

## **Final Outcomes Report**

Agreement Number: ERA018

Ambyint Inc.

Deploying Autonomous Oil & Gas Production Operations with an Adaptive Controller

Prepared by:

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Total ERA Funds Received: \$2,000,000

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Resubmitted: Jan 24, 2022

## **Executive Summary**

In 2018 Ambyint set out to deploy autonomous oil and gas production operations at scale on wells utilizing rod lift and plunger lift. The project's initial focus was on deploying edge/IIoT technologies and data analytics to well optimization. The project transitioned to a greater platform focus to provide a feature set that covers all aspects of production operations. Commercial feedback directed us to focus on supporting multiple deployment models to support the varying environments our customers presented to us. Post project completion we completed a Lifetime Customer Value exercise with a major customer with a 17 month run time and achieved significant benefits across their key metrics.

## **Project Description**

Ambyint set out to deploy autonomous oil and gas production operations on wells utilizing rod lift and plunger lift.

Ambyint's strategy for delivering industrial autonomy is focused on several steps that include:

- Understand customers' problems and end goals
- Perform business analysis to determine company alignment in delivering autonomy
- Evaluate and screen potential solutions
- Concept development and machine learning
- Testing and deployment
- Deliver suitable product solution that provides control in the majority of scenarios

The current 'state of the art' automation and optimization technology stack is fundamentally limited in its ability to enable more advanced control and analytics. Optimization is susceptible to wide dispersion in outcomes when left to manual processes and existing technology. There is therefore significant value in the standardization and alignment that autonomy brings. With the advent of new edge/IIoT technologies and data analytics advances, this serves as an opportunity to bring new capabilities and deliver a step-change in outcomes to the ~1.2 million producing wells in North America.

Through the course of the ERA project Ambyint has submitted a number of 3rd party deliverables to validate and document the activities and objectives outlined above, including the following:

- 1) MAC Consulting Alberta Market Analysis
- 2) Solas Final Milestone Report

In order to centralize the conclusions of those earlier deliverables for ease of reference, Ambyint is providing a summary of each of these reports here.

#### *MAC Consulting Alberta Market Analysis*

The purpose of this report is to provide an unbiased, third-party market assessment of Ambyint's AI and data analysis technology relating to the Canadian market. The averages below are on Rod Lift and Plunger Lift wells alone. Rod Lift wells represent ~24% and Plunger Lift wells represent ~32% of Canadian conventional oil wells.

1. Based on studies performed, electrical consumption would be reduced on wells where this technology is implemented. Projections place reductions at 767.5 kt CO<sub>2</sub>/year with 1194 kt other/year (PM, NO<sub>x</sub>, SO<sub>x</sub>, VOC) by 2025 in Canada alone.
2. Using studies performed, production could be increased on new and existing Rod Lift and Plunger Lift wells. The projected return for operators using today's pricing would yield an additional \$106 million per year for Rod Lift, and \$1.9 billion per year for Plunger Lift based on 2025 projections in Canada.
3. Using studies performed and averages of their results, workover and electrical costs could be decreased on Rod Lift wells. The projected return using today's average would save operators an additional \$227 million per year based on 2025 projections in Canada.

#### *Solas Final Milestone Report*

Ambyint is a privately-owned Canadian developer of an innovative oil and gas pump control technology called the 'Amplify Real-Time Controller'. This technology is a high-resolution adaptive controller (HRAC) that enables autonomous control and optimization of oil and gas wells and fields when paired with Ambyint's supporting cloud software. Ambyint's Amplify technology uses edge devices that integrate with equipment and automation, communications, a cloud software platform, and the deep integration of physics-based analysis with AI/machine learning to deliver autonomous well operations. The HRAC optimizes well performance through autonomous regulation of over-pumping and under-pumping states. As a result, the pumping process is optimized, and efficiencies are gained. The risk of exhausting methane to regulate well pressure is reduced as the HRAC system executes stabilized and continuous adaptive responses. Additionally, the HRAC reduces the risk of liquids exiting the wells at the site. As a successful applicant to Sustainable Development Technology Canada's SD Tech Fund, Ambyint is required to submit a final milestone report on actual environmental impacts and technical performance of the Amplify pump controller (Final Milestone Report). Solas Energy Consulting (Solas), an independent third-party, was engaged by Ambyint to complete the Final Milestone Report. Solas previously completed the milestone one report submitted on behalf of

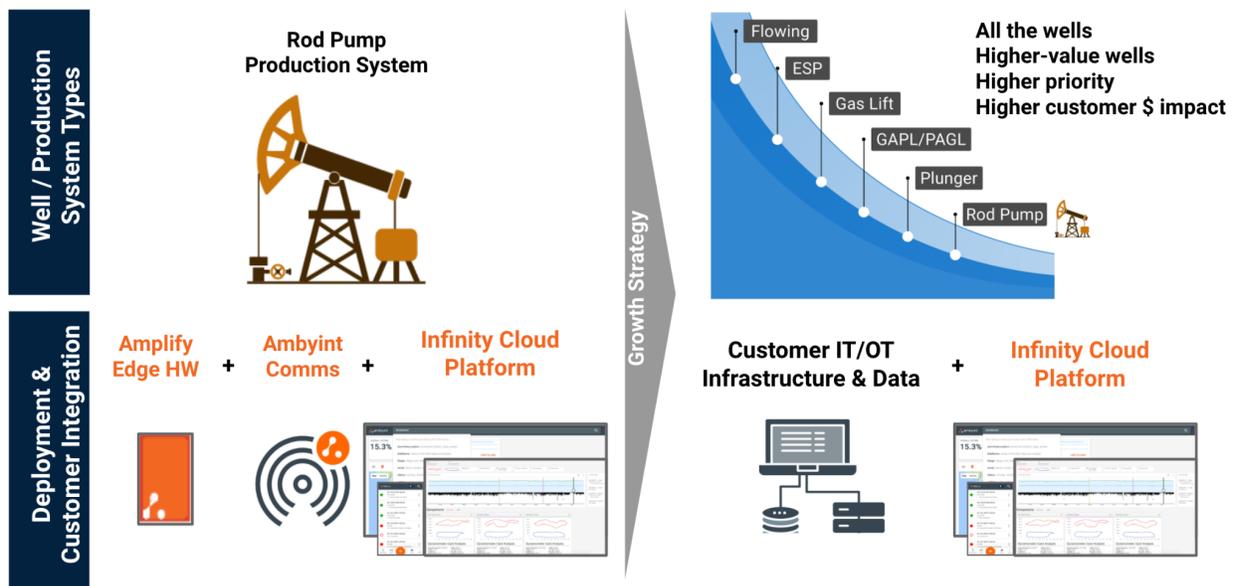
Ambynt to the SDTC in June of 2019 (Milestone One Report). As part of the Final Milestone Reporting, Solas reviewed the asserted environmental benefits documented in the Milestone One Report, identified changes to assumptions, and recalculated the net environmental benefits.

