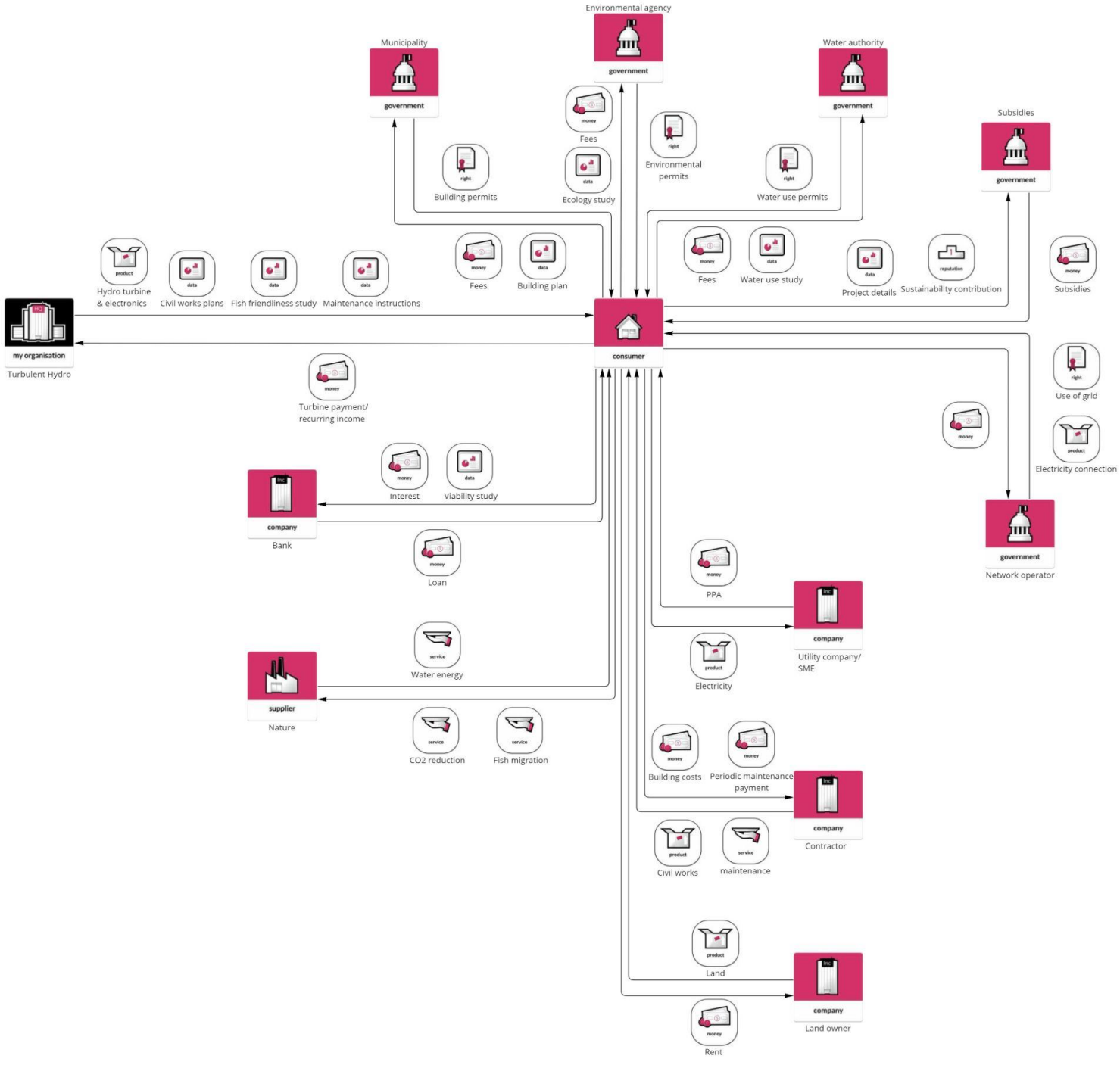
Building permits
Water use permits
Hydro turbine & electronics
Civil works plans
Fish friendliness study
Maintenance instructions
Fees
Building plan
Fees
Ecology study
Project details
Sustainability contribution
Subsidies
my organisation
Turbulent Hydro
consumer
Turbine payment
Use of grid
Electricity connection
Interest
Viability study
company
Bank
Loan
Network operator
Feed-in tariff
company
Utility company
Water energy
Electricity
supplier
Nature
CO2 reduction
Fish migration
Building costs
Periodic maintenance payment
company
Contractor
Civil works
maintenance
Land
company
Land owner
Rent

