GRAVITY POWER

Company Overview

Gravity Power Plants

…a revolution in pumped storage hydro

August 2018

Gravity Power Plant Bulk Storage

Gravity Power Plants (GPPs)…

- store energy from **wind and solar or baseload plants**
- store at **1/5th the overall cost** of Li-ion batteries
- **removes siting obstacles** of pumped storage hydro (PSH), the world's dominant bulk storage technology

…are the **next generation** of PSH

Funding Requirements & Uses

Gravity Power Prior Funding

$5 million in cash and $3.5 million in-kind:

- Original patent issued in 30 countries and pending in 2, follow-on patents pending
- 3rd party expert technical studies and years of internal design analyses
- Business development in MENA, Asia, the EU and U.S.

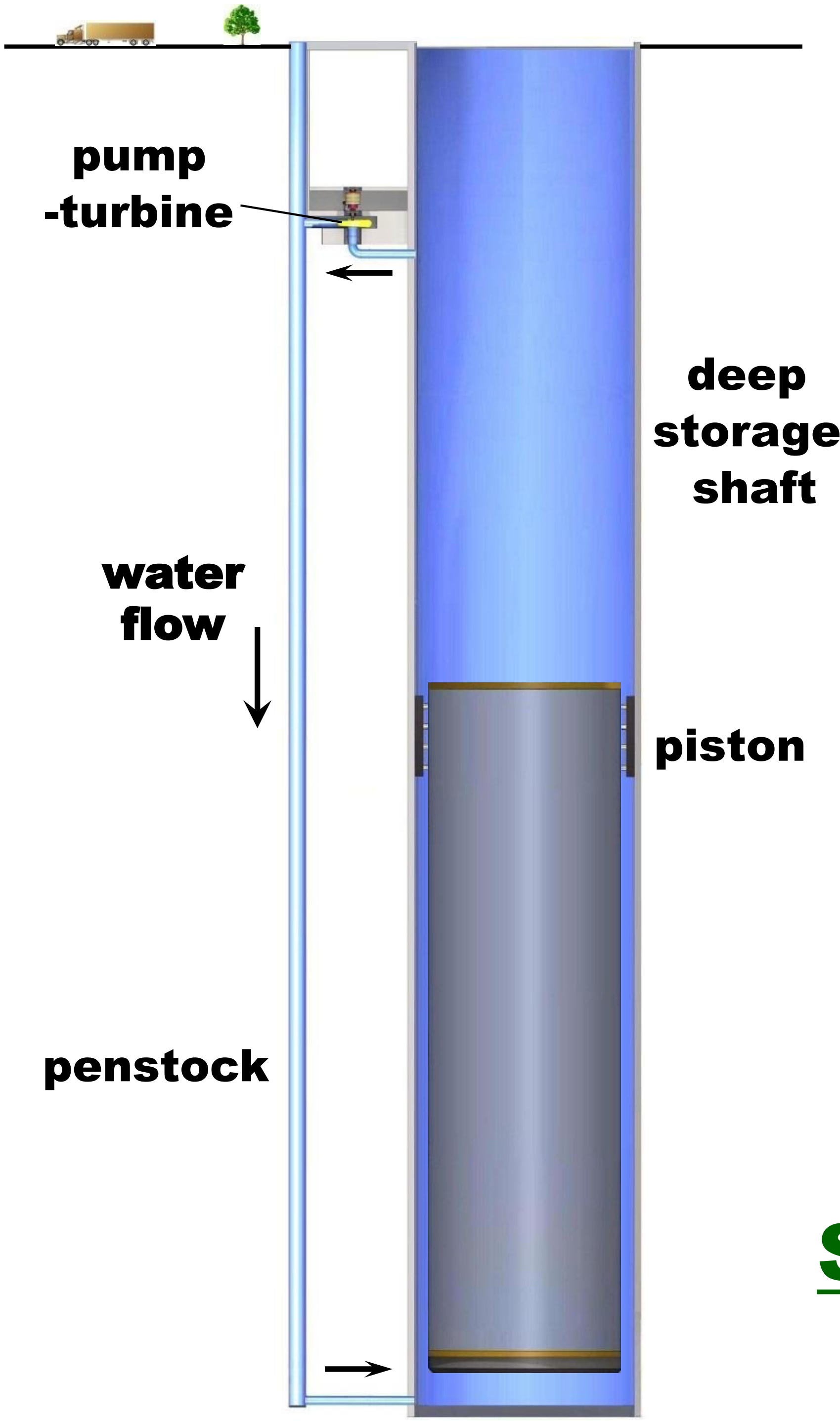
Capital Needed – Series B

$18M
30% equity share

$2M
Seal tests & GP Operations over 1 Year

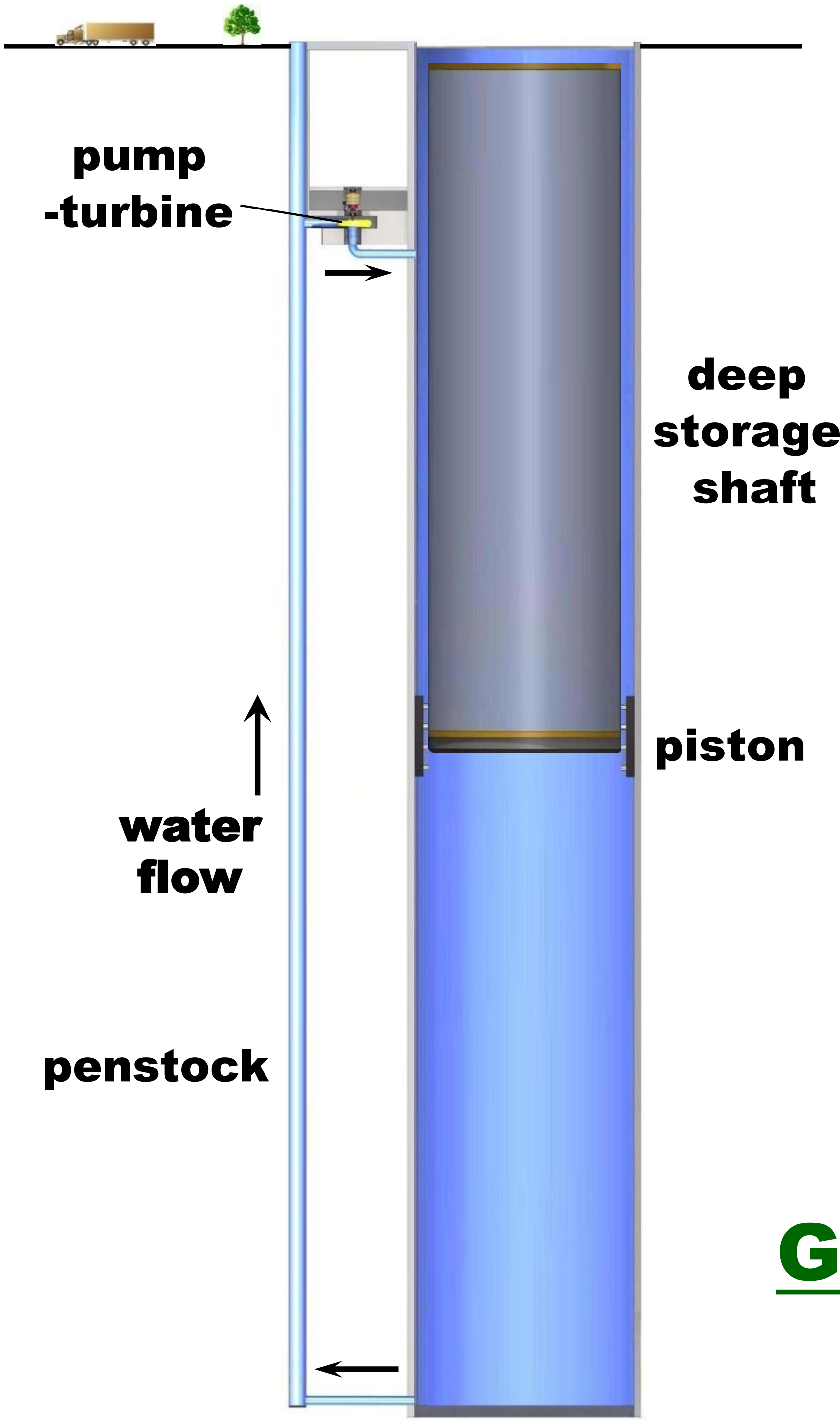
$11M
1MW Demonstration plant construction and testing

$5M
Corporate, Business development, engineering, IP, etc.)