The Milestone One Report identified the inputs and outputs for the baseline case and the project case as they pertained to soil, air contaminants, water, and greenhouse gas impacts or benefits. The Milestone One Report determined net benefits associated with greenhouse gases and air quality, with no expected impacts to water and soils. The Solas team assessed the relevant environmental impacts for the Final Milestone Report by reviewing changes to the process, energy balance models, and documented periodicals.

There have been advancements to the HRAC system between the Milestone One Report and the Final Milestone Report. In addition to the hardware-software integrated HRAC system, Ambynt has developed a software-only solution. This advancement is anticipated to be deployed at a wider scale than the integrated HRAC system. It is anticipated to result in reduced environmental benefits due to decreased data resolution for the HRAC system algorithms. Solas has considered this technological advancement in this Final Milestone Report.

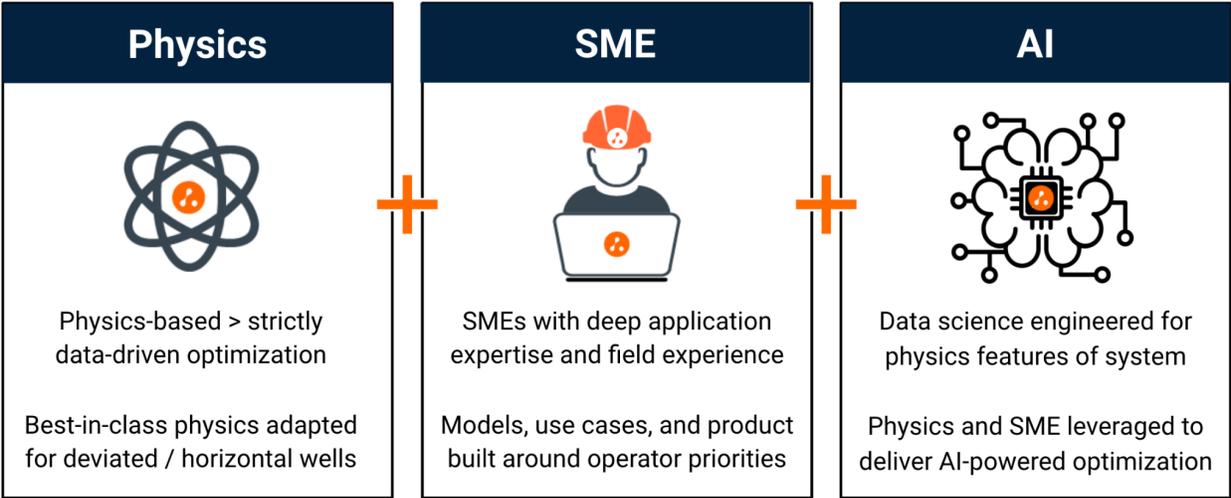
### Project Outcomes and Learnings

The project focus was on supporting Ambynt’s growth strategy via the delivery of optimization (and associated emissions reduction) at scale across multiple lift types and multiple deployment models.

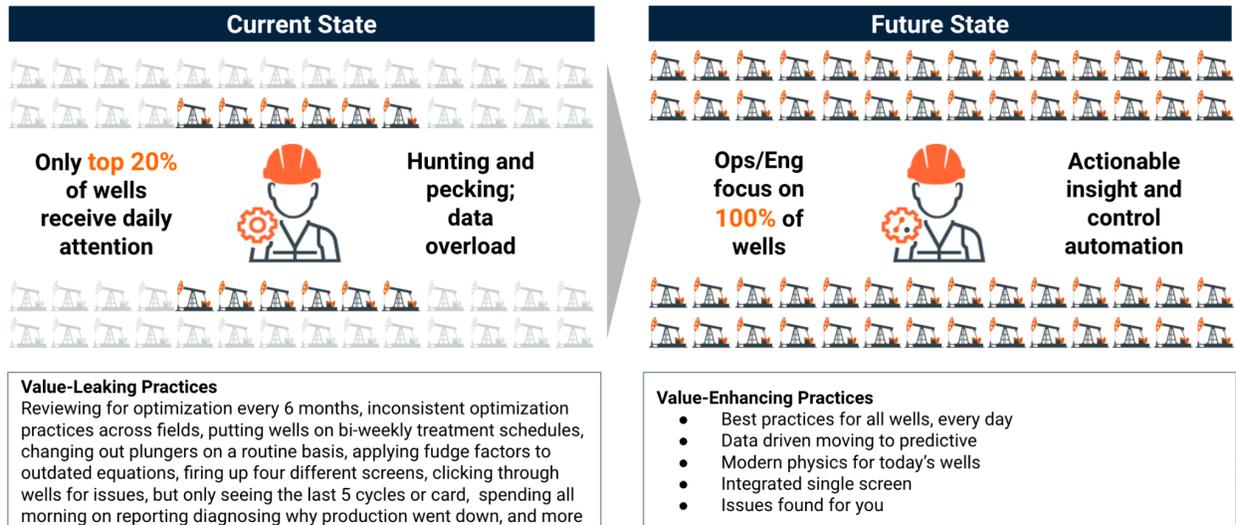


Ambyint’s previous focus was on a single lift type in rod lift and that was enabled via Ambyint’s edge device. The expansion into plunger lift was significant in that it required a re-examination of the approach to a well. Rod lift is the terminal lift type for most oil wells. Throughout a well’s life it may utilize other lift types, this is especially true with wells in unconventional plays. The need for the Ambyint platform to support multiple lift types became apparent as clients are dealing with multiple lift types within a single field and also throughout the life of a well. This operational need translated to a platform developed specifically to address the full life of well.