Project Developer



IPP/Partner


Environmental agency
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Water authority
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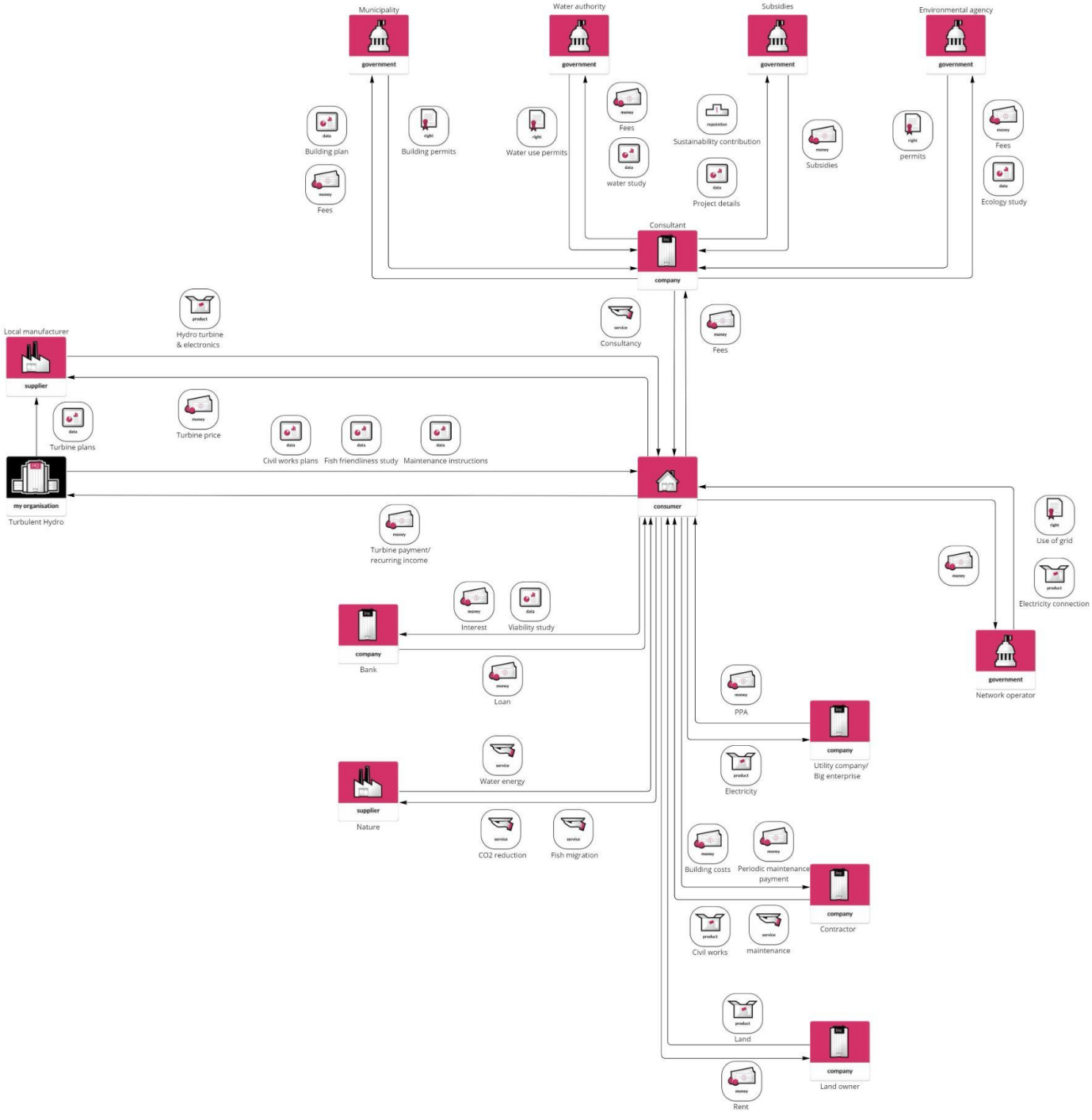
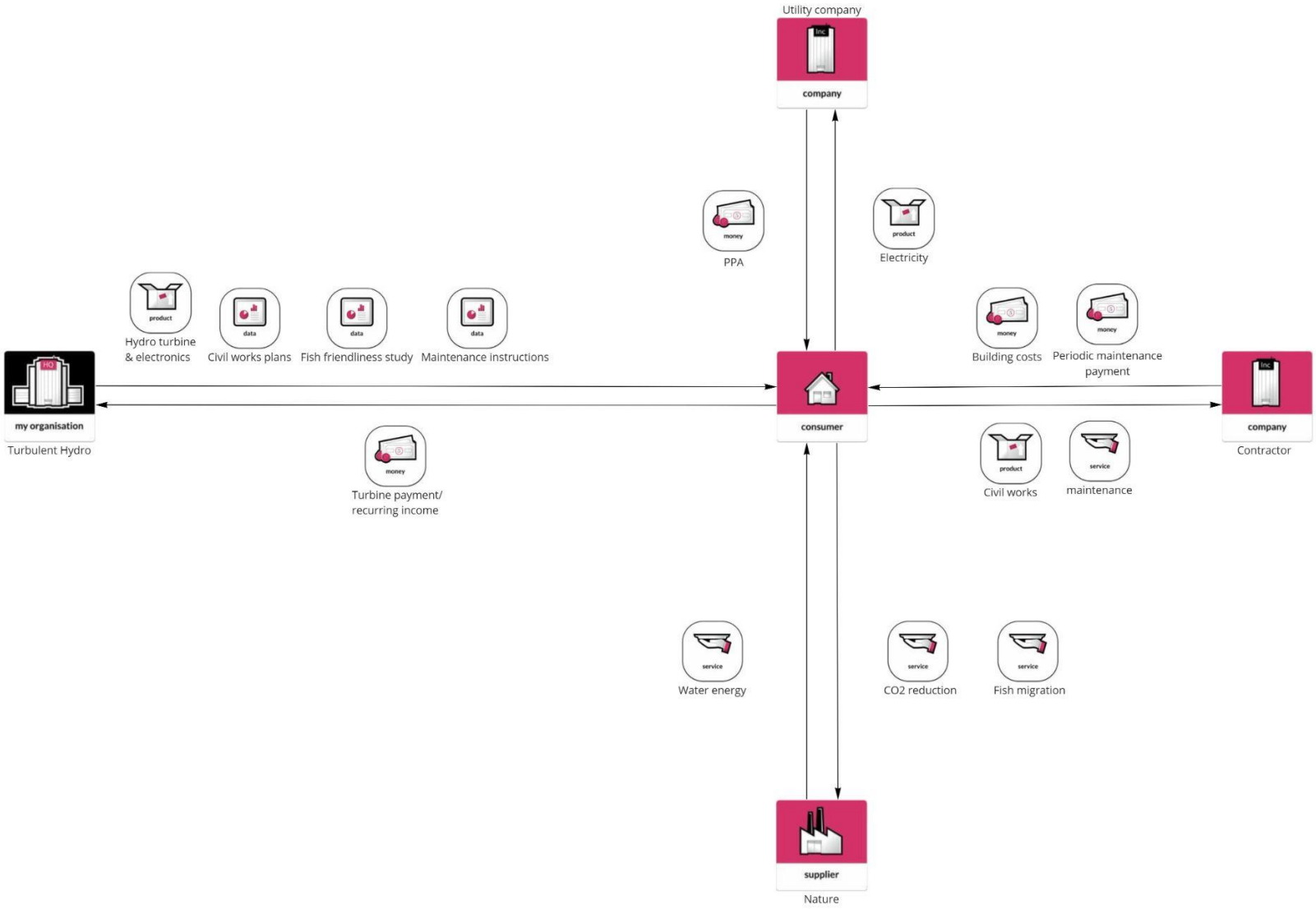
Fees
Environmental permits
Building permits
Ecology study
Water use permits
Fees
Water use study
Project details
Sustainability contribution
Subsidies
Hydro turbine & electronics
Civil works plans
Fish friendliness study
Maintenance instructions
Fees
Building plan
my organisation
Turbulent Hydro
consumer
Turbine payment/ recurring income
Use of grid
Electricity connection
Interest
Viability study
company
Bank
Loan
government
Network operator
PPA
company
Utility company/ SME
Water energy
Electricity
supplier
Nature
CO2 reduction
Fish migration
Building costs
Periodic maintenance payment
company
Contractor
Civil works
maintenance
Land
company
Land owner
Rent

