ENGAGEMENT PLAN · UPSTREAM AI OPERATIONS

Wellhead: industrial AI for *upstream operations.*

Physics-informed by construction, edge-deployed, with regulator-ready ESG signing built in.

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The Problem

Unplanned downtime costs an offshore operator $38 to 88M a year, about 27 days of lost production.[1] The 2018 to 2023 pure-ML wave lost: reservoir engineers don't approve workovers on outputs they can't mechanistically defend. Meanwhile **methane disclosure now demands operator-signed lineage on emissions**, which operators file separately from operations. That disconnect is the gap.

FIGURE 1 · PREDICTIVE SHIFT

Left: black-box ML is rejected because the engineer can't trace a mechanism. Right: prediction plus signed lineage.

Why this matters now

Three forces converge. **Methane disclosure keeps tightening outside the US**: EU importer MRV-equivalence starts 1 January 2027, and OGMP 2.0, covering about 42% of global oil and gas production, gates Gold Standard on Level 4 to 5 reporting. US NSPS OOOOb/c stays in force but has been under EPA reconsideration since March 2025, with compliance dates pushed into late 2026 and January 2027, so US demand is buyer-led, not deadline-led.[3] **ESP failure stays frequent and expensive**: average run life is about three years, unconventional wells average roughly 142 days per run, and each pull costs $100K to $250K plus deferred production.[4] **Physics-informed ML is now tooled well enough to ship at the edge.** The first two are external and dated; the third is our assumption, and the pilot is built to falsify it.

Sizing the opportunity

Size the vendor market, not the value pool. E&Ps spent about **$25B on digital and AI** last year, and Rystad expects that to pass **$35B by 2030**. The operator prize is bigger: Wood Mackenzie puts achievable annual savings at about **$73B**, roughly 10% of global upstream spend.[5] Artificial-lift analytics plus methane MRV is a slice of the vendor market, not all of it. We model **$1.5 to 2.4B / yr addressable**: roughly 60,000 instrumented, artificially lifted wells at an assumed $25K to $40K each per year. Both the well base and the price are our assumptions, not published figures. The base is scoped, not global: the US has 918,481 producing wells, but 78% make 15 BOE/d or less and will never carry a software line item.[2] Capture by year five is **$100 to 200M / yr of ARR**, about 5 to 10% of the slice, wedging in at *one* brownfield.[6]

UPSTREAM DIGITAL + AI SPEND

$25B / yr

Rystad; past $35B by 2030

REALISTIC CAPTURE, YR 5

$100 to 200M / yr

5 to 10% of addressable slice

SOURCES

1. Kimberlite unplanned-downtime benchmark (**2018**), via MaxGrip: offshore operators lose **$38M to $88M a year**, about 27 days of lost production; one point of availability is worth about $5.0M a year. Reported per operator, not per facility. Accessed 12 Jul 2026.
2. EIA, "Distribution of US Oil and Natural Gas Wells by Production Rate," 2024 data (**Dec 2025**): **918,481** producing US wells, 78% at 15 BOE/d or less. No global producing-well count is published. Accessed 12 Jul 2026.
3. EPA NSPS OOOOb/c final rule (**8 Mar 2024**), as amended: reconsideration **12 Mar 2025**; interim final rule **28 Jul 2025**; deadline extension **3 Dec 2025**; reconsideration final rule **4 Apr 2026**. First OOOOb annual reports due 30 Nov 2026; OOOOc state plans and the Super Emitter Program both 22 Jan 2027. Regulation (EU) 2024/1787 (in force **4 Aug 2024**): importer MRV-equivalence from 1 Jan 2027. OGMP 2.0 Reporting Framework, UNEP (**2025**): annual, 31 May submission; Level 4 to 5 gates Gold Standard. Accessed 12 Jul 2026.
4. SPE-183005-MS, "Ten Year ESP Mean Time between Failures" (ADIPEC, **Nov 2016**); Samotics, "Electric submersible pumps" (**2024**): run life about three years, unconventional roughly 142 days per run, a pull costing $100K to $250K onshore plus deferred production. Accessed 12 Jul 2026.
5. Rystad Energy, "AI in upstream oil and gas" (**2026**): E&P digital and AI vendor spend about $25B a year, past $35B by 2030, and about $500B of cumulative operator value over 2026 to 2030. Wood Mackenzie, "Sizing up the digitalisation prize" (**2018 to 2019**): about $73B of achievable annual savings, about 10% of global upstream spend. Accessed 12 Jul 2026.
6. SLB Q4 and full-year 2025 results (**Jan 2026**): Digital revenue about $3B, the largest digital business in the sector. The 60,000-well base, the $25K to $40K per-well price, the $1.5 to 2.4B slice and the $100 to 200M capture range are my own assumptions, not published figures and not validated with operators. Accessed 12 Jul 2026.