At the foundation of Ambyint’s strategy (recipe and key differentiator) is the utilization of advanced physics, SMEs and AI to deliver optimization capabilities that impact wells at scale.



This recipe has proven very successful in the delivery of operational scalability in rod lift and is therefore well suited to other artificial lift types like plunger lift. The ability to give operators a more advanced and scalable operations model is even more attractive if that can be done across multiple artificial lift types.



To further expand the reach and impact of our optimization capabilities we focused on supporting multiple deployment models to support the varying environments our customers presented to us. This also allowed our customers to utilize Ambyint alongside their current infrastructure, avoiding the disruption of our previous edge-only strategy.

Ambyint Turnkey	3rd Party Edge Device	SCADA Integration
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Ambyint edge+cloud SW deployed into Ambyint edge device



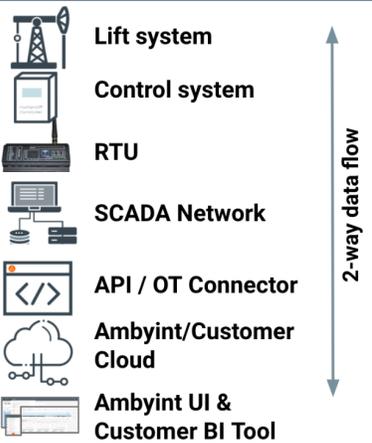
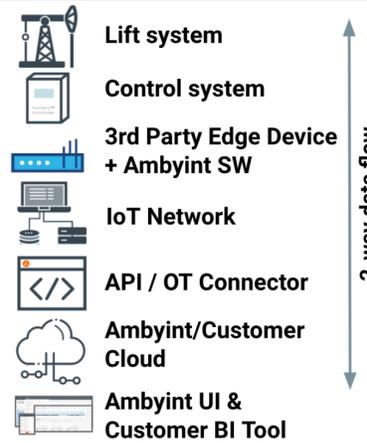
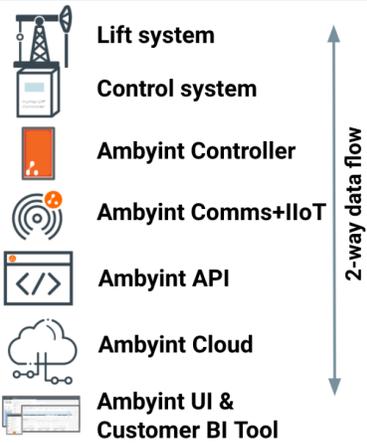
Ambyint edge+cloud SW deployed into 3rd party edge device



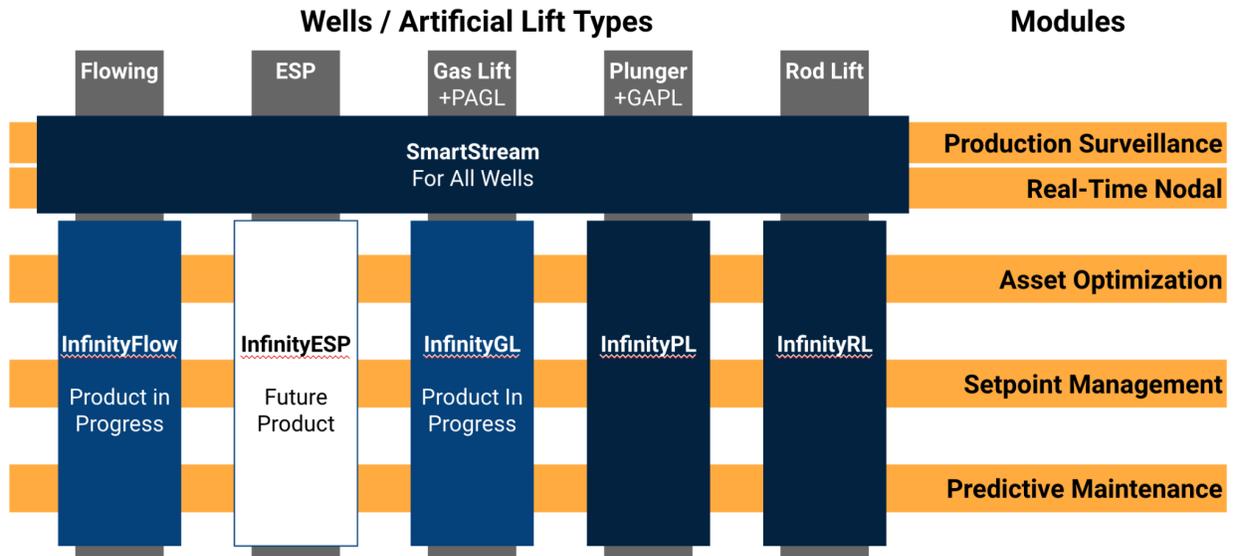
Ambyint cloud SW deployed via data integration w/ SCADA