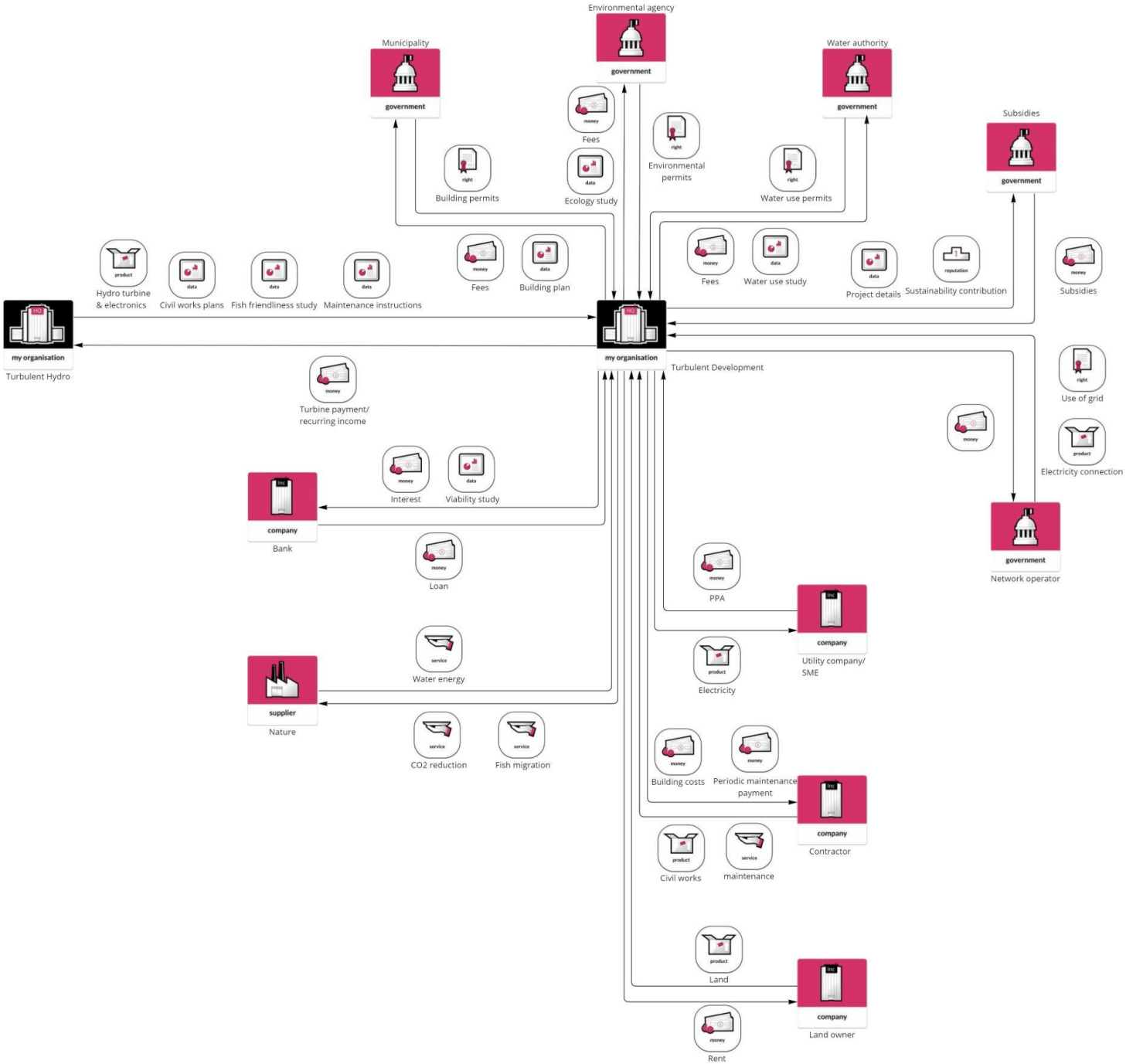
Systematic IPP



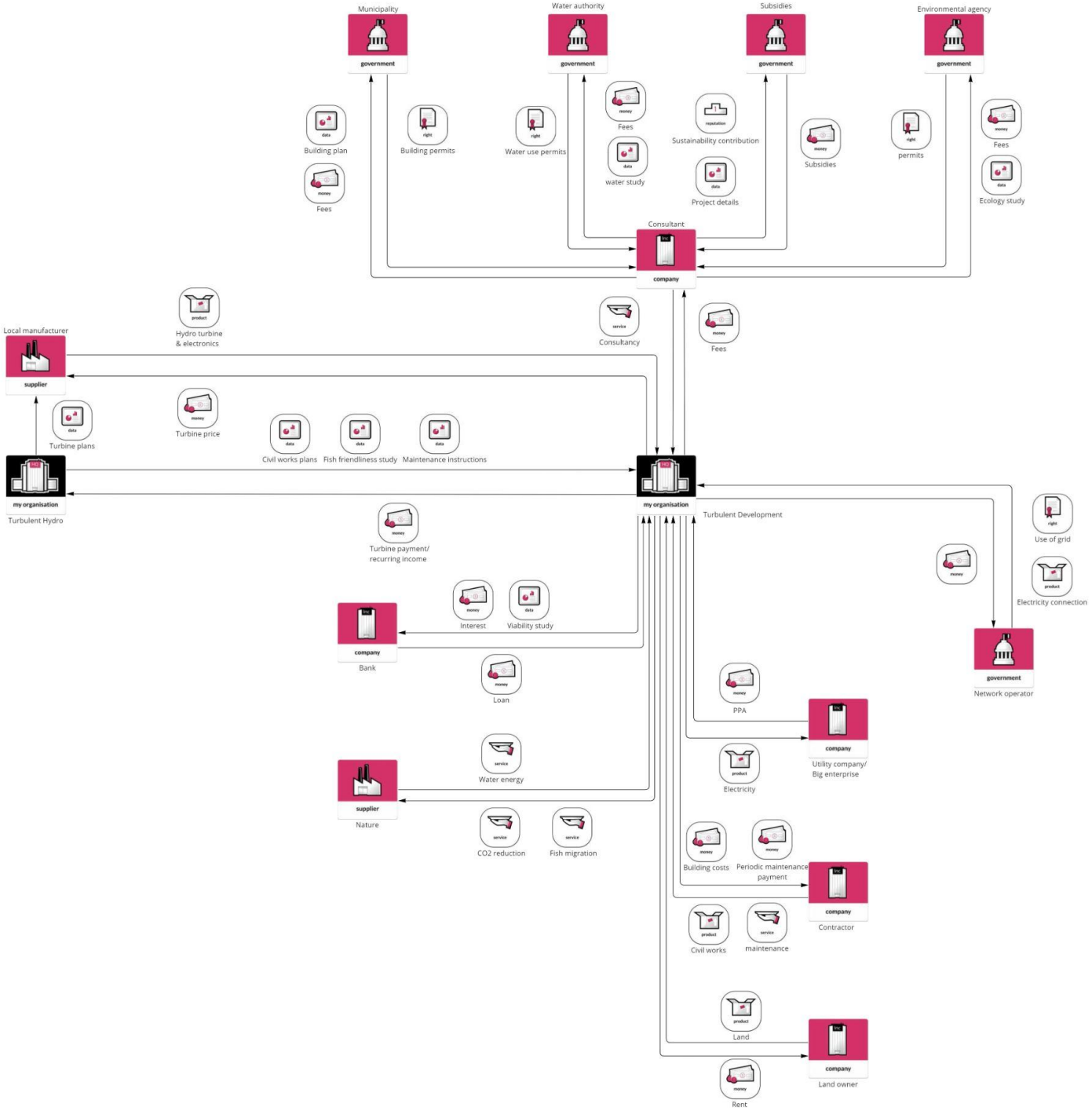
Government


Utility company
company
PPA
Electricity
Hydro turbine & electronics
Civil works plans
Fish friendliness study
Maintenance instructions
Building costs
Periodic maintenance payment
my organisation
Turbulent Hydro
consumer
company
Contractor
Turbine payment/ recurring income
Civil works
maintenance
Water energy
CO2 reduction
Fish migration
supplier
Nature

Turbulent Development



Turbulent Development (large scale)



Appendix C: Interviews with partners

Interview with Partner Taiwan, on 14-4-2022 through Zoom by Marijn Bilsen

Why did you decide to develop hydropower?

I live close to a river and when I saw the video I immediately thought of the potential.
Taiwan is going nuclear free and we need a lot of renewable energy. Space for solar is limited. Micro hydro is not developed yet. It is a blue ocean

What attracted you to Turbulent?

Survivability and fish friendliness

How did you find Turbulent Hydro?

Through a video of Business Insider

Did you look at other hydropower solutions? If so, why did you choose Turbulent?

Yes, a program in Taiwan, but the survivability was low (they would clog all the time)

How has the process of installing hydropower been for you?

Very hard. We have been working for 3 years now on two projects (one 100 kw and four 15 kw). There are no real previous references for projects like this, so we have a lot of difficulty in getting permits or grants. There have also been bad experiences with past micro hydro projects (some projects were never built).