Strategic insight

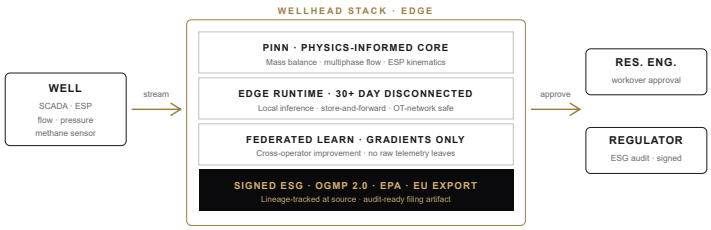
The reservoir engineer is the user; procurement is the buyer; the regulator is the auditor. **All three need a mechanism, not a number.** Our bet is that PINNs are now stable enough to ship and still novel enough to differentiate. The evidence isn't settled: Grossmann et al. find PINNs still trail the finite element method on accuracy and solve time.[7] So M0 to M3 gates on a per-asset accuracy bar instead of assuming one. Bundling PINN prediction with regulator-ready ESG signing collapses two procurements into one and makes compliance a co-buyer.

Defensibility compounds two ways. Federated learning lets every operator's deployment sharpen the shared model without exposing raw telemetry. And once filings run through signed lineage, switching costs turn regulatory rather than technical: the audit trail an operator hands the EPA is the one the runtime produced.

> **THE UNLOCK**
>
> Every prediction emits a defensible mechanism (mass balance, flow regime, ESP kinematics). The edge runtime survives 30+ days disconnected, ESG measurements are signed at source and exportable in OOOOb/c, EU Methane and OGMP 2.0 formats, and cross-operator learning is federated gradients only.

Architecture · Edge runtime and federated learning

FIGURE 2 · SYSTEM ARCHITECTURE



Telemetry stays at the asset and the PINN core runs at the edge. ESG measurements are signed in the same runtime that made the prediction: same record, two consumers.

> **WORKED EXAMPLE · 280-WELL BROWNFIELD, GOM, MIXED ESP RUN-LIFE COHORT**
>
> Pre-deployment baseline: **14% unplanned downtime / quarter**. Wellhead PINN flags 8 ESPs at > 70% bearing-wear envelope; engineer accepts 6, defers 2. Q1 result: **downtime 9.2%** (audited against pre-baseline), a 34% relative reduction worth **roughly $28M / year in avoided downtime cost** (modeled: 4.8 points of availability recovered at the Kimberlite benchmark of about $5M per point per year).[18] OGMP 2.0 Level 4 to 5 inventory kept current, Gold-Standard pathway maintained.[3]

Sequenced delivery

PHASE	SCOPE	FORCING-FUNCTION WORKLOAD	PROOF POINT
Pilot M0 to 9	One brownfield asset · ESP failure prediction	ESP workover cost exposure; first OOOOb annual reports due 30 Nov 2026; OOOOc state plans and the Super Emitter Program live 22 Jan 2027[3]	25%+ downtime reduction · OGMP 2.0 filed clean
Scale M9 to 24	Multi-asset rollout across the client's GoM, Permian and North Sea assets	Cross-asset standardization on a single edge runtime	4,000 wells · federated learning gains measured
Portfolio M24+	Full upstream portfolio, including JV and NOC-partner assets	Sovereign data residency and national-scale ESG filings	Portfolio-wide downtime baseline reset · sovereign-cluster variant in production