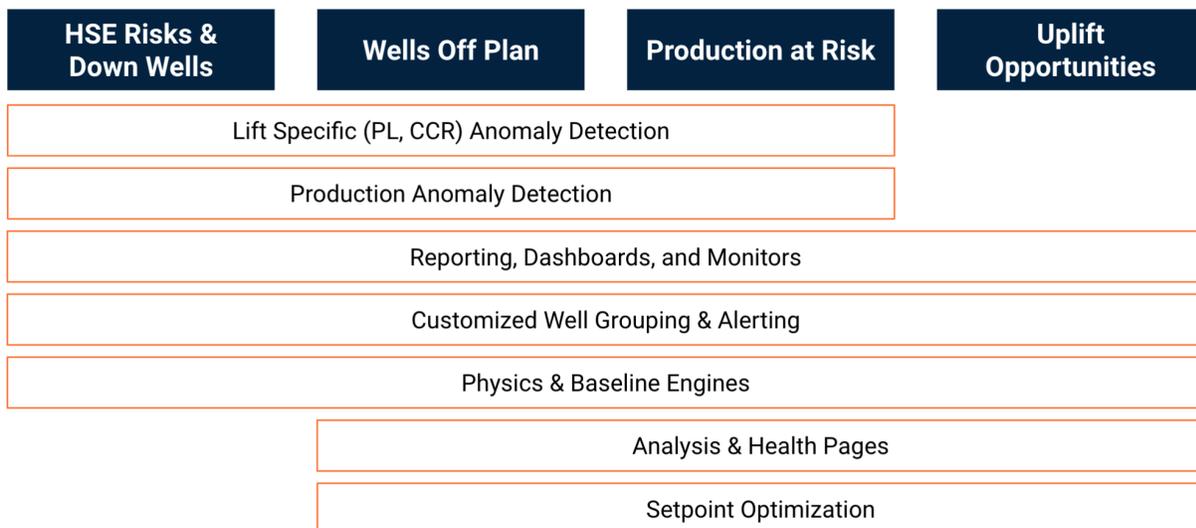
Ambyint Turnkey	3rd Party Edge Device	SCADA Integration
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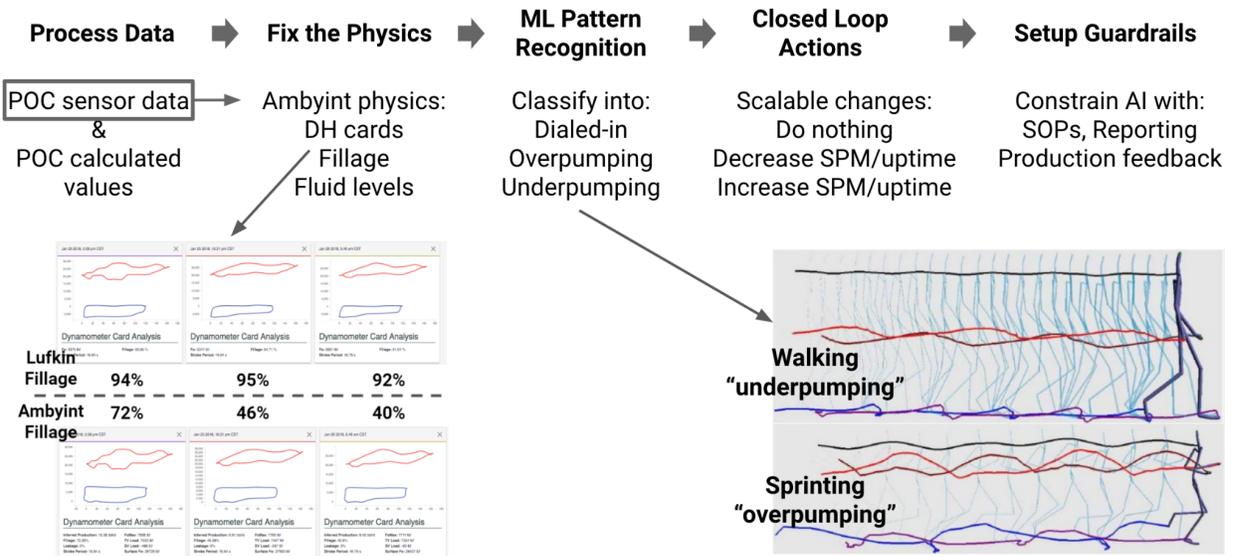
The platform investments that were undertaken during the duration of this project allowed for the expansion of Ambyint’s product suite and will set the stage for additional development in the future. This ultimately presents Ambyint as a full suite offering for our customers.



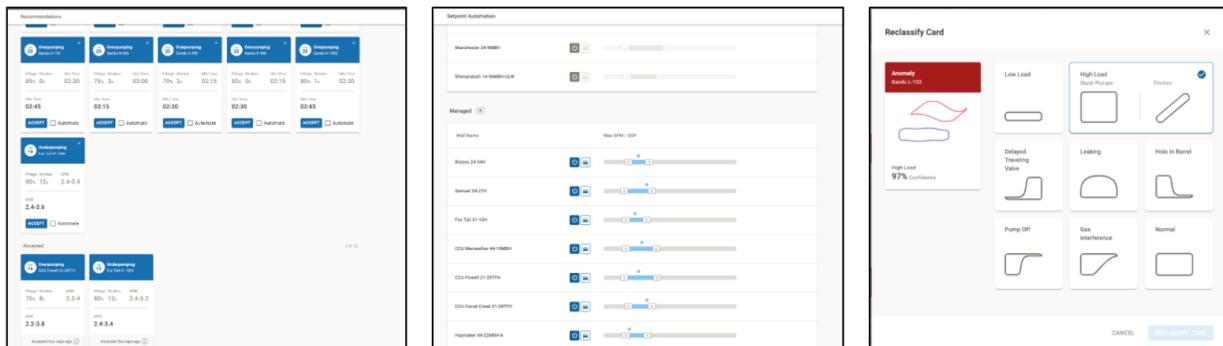
One key learning throughout the project was the fact that even though our autonomy capabilities provided significant benefits, our customers also required the platform to manage other aspects of a customer's day to day production operations to be accepted and utilized on as many wells as possible. Therefore alongside the full suite of offerings, Ambyint's product capabilities (currently focused on rod lift and plunger lift) provide a feature set that covers all aspects of production operations.