Appendix C: Interviews with partners

Permits needed:

- Permit for starting the application process (6 months)
- Property permit
- Use of water permit
- Hydraulic structure review
- Permits for
- Permits for feeding in energy to the grid
- In the future, we want to get a permit to sell energy to any company through a PPA

With who did you have to collaborate to get your project going? (e.g. water authorities, banks, contractors). Which are problematic?

How was your experience with them? How could this be made better?

- Taipower (energy company): difficult as they were unsure whether the energy would be “clean” (right voltage, frequency, etc.). Hydro is very new to them and they don’t know how to handle it
- Irrigation agency
- River agency
- Water and soil reservation agency
- Local governments
- Contractors: somewhat difficult, because they want to do the engineering themselves. However, we can do this in-house.
- Local companies In the future, Taiwanese companies need to buy 100% renewable energy. Some will do this through PPAs

Appendix C: Interviews with partners

Anything with permits is difficult

What are your goals in hydro?

We see this project as a pilot that we finance ourselves. If it shows to be successful, we want to install much more hydro and get subsidies for it.

What are the top 3 pains you experienced while installing hydropower?

- Viability: Feed-in-tariffs do not cover the costs that well. Construction is very expensive right now. Payback time is something like 12 years. It used to be 8 years.
- Permits: authorities don't have previous successful examples of micro-hydro and are reluctant to give permits
- Construction: high construction costs

What could Turbulent improve on to make your business as a hydropower developer easier?

- Learn us how to do a feasibility study (i.e. defining the kw) of a site. We want to quickly survey many sites and now we have to wait for Turbulent to do some calculations, which slows down the process. In 2 years a lot of potential sites will be released and we want to do quick tendering and bidding, so we want to move quickly.
- Do co-marketing and branding of the technology. We need to convince many different stakeholders that this is a good renewable technology, so they will more fluently give permits, funding, etc.
- Local manufacturing would be great to be able to get permits easier ("Made in Taiwan" works great with local governments), to cut costs (labour, transport) and to lower transport emissions.

Appendix C: Interviews with partners

- Foreign investment. Taiwanese government is very much in favour of this. If there is co-investment from Turbulent or some other foreign party, that is a big plus for the Taiwanese government

How important is local manufacturing in your view? How would you unlock such possibilities? Would you be willing to invest in such a setup when it brings long term cost reductions?

Investment by us or by Turbulent in local manufacturing would both work. Maybe an authorized manufacturer, joint venture, or Turbulent opening a factory in Taiwan

What info are you missing? What help do you miss when trying to secure a project?

- Local manufacturing: lower cost, easier permits, we can outcompete other bidders, grants for foreign technologies to come to Taiwan. Maybe in the future, we could also export turbines made in Taiwan to South Eastern Asia. Lot of potential there. We have a network there.

How important is the ecological aspect and fish friendliness of our turbine in your market segments? Are there other features that are important?

- Fish friendliness is one of the major reasons for choosing Turbulent.
- High survivability: large debris can get through
- Low maintenance

Main Insights

- Learn them to do a feasibility study so they can quickly assess a potential site
- Do co-marketing and branding of the technology to convince governmental organisations
- Set up local manufacturing to lower costs, convince government agencies, and cut emissions
- Co-invest, to convince government agencies

Appendix C: Interviews with partners

Interview with Partner USA, on 22-4-2022 through Zoom by Marijn Bilsen

Why did you decide to develop hydropower?

We have a house near a river and wanted to power the house.

What attracted you to Turbulent?

Low head solution

How did you find Turbulent Hydro?

Through the web

Did you look at other hydropower solutions? If so, why did you choose Turbulent?

Efficiency, good communications (other companies never answered), low rpm, simple construction, low maintenance, fish friendliness.

How has the process of installing hydropower been for you?

With who did you have to collaborate to get your project going? (e.g. water authorities, banks, contractors). Which are problematic?

Appendix C: Interviews with partners

Assistance program from Vermont State to go through hoops and loops of Federal and local agencies. Regulations, applications, etc.

DoE Department of Energy: They need to certify the Turbulent technology. Maybe Turbulent can help in convincing them. Demonstrate, provide information, fish studies that Turbulent did. We would be the middle man in communication with the DoE. Certification makes permitting by FERC much easier.

FERC Federal Energy Regulatory Commission: is geared towards large hydro. They have some exceptions for small hydro, but they have little experience with it. We can now sent 4-5 applications together, which is great.

ANR Agency of Natural Resources: goes to the site to do field research. Needs to know what the regime of the river is. There needs to be a measurement system that has measured the river for a full year, if not longer. They need to know if enough water will be able to bypass the system. Otherwise, the ANR will not give permits.

About 1200 dams, many unused. Weir owners are sometimes difficult to find. Often it is the state or a town. Sometimes an electricity company.

Private mill owners react very differently to proposals to install a turbine at their place. Some give away the space for free, some want to get electricity (through a PPA), and others want money. The power company (Green Mountain Power) does not like the electricity being sold through a PPA, because then they can't claim the green rights. They prefer net-metering

Investment is gathered through banks, private investors, or through grants

We introduce the technology to local schools.

Appendix C: Interviews with partners

How was your experience with them? How could this be made better?

Everybody is working with you, but they work slow.

What are your goals in hydro?

We have about 200 locations in mind. We want to show through a pilot that this project works. We want to take about 3 years to install approximately 500-750 kW. For this, we need loans, investments, and grants. After that, we would be able to grow the business sustainably through in house financing.

Combination with batteries could be valuable. Great selling point to villages that sometimes have power cuts.

What are the top 3 pains you experienced while installing hydropower?

- Get a location
- Know what the water volumes are
- Bureaucracy (1-3 year permit process)

What could Turbulent improve on to make your business as a hydropower developer easier?

Certification by DoE. Pilot project to show to FERC that it works.

How could Turbulent better assist you in getting permits?

Appendix C: Interviews with partners

How important is local manufacturing in your view? How would you unlock such possibilities? Would you be willing to invest in such a setup when it brings long term cost reductions?

Do electrical works here. It makes more sense as we know how to work with US standards and can certify it here locally. Eventually maybe also generator production/buying
Eliminate shipping.
We can set the manufacturing capacity

What info are you missing? What help do you miss when trying to secure a project?

Preliminary design

What minimum power makes sense for you?

100 kW, otherwise it doesn't make sense going through all the permitting.
500 kW is right now the upper limit, as this is when net-metering stops.

How do you define your pricing?

Net metering, right now 14 cents/kWh

What is your average time for closing a deal and delivering a project?

About 2 years, but after a pilot we might move faster

Appendix C: Interviews with partners

Main insights

We would like:

- A better database of river flows.
- To have Turbulent learn our local contractor to do a preliminary study
- To be the go to partner for people in this region that want to work with Turbulent. We have the local knowledge.
- To eventually do some local manufacturing, especially the electrical connections made to US code.
- Get certification of Turbulent technology by DoE

Appendix C: Interviews with partners

Interview with Partner Philippines, on 26-4-2022 through Google Meets by Marijn Bilsen

Why did you decide to develop hydropower?
I am an engineer. Always on the look for interesting technologies to apply. The market has a significant need for electricity. The legal framework for small electric producers is already in place. As climate change becomes worse, the business opportunity for clean technologies becomes better. The solutions to climate change exist, but need to be deployed

What attracted you to Turbulent?
Compactness
Easy to deploy
Easy to handle
Easy to distribute
marketing at World Economic Forum makes it legitimate
Low investment threshold
Rapidly deployable
No specialised knowledge needed
Low maintenance costs

How did you find Turbulent Hydro?
Social media. Twitter. World Economic Forum

Appendix C: Interviews with partners

Did you look at other hydropower solutions? If so, why did you choose Turbulent?