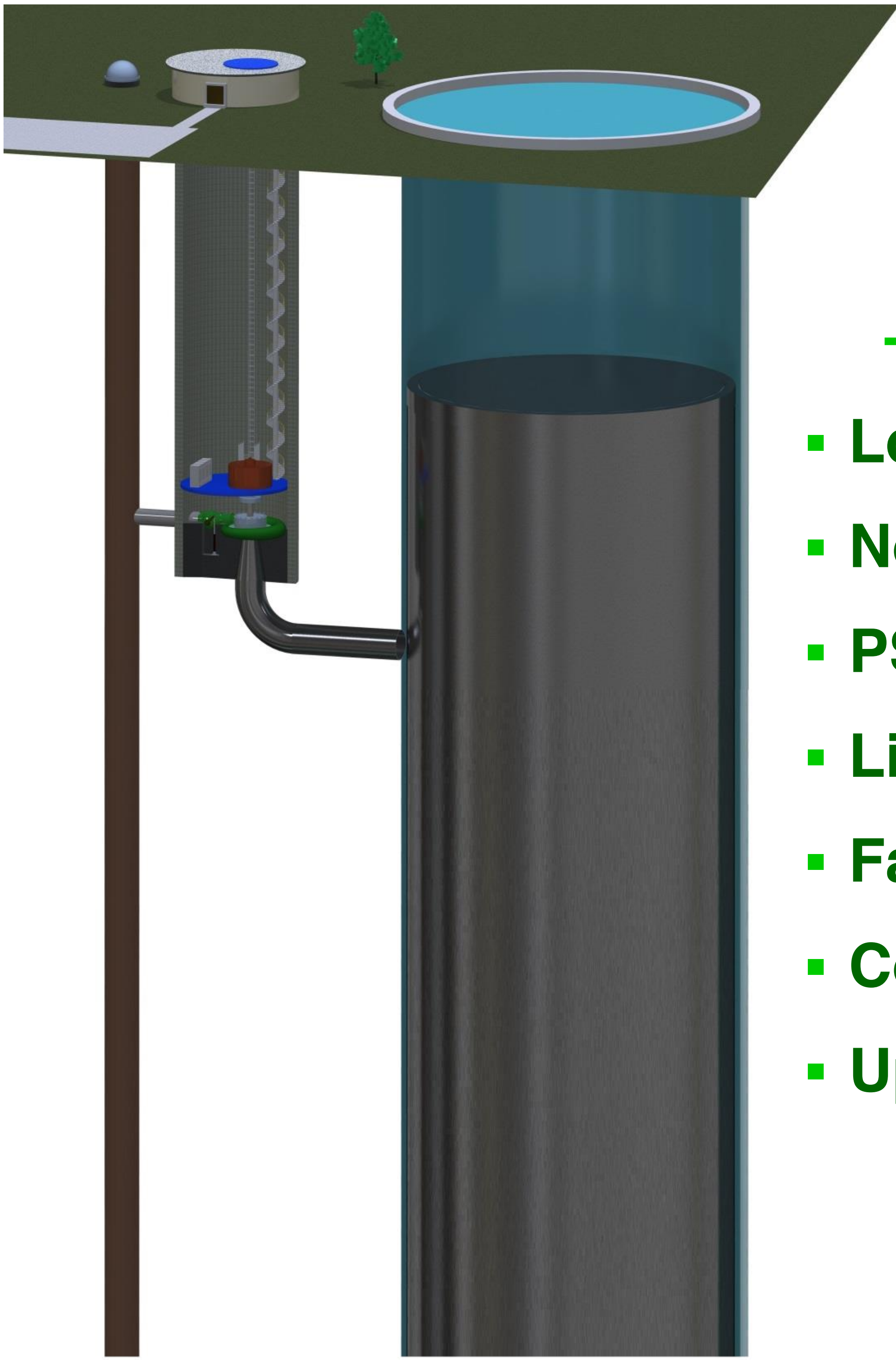
The Gravity Power Plant

Storing Energy



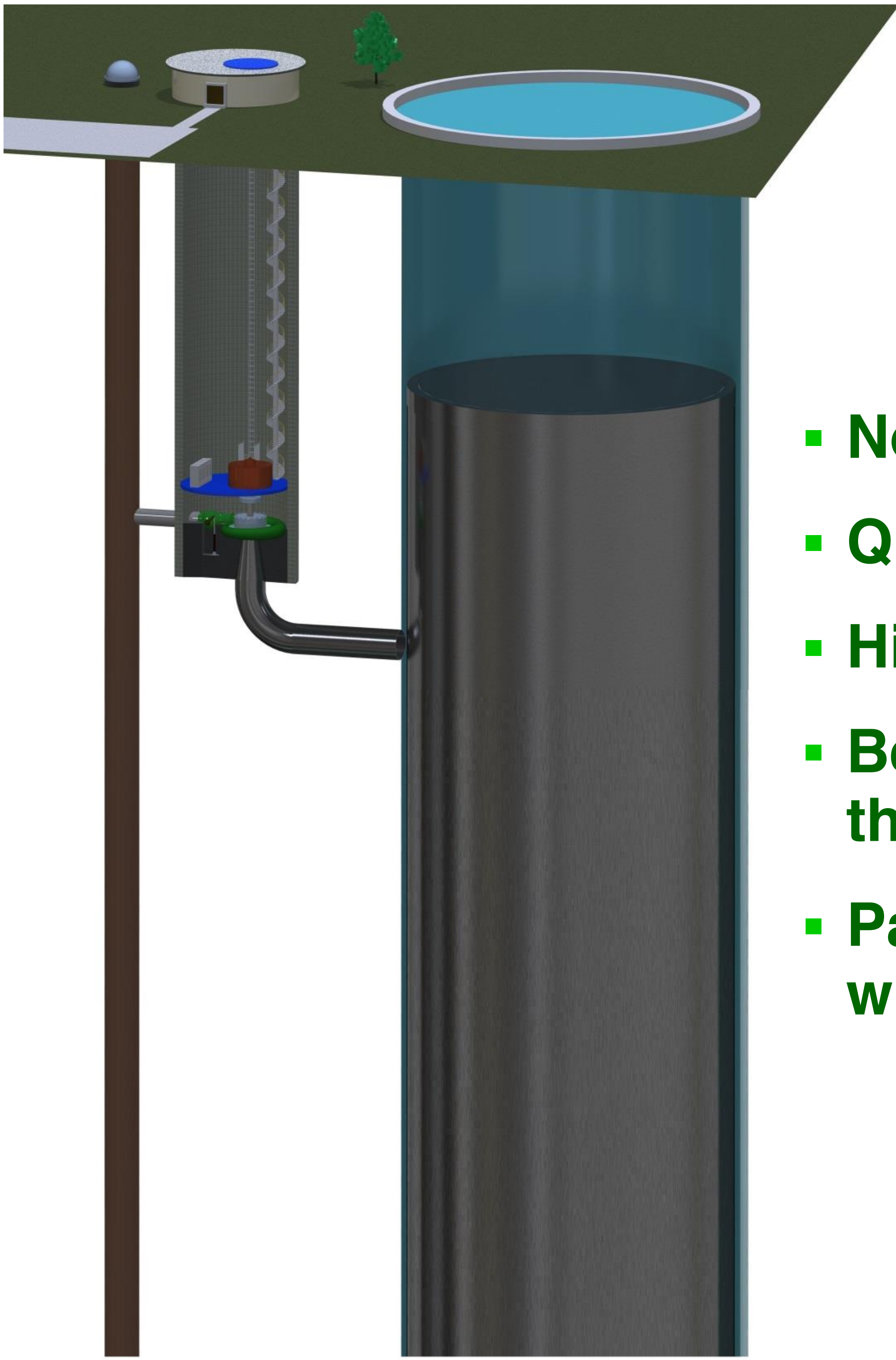
The Gravity Power Plant

Generating Power



GPP Features

- Lowest cost
- No new factories required
- PSH sited on flat ground
- Little land use
- Fast permitting
- Construction (3 - 4 years)
- Up to 84% round-trip efficiency



GRAVITY POWER

GPP Features, Cont.

- No water consumption
- Quiet & invisible
- High local content
- Better operating characteristics than PSH or Gas Turbines
- Patents issued in 30 countries with additional patents pending