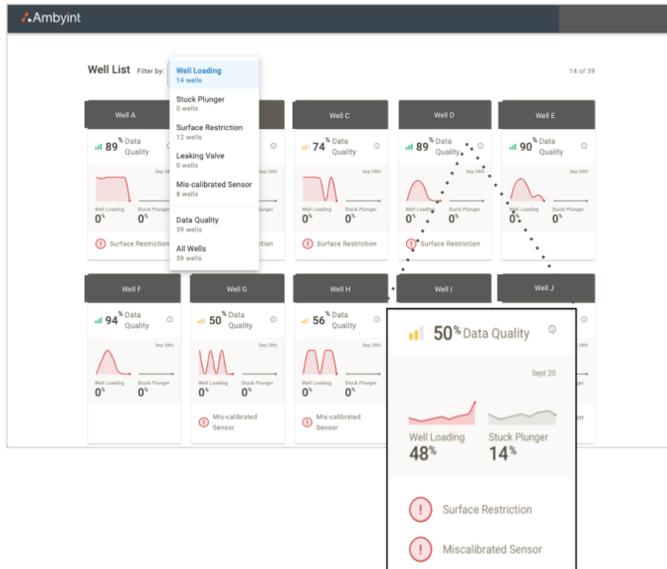
The development of AI data products (ASPM, anomaly detection) required many supporting capabilities to ensure improvement and effectiveness in those models. The product strategy was focused on transparency, guardrails and continuous feedback loop to ensure models operated and improved operations at scale.



The platform was developed with multiple feedback loops to allow users to interject themselves in the autonomous operation of their wells (i.e. setpoint recommendations) or to correct places where they disagreed with Ambyint’s anomaly detection decisions.



The platform was also developed to utilize anomaly detection capabilities to highlight wells and configurations that may prevent the ability to enable autonomous setpoint management. This is key because it proactively ensures that customers are focused on these wells with the hope of dealing with these issues and moving the wells to a state where they can be autonomously managed (and capture the significant benefits that provides).



- Empirically, up to 80% of wells struggle with anomalies leading to:
  - Well instability
  - Inability to optimize setpoints at scale
- Anomaly detection of five key issues preventing setpoint optimization
  - Well loading
  - Stuck plunger
  - Surface restriction
  - Leaking valve
  - Mis-calibrated sensors

In the case of plunger lift setpoint management an additional approach was developed to help baseline the operation of the plungers before moving forward with the more advanced autonomous setpoint management. This baseline engine provided standardization and explainability as it was rooted in advanced physics versus black box AI approaches. It provided the AI optimization models with an initial starting point for them to explore and ultimately optimize in.

**Setpoint Approach:**

1. Baseline uses physics to standardize/stabilize setpoints based on well conditions
2. AI Numerical Optimization approach used to iterate on setpoints using physics to constrain results

Previous and current production  
Previous and current setpoints



New setpoints

An example of the impact Ambyint’s capabilities (many of which were developed during the course of the project) are highlighted in the long term customer value (LCV) details below.

### Lifetime Impact on Failure Analysis

Inputs		Economic Metrics		
Parameter	Value		Non-Amb	Amb
# Wells w/ Conclusive Results in FA	211 Wells	# Workovers	211	138
Avg. MTBF Impact	+35%	Workover Spend (\$MM)	\$ 12.7	\$ 8.3
Avg. NPT (Waiting on Rig + Workover)	13 days	Workover Savings (\$MM)	\$ -	\$ 4.4
Baseline BOPD	50 bbls	Total NPT (days)	2710	1768
Oil Price (based on avg. WTI from 2017 - 2020)	\$53/bbl	Total Deferred Prod (bbls)	143,640	93,716
Avg. Workover Cost	\$60k	Deferred Rev. (\$MM)	\$ 7.2	\$ 4.7
		Deferred Rev. Savings (\$MM)	\$ -	\$ 2.5
		<b>Total Impact (\$MM)</b>	<b>\$</b>	<b>6.9</b>

### Lifetime Impact on Oil Production

Inputs		Economic Metrics	
Parameter	Value	Mean Time on ASPM (days)	518
Net Production Impact / Rec (Avg. Model 1 / Model 2)	+0.43%	# Wells in Recs Analysis	315
<i>Prod. Impact of Positive Recs (Model 1 / Model 2)</i>	<i>+1% / +3%</i>	Baseline Prod (bopd)	50
<i>Prod. Impact of Negative Recs (Model 1 / Model 2)</i>	<i>-2% / -6%</i>	Baseline Prod / Time on ASPM (bbls)	8,158,500
Avg. # of Recs / Well	15	Net Prod. Impact / Well	6%
Net Production Impact / Well	+6%	Amb Prod Impact (bopd)	53
Baseline BOPD	50 bbls	Amb - Prod/Time on ASPM (bbls)	8,684,723
Oil Price (based on avg. WTI from 2017 - 2020)	\$53/bbl	Prod Uplift (bbls)	526,223
		<b>Prod Uplift (\$MM)</b>	<b>\$ 27.9</b>

### Electricity Costs

Inputs		Economic Metrics		
Parameter	Value		Non-Amb	Amb
Baseline SPM	4.5	Power (HHP)	15.16	13.65
Net Impact on SPM / Well	-10%	<i>Q (Calc. Liquid Production, Bbl/d)</i>	228.92	206.03
Avg. Plunger Diameter (in)	1.57	<i>SG (Specific Gravity)</i>	0.90	0.90
Avg. Stroke Length (in)	177	<i>LL (Dynamic Liquid Level, ft)</i>	10,000	10,000
Avg. Liquid Production (blpd)	136 bbls	<i>Service Factor (Optional)</i>	1.00	1.00
Power Cost (c/kwh)	12	Power (KW)	11.31	10.18
		Power Cost (c/kWh)	12	12
		Run-time (hrs)	24	24
		Power Cost /Well (\$)	\$16,869	\$15,182
		Power Cost /Well (\$k)	\$17	\$15
		# Wells	315	315
		Total Power Cost	\$5,313,747	\$4,782,373
		<b>Total Power Savings (\$MM)</b>		<b>\$0.53</b>



With rod lift we had good success using our first generation edge device for pilots but encountered customer resistance for commercial scale adoptions using proprietary hardware. There were some obvious advantages from a technology standpoint in staying with an end-to-end solution based on our hardware but it would be very difficult to deploy at scale. Aversion to vendor lock-in was a common objection. There was also a split between organizations that were actively looking for an edge device solution and those that were looking to leverage their legacy systems. We positioned the rod lift product as a solution with multiple deployment models. We can deploy onto our own edge device, into a third party edge device and as a software only implementation.