How has the process of installing hydropower been for you?
Difficult and takes a long time. When we have a pilot project, we expect things to become easier

With who did you have to collaborate to get your project going? (e.g. water authorities, banks, contractors). Which are problematic?
RCDTC Cooperation local distributor
Civil Engineer
United Hydropower Builders: hydropower construction team
Department of Energy (open to talk)
Water Board (Bureaucratic)
Utility company (difficult contact)
Finexpo (Belgian governmental development export initiative)
National irrigation authority (bad in communication/possibly very corrupt)

How was your experience with them? How could this be made better?
Use marketing material from Turbulent.
Make a pilot project to show that it works.

What are your goals in hydro?
Complete my 2 projects and then we'll see if it is worth developing further
Maybe partner with another company to do bigger projects

Appendix C: Interviews with partners

What are the top 3 pains you experienced while installing hydropower?

- Finding the customer for the electricity. The market here in the Philippines is not ready for buying energy from this new technology
- Finding technical data for the sites.
- Financing
- Hydrology patterns are changing and there might be less water in the future

What could Turbulent improve on to make your business as a hydropower developer easier?

- Use your the GIS tool
- Software to calculate the flow duration curve based on rainfall, catchment area etc.
- Standardise site finding
- Pre drafted feasibility study from GIS tool
- Pre drafted viability indication of a site in GIS tool
- Share success stories from other developers. Lessons learned by other developers. Copy good practices.

How could Turbulent better assist you in getting permits?

No

How important is local manufacturing in your view? How would you unlock such possibilities? Would you be willing to invest in such a setup when it brings long term cost reductions?

No, not in the Philippines. Making an engineering company is very difficult here. Maybe in Malaysia or Taiwan

What info are you missing? What help do you miss when trying to secure a project?

Appendix C: Interviews with partners

How important is the ecological aspect and fish friendliness of our turbine in your market segments? Are there other features that are important?
Moderately important. Permitters ask for this

We need proof of concept. We need a project in the Philippines

What minimum power makes sense for you?
Something like 30 kW. Here you can go through the whole process and make money.

How do you define your pricing?
0.12 dollar per kWh.

Financing through (development) banks

What is your average time for closing a deal and delivering a project?
Almost 2 years and we are not yet there.
The absolute minimum would be 8-9 months

Doing a project with some turbines from Turbulent and some horizontal Kaplan turbines from another supplier

Main Insights

- We want to use your GIS tool
- Would be great to have a pre-drafted version of a feasibility and viability study from the GIS tool
- Share success stories and lessons learned from developers in other regions. We want to learn from them

Appendix C: Interviews with single household clients

Interview with Single Household 1 from the USA on 3-5-2022 through Google Meets by Marijn Bilsen

Questions Single Households

Why do you want to install hydropower?
Energy is too expensive

What attracted you to Turbulent?

How did you find Turbulent?

Do you have flowing water (e.g. river) nearby?

Is it on your property?

Do you know what kind of permits you need?
Not really. Probably water use rights.

Would you want to get the permits yourself or pay somebody (around $500) to do that?
That's good

Would you want to do the installation yourself or pay somebody (around $1000) to do that?
Local partner

Appendix C: Interviews with single household clients

Would you prefer to get support from Turbulent directly or from a local partner?
Local partner

What kind of size in kW would you need?
Both bigger and smaller

Can we contact you in the future about the design of this turbine?
Yes

Runnig for the city council. Small city (20,000 people). We have running creeks. Oregon

Is also looking for a bigger project. We need to spend 14 million to demolish a dam. We should just put in a hydro project.

Single household would be interesting for some houses.

Contact Geert for bigger turbines

This is one of the turbines that I'm running my campaign on

Main insights

- Cities sometimes want to develop their own hydropower
- Energy independence is important
- Turbines can be part of a renovation project

Appendix C: Interviews with single household clients

Interview with Single Household 2 from the UK on 4-5-2022 through Google Meets by Marijn Bilsen

Questions Single Households

Why do you want to install hydropower?
We are a contractor wanting to install hydropower. We had an inquiry for installing hydropower on a client's property. We are not yet involved in hydropower.

What attracted you to Turbulent?
Saw it on the internet. Fish friendliness, high quality manufacturer,

How did you find Turbulent Hydro?
Through the internet. I looked around micro hydro a bit and came across a lot of Chinese stuff (not too keen on buying that) and a Canadian manufacturer who had a water wheel. Your solution seems the most sensible.

Do you know what kind of permits you need?
This goes through SEPA in Scotland.
I'll check with the local council
Somewhat, but I will look into this and get back to you in about 10 days

Would you want to get the permits yourself or pay somebody (around $500) to do that?
I would do that for clients. This would probably take a day and cost 400 UK pounds.
Clients would be scared of doing this.

Appendix C: Interviews with single household clients

Would you want to do the installation yourself or pay somebody (around $1000) to do that?
Our company would do it. The solution would preferably be plug and play.

Would you prefer to get support from Turbulent directly or from a local partner?
We could be a partner and install turbines in Scotland

Would you agree with a price of the total installation of $6000 for a 2 kW version? If not, what would be acceptable?
Sounds good! Probably better than solar
Solar installed was somewhere around 7500 UK pounds

Can we contact you in the future about the design of this turbine?
Yes

Has a company in smart electronics
We will be doing our first battery install in a couple of weeks
There has been an upturn in energy reduction (e.g. solar and battery systems)
We had an inquiry for a hydro installation. A farm with a good stream
It makes more sense here in Scotland as in the winter, we do not have a lot of solar energy, but we do have streams.
We also do infrared heating. Hydropower would work great in conjunction with this heating.
Possibly an integration with batteries would be great.
Old buildings would need higher kW versions
Maybe it makes more sense to target communities
I know some people in the highlands and islands development board
Adding hydrogen to natural gas. Standard boilers can take up to 20% hydrogen.

Appendix C: Interviews with single household clients

Main Insights

- Potential partner for installing hydropower in Scotland
- Inquiries are coming in for small-scale hydro
- SEPA seems to be in favour of small-scale hydropower
- Permits need to be done by a contractor because it scares off people
- Getting the permits fixed takes probably around a day and costs 400 UK pounds
- The solution should be as plug and play as possible
- Pricing is alright
- Increased interest in renewable energy
- Old buildings may need higher kW versions, say 3-4 kW

Appendix C: Interviews with single household clients

Interview with Single Household 3 from France on 6-5-2022 through Google Meets by Marijn Bilsen

Questions Single Households

Why do you want to install hydropower?
I am thinking about buying a house near the water. An old water mill for example, because it has a permit.
For personal use and reselling to the grid.
For sustainability. Local clean energy is the best approach

How did you find Turbulent?
Internet, looking for innovation

Do you have flowing water (e.g. river) nearby?
Not yet, but in the future yes. 4-5 years.