SOURCES

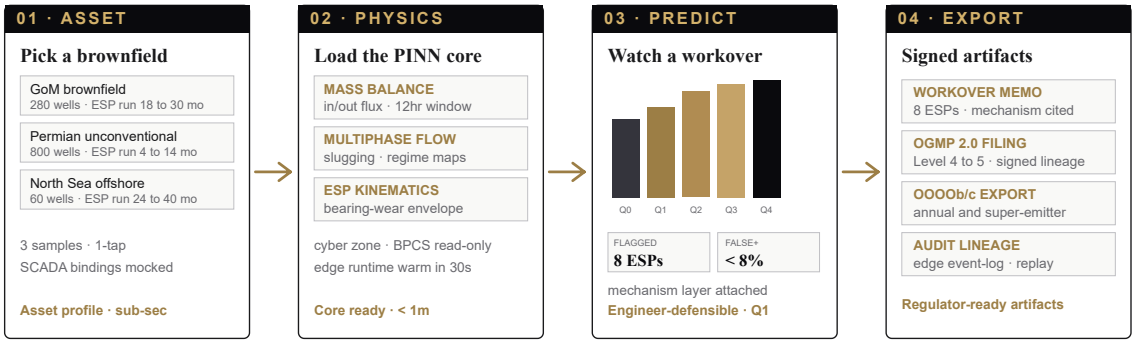
7. Grossmann, T. G., Komorowska, U. J., Latz, J., Schönlieb, C.-B., "Can physics-informed neural networks beat the finite element method?", *IMA Journal of Applied Mathematics* 89(1), 143-174 (issue dated **January 2024**, published online **23 May 2024**): PINNs still trail FEM on accuracy and solve time, winning only on post-training inference speed. Accessed 12 Jul 2026.

8. The worked example is modeled, not a delivered client result. Downtime cost converts at the Kimberlite benchmark (**2018**) of about $5.0M per point of availability per year (note 1): 4.8 points recovered gives about $24M a year, while 34.3% of the $88M worst-performer ceiling gives about $30M, so $28M sits between the two and inside the page-1 envelope. Accessed 12 Jul 2026.

Prototype walkthrough

An interactive edge-runtime simulator runs the operator-side view end to end: pick a brownfield asset, load the physics-informed core against a cyber zone, watch a PINN prediction build with its mechanism layer (mass balance · multiphase flow · ESP kinematics) and emit an engineer-defensible workover recommendation, then export the artifacts the engagement contracts against. Built to demonstrate that **physics-informed prediction**, **edge-resident inference**, and **regulator-grade ESG signing** are concrete outputs, not language in a deck.[9]

FIGURE 3 · EDGE-RUNTIME SIMULATOR, FOUR INTERACTIVE STEPS



Schematic of the live UI; all four steps are interactive in the demo. Pick an asset, load the physics, watch the prediction with its mechanism layer, export signed artifacts.

What the prototype proves, and what it doesn't yet

Proven on the prototype

- PINN flags ESPs above the bearing-wear envelope with mechanism citations the reservoir engineer can defend
- Edge runtime simulates 30+ days disconnected; predictions store-and-forward with no quality loss
- OGMP 2.0 Level 4 to 5 export and OOOOb/c annual filing both render with signed lineage
- Federated gradient round across 5 simulated peer operators; no raw telemetry leaves the asset
- Workover memo and OGMP filing render from one event log, so the prediction and the regulator artifact never diverge

Out of scope, by design

- SCADA and ESP telemetry is mocked; live ingest is brownfield M0 to 3 work on real assets
- IEC 62443-3-3 SL2 certification is a real third-party audit, not simulated in the prototype
- NOC sovereign-cluster variant requires production deployment with operator-controlled key custody
- Per-asset PINN training on client-specific physics constants is post-engagement work
- Multi-year PINN drift monitoring and re-calibration cadence are scoped in the engagement, not the prototype

THREE PATHS TO TRY IN THE LIVE DEMO

ESP failure prediction at a GoM brownfield: 280 wells, 14% baseline downtime → PINN flags 8 ESPs at > 70% bearing-wear; engineer accepts 6, defers 2; workover memo and OGMP filing drafted.

OGMP 2.0 annual methane filing: Level 4 to 5 schema render with signed lineage, on the 31 May submission cycle; the OOOOb/c annual filing is produced from the same event log without re-measurement.[3]

Federated gradient sync across 5 simulated peer operators: aggregated gradient round completes; raw telemetry remains at the asset; cross-operator prediction-quality lift measured against the held-out cohort.