Covid-19 presented many challenges to large portions of the economy. For Ambyint the impact was a significant pause in the commercialization process as many customers reorganized and re-evaluated their organizations. These changes were still playing out at the end of the project and are still playing out into 2021 with M&A activities.

Many of the adoption constraints experienced were amplified in Alberta relative to the USA market. Lower commodity prices for both oil and natural gas, constrained pipeline capacity, government sanctioned oil production curtailments for larger producers, COVID-19 impacts, access to capital, cloud residency issues and mergers and acquisitions all had a more significant impact in Alberta. Unsustainably low natural gas prices in particular prevented even pilot level deployment of the plunger lift product in the Alberta market.

#### Aggregate and Alberta Deployments, by Well Type

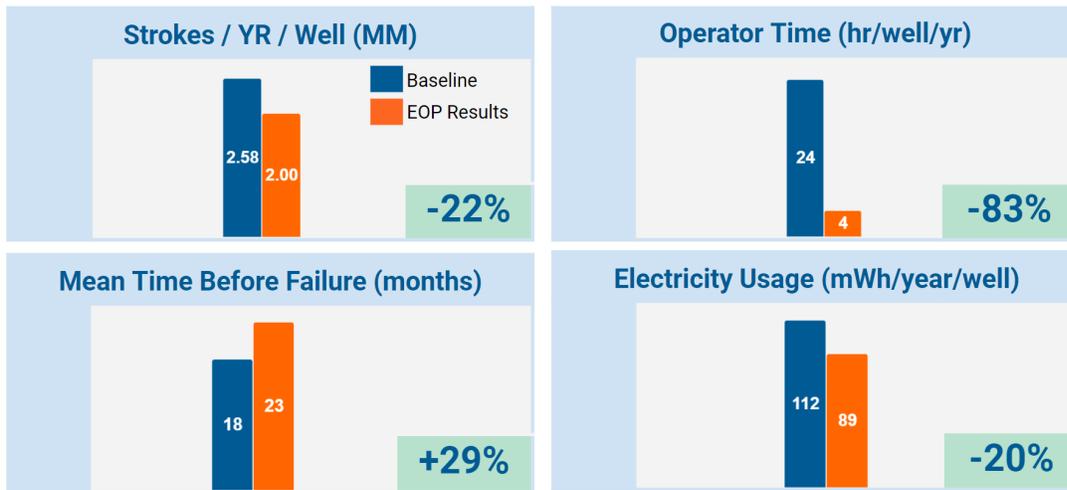
<b>All Wells</b>	<b>2020 Exit</b>	<b>2021 Exit</b>	<b>Increase</b>
Rod lift	1482	3380	128%
Plunger	472	2325	393%
Surveillance	52	56	8%
<b>Total</b>	<b>2006</b>	<b>5761</b>	<b>187%</b>
<b>Alberta Wells</b>	<b>2020 Exit</b>	<b>2021 Exit</b>	<b>Increase</b>
Rod lift	141	147	4%
Plunger	0	50	+
Surveillance	52	56	8%
<b>Total</b>	<b>193</b>	<b>253</b>	<b>31%</b>

#### *Alberta Customer Case Study*

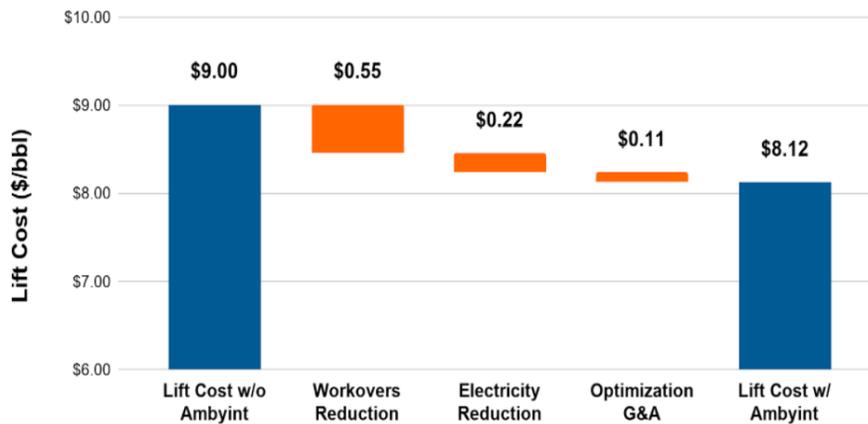
One of Ambyint’s oldest Canadian customers provides a good representation of the challenges of the Canadian market over the last two years.

Ambyint initiated a pilot with the customer in June 2019 and was completed 6 months later in December 2019. The outcomes demonstrated through the course of the pilot were extremely positive and well received by the key Engineering and Operations stakeholders in the operating asset. The results are summarized below:

Pilot Results: Impact on key KPIs



Pilot Results: Impact on Lifting Cost



Assuming WO - \$2.50/bbl, Electricity - \$1.00/bbl, G&A = \$0.50/bbl

The 20% electricity reduction demonstrated through the course of the pilot in Alberta is better than the 16% validated by Solas Energy Consulting in the Trinity pilot in the US Eagle Ford play. In addition to the economic benefit quantified above, Alberta GHG emissions reductions are expected to be as good or better as results quantified elsewhere.