Is it on your property?
It would be, with a side channel of the main river.

Do you know what kind of permits you need?
Water rights (droit d'eau). Has to be an existing right. Municipal permits are probably needed. You need to declare your project and show that you do not have an impact on the ecology.

Would you want to get the permits yourself or pay somebody (around $500) to do that?
I would like to do us much as possible myself. For this cost it might be worth it to let someone else do it.

Appendix C: Interviews with single household clients

Would you want to do the installation yourself or pay somebody (around $1000) to do that?
Concrete structure I can not build.
Electrical I can do myself, but for insurance reasons I would go through a professional installer, especially the plug in to the grid.
Plastic/steel casing seems sensible.

Would you prefer to get support from Turbulent directly or from a local partner?
Direct support from Turbulent.
For installation, maintenance, regulations, permit process, etc. local partners
For technical support Turbulent would be great.

Would you agree with a price of the materials of $6000 for a 2 kW version? If not, what would be acceptable?
Sounds totally affordable and cheaper than other options

Can we contact you in the future about the design of this turbine?
Yes

West of Europe has a lot of old water mills that are interesting to develop
Pay as you produce could be interesting for some people. I would go for buying it in one go.

Possibly I would not live there all the time that the turbine gives a return.
How can we make it comply with grants?

Automatic cleaning would be great.

Something connected that you can remotely clean it.

Are you looking for investors?

Appendix C: Interviews with single household clients

Main insights

- Would like to do permitting process myself, unless it is very cheap
- Water rights in France are very difficult to get, unless there are existing water rights (old mill)
- Would like to have the installation done by a professional, not because he can't do it, but for insurance reasons. Especially the connection to the grid
- Plastic/steel casing seems sensible
- Price of $3000/kW is good
- Prefers local partners for: installation, maintenance, regulations, permit process, etc.
- Technical support would preferably come directly from Turbulent
- Pay as you produce could be interesting for some people
- Automatic cleaning needs to be an option

Appendix C: Interviews with single household clients

Interview with Single Household 4 from St. Kitts & Nevis on 6-5-2022 through Google Meets by Marijn Bilsen

Questions Single Households

Why do you want to install hydropower?
Solar is dirty electricity. Can not be recycled very well.

Has no idea how energy works. Wants to pump water to then let it flow down. Wants to use a solar panel to drive a generator to turn water and get that energy out using a turbine. Insane.

Pays $6/kWh, due to the electricity coming from propane from a boat that constantly lays in port.

Main insights

- Some leads are highly uninformed
- Some places have very high electricity costs
- We need to work with partners, so we don't have to deal with uninformed leads

Appendix C: Interviews with single household clients

Interview with Single Household 5 from Sweden by Marijn Bilsen on 11-5 through Google Meets

Questions Single Households

Why do you want to install hydropower?
Good for the environment, I have a stream I want to use

What attracted you to Turbulent?

How did you find Turbulent?

Do you have flowing water (e.g. river) nearby?
Yes

Is it on your property?
Yes

Do you know what kind of permits you need?
No

Would you want to get the permits yourself or pay somebody (around $500) to do that?
Consultant

Appendix C: Interviews with single household clients

Would you want to do the installation yourself or pay somebody (around $1500) to do that?
I can do this myself

Would you prefer to get support from Turbulent directly or from a local partner?
Turbulent, as I will do the installation myself

What kind of size in kW would you need?
15 kW, to sell back to the grid

Would you agree with a price of the materials of $7000 for a 2 kW version? If not, what would be acceptable?
Sounds fair

Can we contact you in the future about the design of this turbine?
Yes

Appendix C: Interviews with single household clients

Interview with Single Household 6 from the US by Marijn Bilsen on 12-5 through phone call

Questions Single Households

Why do you want to install hydropower?
Power our 200 farms more sustainably

What attracted you to Turbulent?
Low cost, fish friendliness

How did you find Turbulent?
Web

Do you have flowing water (e.g. river) nearby?
Yes, many farms do

Is it on your property?
Yes

Do you know what kind of permits you need?
Not yet, but will find out

Would you want to get the permits yourself or pay somebody (around $500) to do that?
Consultant

Appendix C: Interviews with single household clients

Would you want to do the installation yourself or pay somebody (around $1500) to do that?
Contractor

Would you prefer to get support from Turbulent directly or from a local partner?
Local partner

What kind of size in kW would you need?
5 kW usually

Would you agree with a price of the materials of $7000 for a 2 kW version? If not, what would be acceptable?
Sounds good

Can we contact you in the future about the design of this turbine?
Yes

Appendix C: Interviews with single household clients

Interview with Single Household 7 from Slovakia by Marijn Bilsen on 13-5-2022 through phone call

Questions Single Households

Do you have flowing water (e.g. river) nearby?
Yes

Is it on your property?
Yes

Do you know what kind of permits you need?
Building permit, but thinks that he has the water rights, because it is on his land. Probably not right.

Would you want to get the permits yourself or pay somebody (around $500) to do that?
Do myself

Would you want to do the installation yourself or pay somebody (around $1500) to do that?
I have a small construction company, so I would do this myself.

Would you prefer to get support from Turbulent directly or from a local partner?
I would want to be your partner

What kind of size in kW would you need?
At first, just a small house
After that, a farm, some flats
Something like 1-15 kW

Appendix C: Interviews with single household clients

Would you agree with a price of the materials of $7000 for a 2 kW version? If not, what would be acceptable?
Sounds fair

What if it would be a different kind of turbine?
I would prefer a Turbulent turbine

Can we contact you in the future about the design of this turbine?
Yes

Appendix C: Interviews with single household clients

Interview with Single Household 8 from Belgium by Marijn Bilsen on 13-5 through phone

Questions Single Households

Why do you want to install hydropower?

What attracted you to Turbulent?

How did you find Turbulent?

Do you have flowing water (e.g. river) nearby?
Yes, old watermill

Is it on your property?
Yes

Do you know what kind of permits you need?
Yes, already in place

Would you want to get the permits yourself or pay somebody (around $500) to do that?
Not applicable

Appendix C: Interviews with single household clients

Would you want to do the installation yourself or pay somebody (around $1500) to do that?
We need a consultant on the feasibility and a contractor

Would you prefer to get support from Turbulent directly or from a local partner?

What kind of size in kW would you need?
Unsure

Would you agree with a price of the materials of $7000 for a 2 kW version? If not, what would be acceptable?
Sounds alright

Can we contact you in the future about the design of this turbine?
Yes

Appendix C: Interviews with single household clients

Interview with Single Household 9 from France by Marijn Bilsen on 13-5 through phone call

Questions Single Households

Do you have flowing water (e.g. river) nearby?
Yes

Is it on your property?
Yes

Do you know what kind of permits you need?
Yes, but I don't have them. The drops in the river are too small

What kind of size in kW would you need?
1 or 2 kW

Would you agree with a price of the materials of $7000 for a 2 kW version? If not, what would be acceptable?
Sounds alright

On or off grid?
Off grid

Appendix C: Interviews with single household clients

Interview with Single Household 10 from France by Marijn Bilsen on 13-5 through phone call

Questions Single Households

Do you have flowing water (e.g. river) nearby?
Yes

Is it on your property?
Yes

Do you know what kind of permits you need?
Somewhat. Says that they just need permission from the mayor, who they have good relations with.