SOURCES

). The prototype is a browser simulation: SCADA and ESP telemetry are mocked, the federated round runs against simulated peers, and no live operator data is used. Reporting cadence follows the OGMP 2.0 Reporting Framework, UNEP (**2025**), which is annual on a 31 May submission cycle (note 3). IEC 62443-3-3:2013 (published **Aug 2013**) SL2 is a third-party certification and is not simulated here. Accessed 12 Jul 2026.

Metrics that matter

LAYER	METRIC	Y1 TARGET	WHY IT MATTERS
North-star	Unplanned downtime hrs / asset / quarter	−25% vs pre-deploy	Audited against operator-attested baseline
Quality	False-positive rate on workover predictions	< 8%	Above this, engineers stop running the queue
ESG	OGMP 2.0 / OOOOb/c filings accepted clean	100%	Below this, compliance team rolls back
Resilience	Edge runtime disconnected operation	> 30 days	Offshore and remote uptime constraint
Liquidity	Wells under runtime (paying)	2,500+ by Y1	Federated gains need well count; day-90 gate is 1,200
Business	Net revenue retention (well-expansion)	> 130%	Lands at brownfield, expands to greenfield

Risks & mitigations

HIGH **PINN model drift on novel reservoir / equipment classes (deepwater, sour gas).**

Mitigation: per-asset model with explicit physics constraints; novel-class flagging triggers conservative mode, predicting only on kinematic envelopes that match the training distribution. Reservoir engineers validate each new class before unlock.

HIGH **OT cybersecurity: edge runtime touches an operations-network process control system.**

Mitigation: read-only on the PCN; outbound store-and-forward over a unidirectional gateway; certified to IEC 62443-3-3 SL2 before the first asset goes live, with third-party penetration testing on a contractual cadence.

MED **Operator data sovereignty: NOCs prohibit cross-operator gradient sharing.**

Mitigation: federated learning is opt-in per asset; the sovereign tier runs a private-cluster variant where gradients never leave operator borders. Feature parity holds; only the cross-operator improvement rate differs.

MED **Regulatory format drift: OGMP 2.0 / EPA / EU schemas change mid-deployment.**

Mitigation: ESG export is schema-versioned; the lossless edge event store makes re-export against a new schema a software upgrade, not a re-measurement. 90-day SLA on new formats.

30 / 60 / 90, first quarter sprint plan

30 DAYS

PINN core and edge runtime v0

- Mass balance, multiphase flow, ESP kinematics
- Edge runtime · 30-day disconnected proof
- 1 design-partner asset (40 wells)

60 DAYS

ESG signing and OT cyber cert

- OGMP 2.0 / EPA / EU export adapters
- IEC 62443-3-3 SL2 cert · pen-test pass
- 2nd design partner · 280 wells live

90 DAYS

Federated learn and audit

- Cross-operator gradient sharing live
- Q1 audited downtime read · 25% target
- 3rd operator signed · 1,200 wells live

DECISION ASKED

Authorize a 90-day brownfield pilot sprint with a ten-person team (PM, three ML/PINN engineers, two systems/edge engineers, OT-cyber lead, reservoir-engineer SME, ESG/regulatory counsel, client success) and a budget of **$5.6M**: $1.3M team, $2.9M edge hardware and retrofit across 1,200 wells, $0.8M deployment and SCADA integration, $0.6M IEC 62443-3-3 SL2 certification and pen-test.[10] Success at day 90: 1,200 wells under runtime, 25% audited downtime reduction against the pre-deployment baseline, 100% clean OGMP 2.0 filings, false-positive < 8%. Retention clears 130% on the Y1 read, not this one. **Counter-metric:** no rise in deferred-maintenance backlog or HSE incident rate.

SOURCES

). Budget lines are modeled and sum to $5.6M: $1.3M is ten fully loaded FTEs for one quarter; $2.9M is edge hardware and retrofit at roughly $2.4K per well across 1,200 wells; $0.8M is deployment and SCADA integration; $0.6M is IEC 62443-3-3:2013 (**Aug 2013**) SL2 certification plus penetration testing. My own assumptions, not vendor quotes; metric targets are engagement targets, not benchmarks. Accessed 12 Jul 2026.