As we entered 2020 Ambyint was engaged in commercial discussions with the customer's asset and a number of other assets in broader Alberta oil producing operations to expand Ambyint's footprint across all 1,000 Rod Lift wells in the operating area. When Covid hit in February 2020, the commercial discussions were put on a temporary pause. In March and April 2020, the Alberta government instituted mandatory production curtailments on oil producers in the province. The customer's assets in the operating area were impacted by the curtailment. In addition, the customer's IT team expressed concerns that Ambyint's software solution was hosted in Ambyint's US-based AWS cloud rather than in a cloud operated and controlled by the customer and maintained in Canada. Due to the high level of business uncertainty, major organizational changes, and IT concerns, the potential Ambyint expansion was taken off the table for 2020, despite the positive results demonstrated in the pilot and the substantial economic value to be had through a larger scale expansion of Ambyint.

**Greenhouse Gas Benefits**

GHG benefits will result from deployment of the project technology on customer wells in Alberta. The amount of the benefit is determined by the commercial rollout of the technology.

The benefits come from reduction of electricity consumption in the case of rod lift wells and reduction in venting in the case of plunger wells.

The company collaborated with a customer in the Eagleford Basin in Texas to monitor electricity consumption on 55 wells. The detailed analysis provided a validated baseline position and demonstrated a 16% electricity saving. These results corroborate Alberta based results based on stroke reduction which implied a 20% saving.

GHG benefits based on our current anticipated rollout in Alberta are:

	1 Year After Project Completion	5 Years After Project Completion	10 Years After Project Completion
CO2 (ktonnes)	0.00	9.77	18.78
PM (tonnes)	0.02	0.20	0.38
NOX (tonnes)	0.79	10.29	19.09

SOX (tonnes)	1.37	17.76	32.95
VOC's (tonnes)	0.01	0.08	0.15
Methane in CO2 equivalent (ktonnes)	40.28	274.23	491.97

### **Economic and Environmental Impacts**

Economic impacts in Alberta will be for the sale of hardware and software platform access as well as emissions reduction and cost savings to operators in Alberta deploying the technology. Ambyint has also spawned another startup in the area of oil and gas technology (Qube Technologies was mentored in their development by Ambyint as well as their founder being a former member of our business development team). In addition there has been significant growth in the team (and individual team members) abilities in data engineering, AI and data product development that we believe can be broadly applicable across many industrial verticals.

#### Total Economic Benefit for Alberta

	1 Year After Project Completion	5 Years After Project Completion	10 Years After Project Completion
Revenue - hardware	1,000,000	5,000,000	5,000,000
Revenue - software	4,404,000	24,928,800	49,516,800
Cost savings	10,265,625	139,301,578	258,841,054
Total	15,669,625	169,230,378	313,357,854

### **Future is Bright at Ambyint**

2020 was a tough year in the North American O&G and we felt it. That said, we hunkered down and achieved a lot in that fiscal year from maturing our Rod Lift Offering, fully commercializing our Plunger Lift offering, replatforming our software to work with multiple lift types greeting more enterprise wide applications, and continuing to educate the target market on the GHG impact they can drive through a more robust perspective on aging or declining onshore production wells. All this positioned us well for a successful 2021.

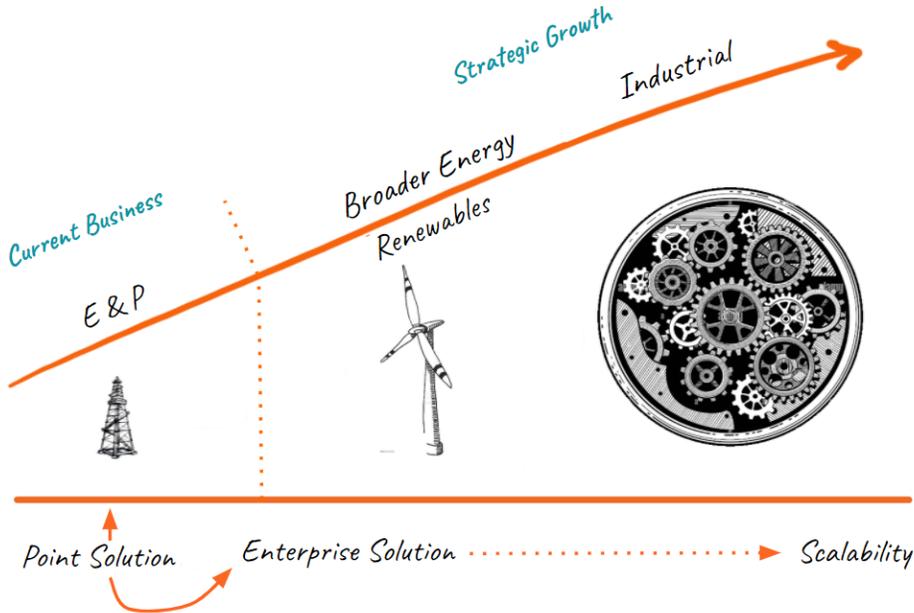
We increased our installed base of wells in the North American market, with substantial growth in both Rod Lift and Plunger Lift installed base. The majority was driven by deployments in the US market, however we secured a flagship Canadian customer headquartered in Calgary,

Alberta. As a high growth company they are looking for ways to find better ways of working while reducing the stresses inefficient well operations have on the environment, people, and performance. Our relationship with them currently focuses on assets in both Alberta and British Columbia. This will be a showcase for our digital impact and associated GHG reductions in Alberta.

While the Canadian market has proven slower to respond in 2021 than the US domestic market, this addition compliments our credibility in the Canadian market place with major players looking to Ambyint to drive performance.

Specific to Alberta, many of the previous constraints have been managed or alleviated setting up the local market for digitization success in 2022 and beyond. Cloud providers such as AWS and Microsoft have worked hard to establish fully functional Canadian data centers to remove data residency objections from the larger Canadian operators, several of whom we have worked with on an evaluation scale but were unable to advance large scale adoption conversations.