Would you want to get the permits yourself or pay somebody (around $500) to do that?
We can do it ourselves

Would you want to do the installation yourself or pay somebody (around $1500) to do that?
Hire a contractor and have someone from Turbulent come

Would you prefer to get support from Turbulent directly or from a local partner?
Someone on the ground from Turbulent, installing by a local contractor

What kind of size in kW would you need?
Around 30 kW

Can we contact you in the future about the design of this turbine?
Yes

Appendix C: Interviews with single household clients

Interview with Single Household 11 from France by Marijn Bilsen on 13-5 through phone call

Questions Single Households

Why do you want to install hydropower?
I have a stream on my property and I want to use the energy

Do you have flowing water (e.g. river) nearby?
Yes, a river and a small lake

Is it on your property?
Yes

Do you know what kind of permits you need?
Not really, I have to look into this

Would you want to get the permits yourself or pay somebody (around $500) to do that?
Pay someone

Would you want to do the installation yourself or pay somebody (around $1500) to do that?
Find a local contractor

Would you prefer to get support from Turbulent directly or from a local partner?
I don't care, but a local partner makes sense

Appendix C: Interviews with single household clients

What kind of size in kW would you need?
2 or 3 kW

Would you agree with a price of the materials of $7000 for a 2 kW version? If not, what would be acceptable?
Sounds good

On or off grid?
On

Can we contact you in the future about the design of this turbine?
Yes

Appendix C: Interviews with single household clients

Interview with Single Household 12 from Belgium by Marijn Bilsen on 13-5 through phone call

Questions Single Households

Why do you want to install hydropower?
We have an old water mill

Do you have flowing water (e.g. river) nearby?
Yes

Is it on your property?
Yes

Do you know what kind of permits you need?
Yes, water rights are in place. We need permits for building in a monument

Would you want to get the permits yourself or pay somebody (around $500) to do that?

Would you want to do the installation yourself or pay somebody (around $1500) to do that?
Contractor

Appendix C: Interviews with single household clients

Would you prefer to get support from Turbulent directly or from a local partner?
Turbulent

What kind of size in kW would you need?
10 kW

Would you agree with a price of the materials of $7000 for a 2 kW version? If not, what would be acceptable?

Can we contact you in the future about the design of this turbine?
Yes, but the project will start only at the end of 2023

Appendix C: Interviews with single household clients

Interview with Single Household 13 from France by Marijn Bilsen on 13-5 through phone

Questions Single Households

Do you have flowing water (e.g. river) nearby?
Yes, a mill

Is it on your property?
Yes

Do you know what kind of permits you need?
Yes, we have the water rights. The old ones for the mill.

Would you want to get the permits yourself or pay somebody (around $500) to do that?
Not needed, as they are already in place

Would you want to do the installation yourself or pay somebody (around $1500) to do that?
Pay somebody to do that

Would you prefer to get support from Turbulent directly or from a local partner?
Preferably from Turbulent directly. Local partner would also be allright

Appendix C: Interviews with single household clients

What kind of size in kW would you need?
2 kW

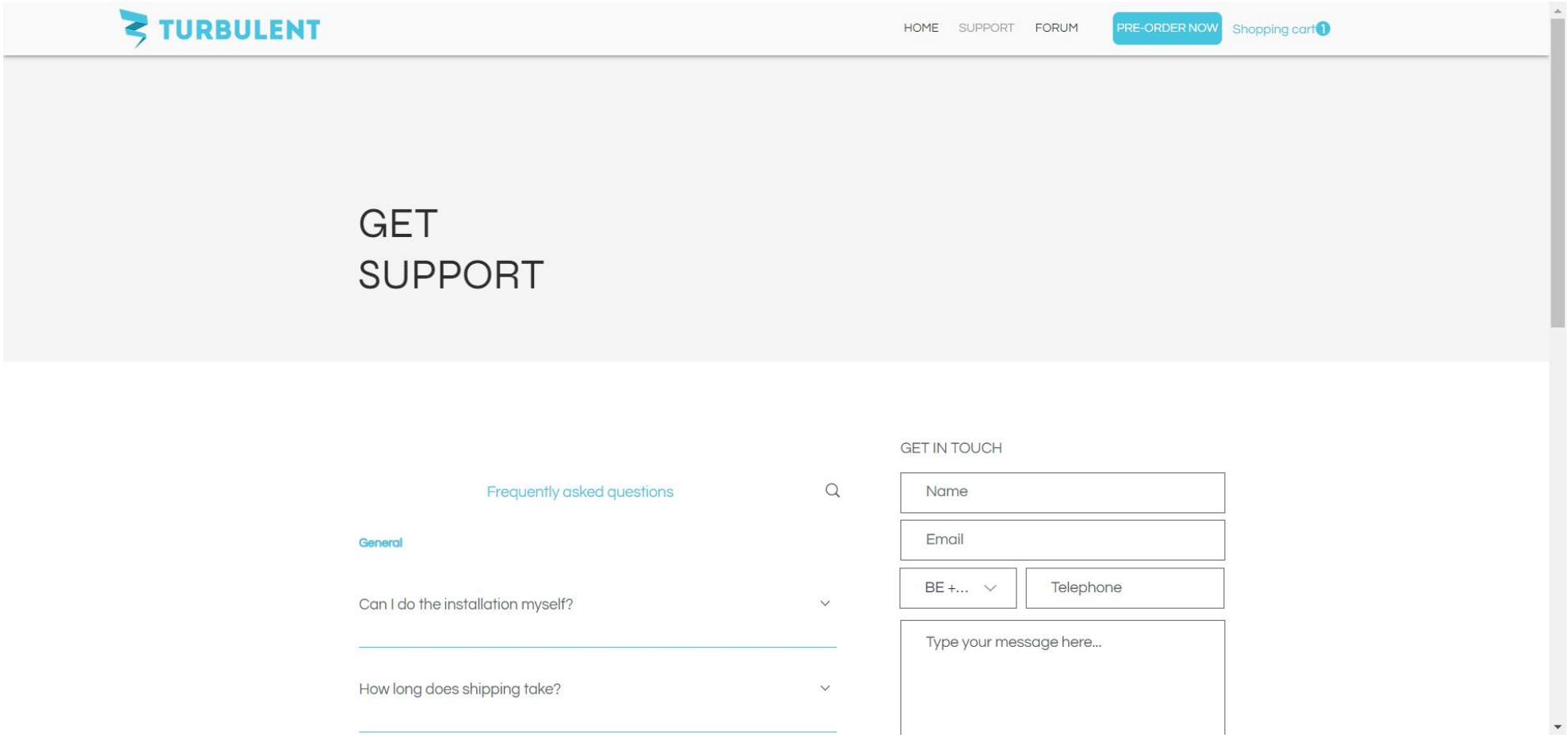
Would you agree with a price of the materials of €8000 for a 2 kW version? If not, what would be acceptable?
Yes, sound alright