Our efforts in 2021 sets Ambyint up for continued growth in 2022. We are targeting another two fold growth year, with 95% of our attention focused on the North American market. This growth will be fuelled by adding staff in our Calgary office, our newly appointed CEO resides in Calgary, and we anticipate strong growth in the Alberta market place. We have invested in quality subject matter experts, including our newest hire in Grande Prairie, Alberta that formerly worked for ConocoPhillips and Cenovus, their time will be centered on our Canadian growth plans.



In support of our company vision, pictured above, we are continuing to ramp our GHG emissions reduction leadership. That has us ambitious in our ability to support the Wind Energy sector in the near term. To that end, we have partnered with the University of Calgary (UofC) to secure our first ESG focused intern to support our continued GHG reduction efforts. Our intern is a chemical engineering student at UofC, co-president of Women in Science and Engineering at the University, and passionate about all things related to engineering and making a difference in our society.

The stage is set to continue to build on the ERA's funding with Ambyint and see incremental impact on a wider scale here in Alberta and further afield.

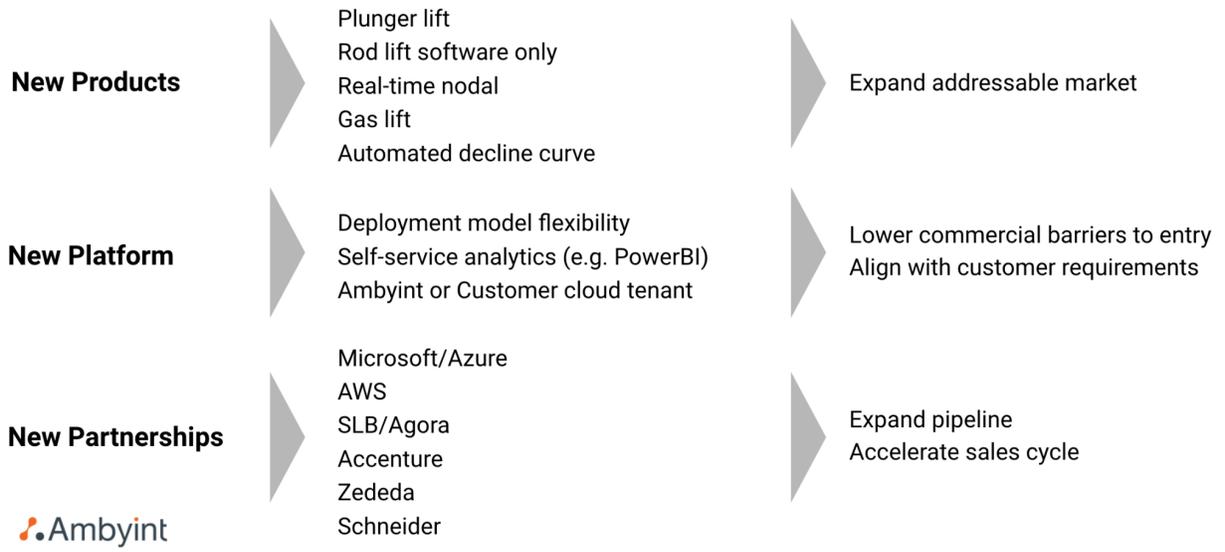
## **Scientific Achievements**

### Technical Papers and Presentations

1. 2020 Artificial Lift R & D Council Artificial Lift Workshop
2. SPE-190955-MS Enabling Autonomous Well Optimization Via Using IoT-Enabled Devices and Machine Learning in Bakken Horizontal Wells
3. SPE-113186 Optimizing Downhole Fluid Production of Sucker-Rod Pumps With Variable Motor Speed
4. SPE-201132-MS The Future of Plunger Lift Control Using Artificial Intelligence

## **Next Steps**

The investments that Ambyint has put forward as part of this project will continue to form the foundation of future investments. Ambyint's commercial and technology strategy in 2021 and beyond is focused on the ability to expand our addressable market via investments in other artificial lift types, to lower commercial barriers to entry by making our platform more enterprise-ready, and to utilize partnerships and multi-cloud availability (AWS and Microsoft) to access customers that we may have previously had limited access to.



## Communications Plan

The project forms key portions of a commercial product offering. Knowledge sharing of the outcomes is an integral part of the commercialization effort. The communications include case studies, white papers and presentations at conferences. Digital outreach has been especially critical in a Covid-19 impacted world. In 2020 we significantly increased the use of webinars and blogs as a communication tool.

Links to resources: <https://www.ambyint.com/our-resources/>

### Highlights

#### Case Studies

1. Case Study Rod Lift Emissions
2. Case Study Bakken Rod Lift
3. Case Study Eagleford Rod Lift
4. Case Study Marcellus Plunger Lift
5. Case Study Marcellus Smart Stream

#### Technical Papers and Presentations

5. 2020 Artificial Lift R & D Council Artificial Lift Workshop
6. SPE-190955-MS Enabling Autonomous Well Optimization Via Using IoT-Enabled Devices and Machine Learning in Bakken Horizontal Wells
7. SPE-113186 Optimizing Downhole Fluid Production of Sucker-Rod Pumps With Variable Motor Speed
8. SPE-201132-MS The Future of Plunger Lift Control Using Artificial Intelligence

#### Webinars

1. Measuring the Impact of Reduced Compressive Strokes on Failure Rate Reduction'
2. Well Optimization Strategies for Improved Bottom Line Performance
3. Unlocking Lower Emissions with Production Optimization
4. Debunking the Top 5 Myths of Production Optimization
5. AI-Driven Plunger Lift Production Optimization (2 parts)
6. Change Management: Managing Technological Changes in Oil & Gas
7. Cybersecurity in the Oil & Gas Industry & Big Data Management

#### Blogs

1. Unstandard is the Standard in Plunger Lift Optimization
2. Case Study on Lower Strokes, Flat Production, and 35% MTBF Increase
3. The Stroke Reduction Long Game to Failure Rate Reduction

4. Operations Benchmarking Leads to Company Alignment
5. Reducing Emissions with Production Optimization
6. PLCs Are Like Washing Machines