How important is the fish friendliness to you?
Very important

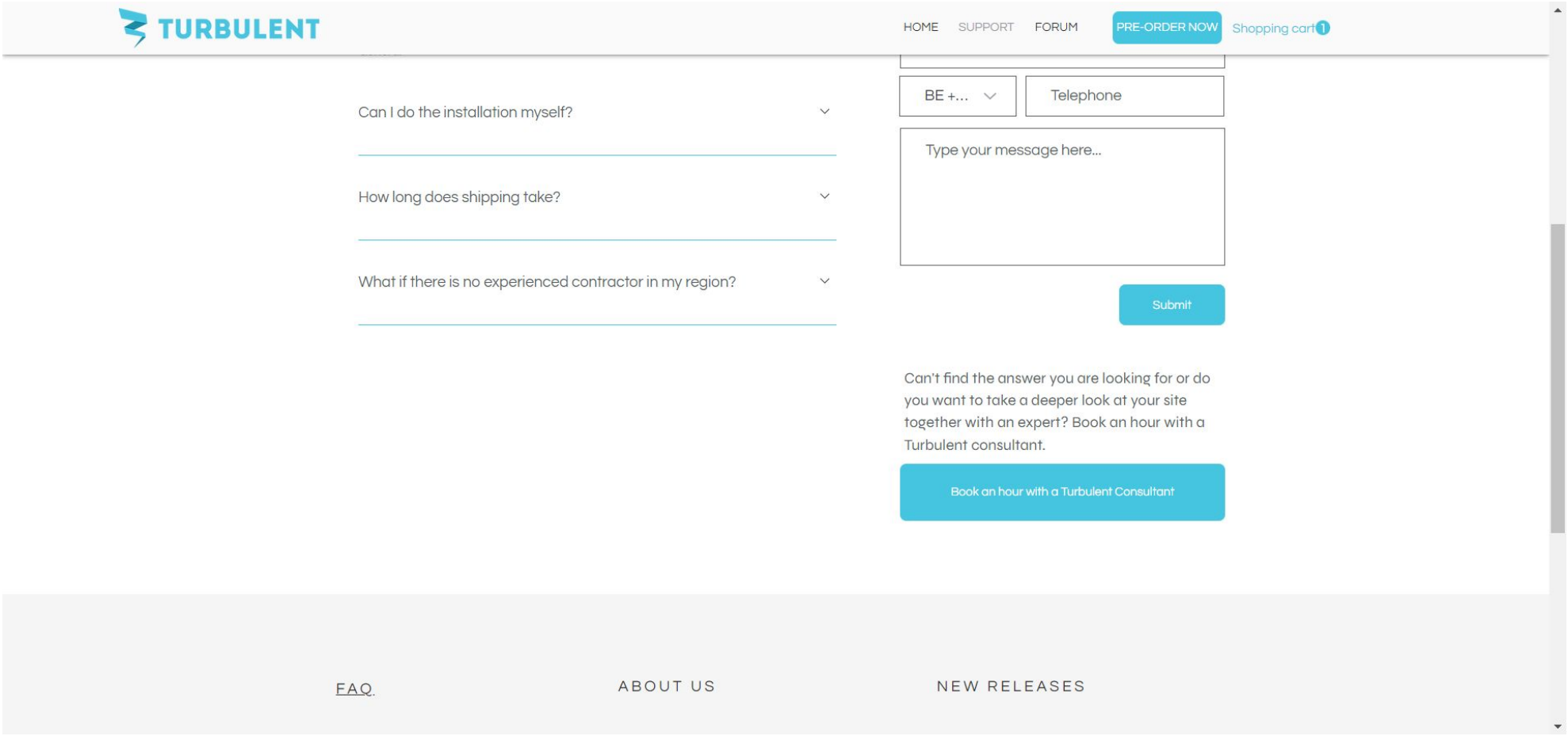
What if it would be a different kind of turbine?
We want the Turbulent turbine.

Can we contact you in the future about the design of this turbine?
Yes

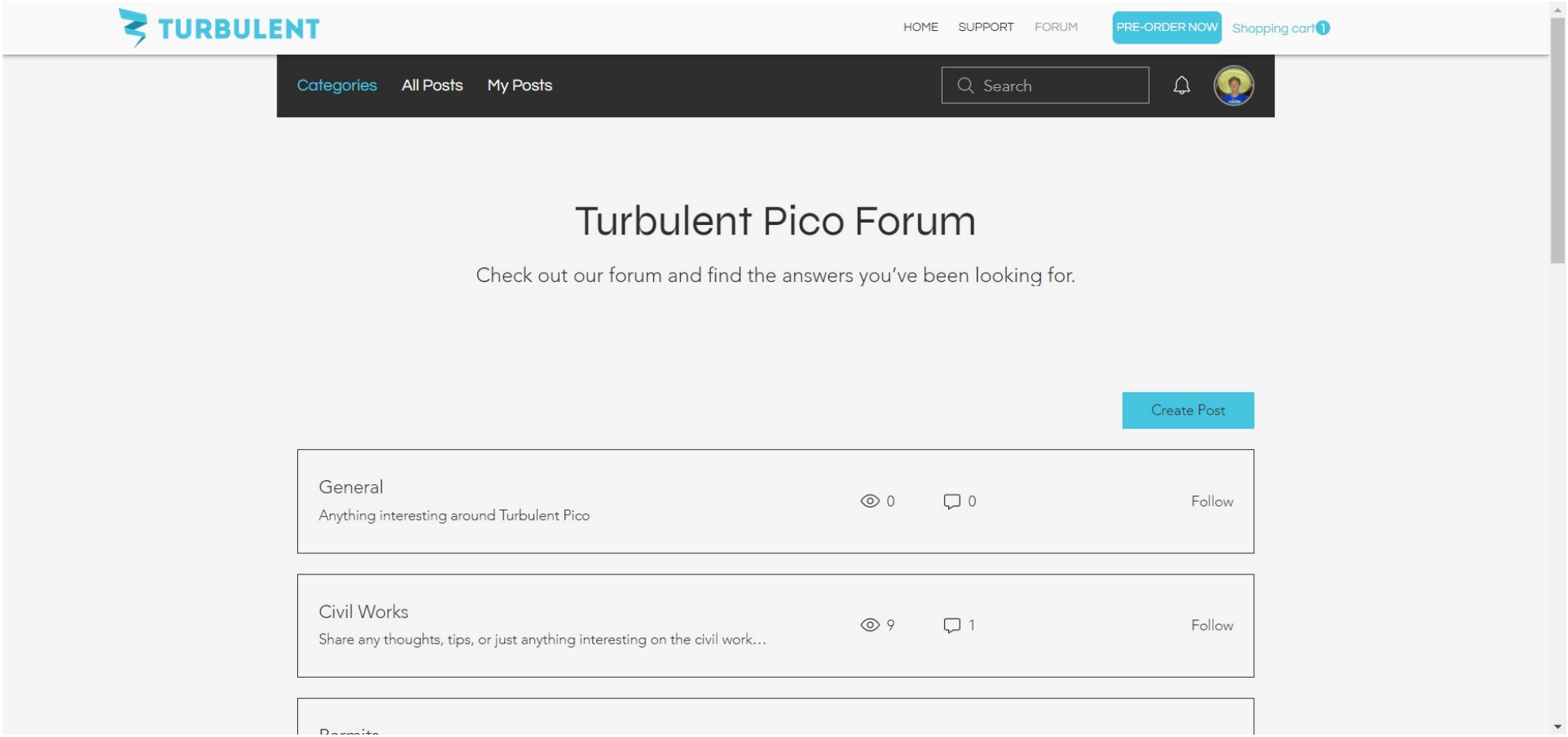
Appendix D: Website support and forum



Appendix D: Website support and forum



Appendix D: Website support and forum



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