GPP upgrades PSH technology

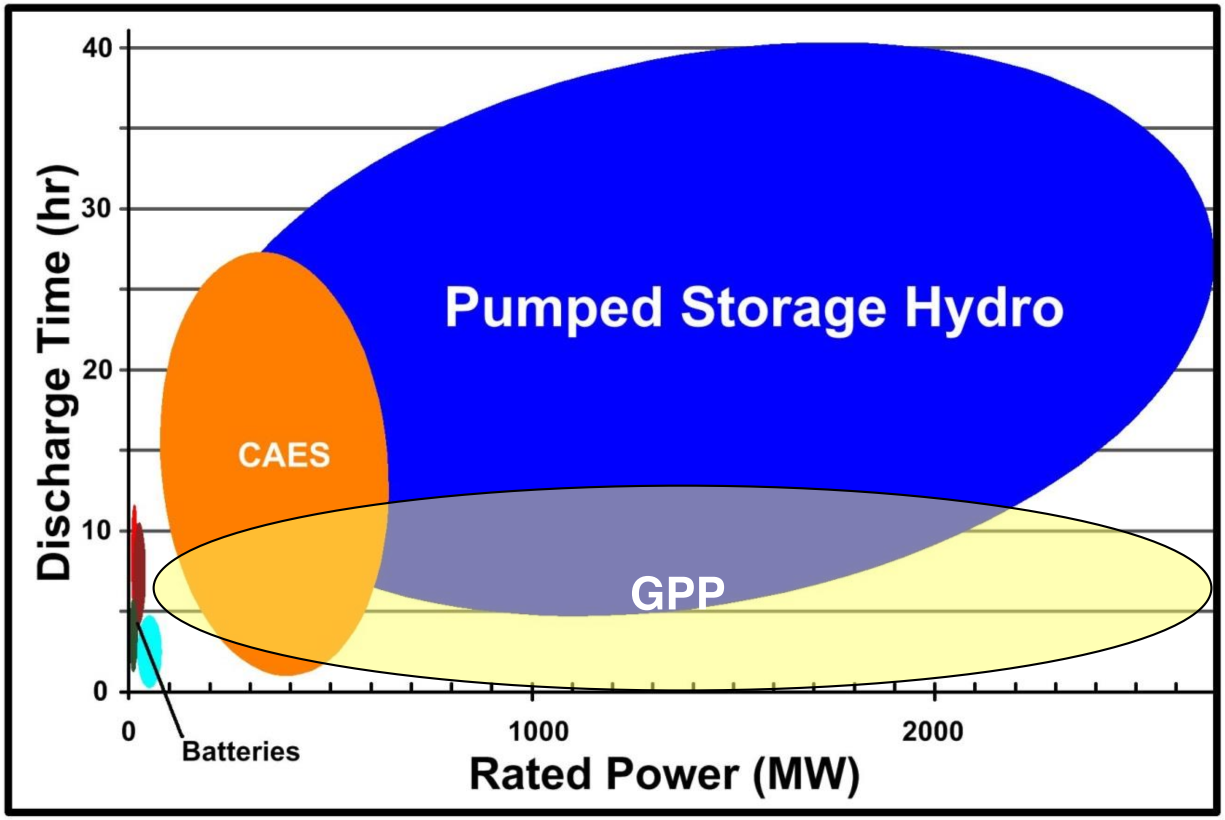
A GPP operates like a modern PSH plant but with advantages

Modern PSH	GPP Solution
Maximum power output **decreases** as the upper reservoir empties and pressure drops	Maximum power stays **constant** due to the **unchanging pressure** produced by the piston

- **Flexibly sited** on flat ground
- Round-trip efficiency (**78-84%**) **exceeds** that of PSH due to its constant pressure
- **Environmentally benign**, relatively easy to permit

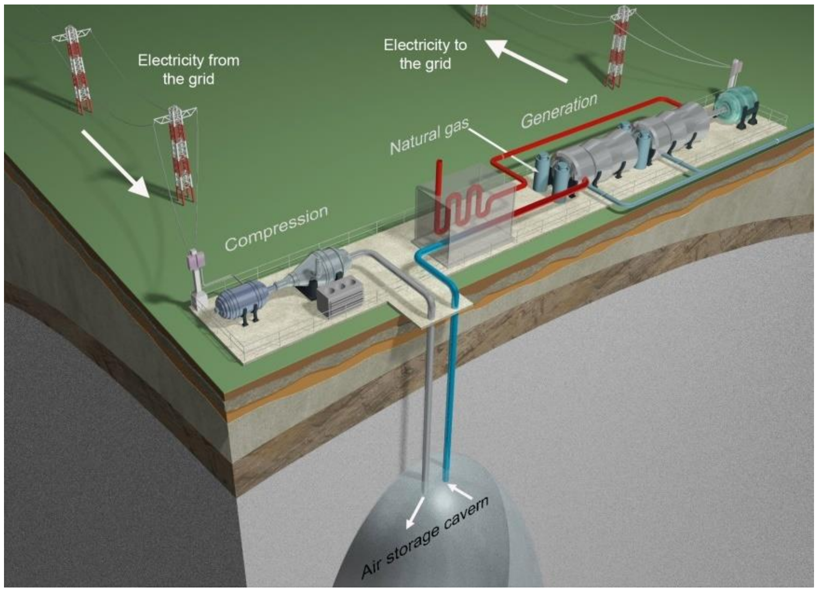
Competing Technologies

PSH provides over 96% of world storage capacity



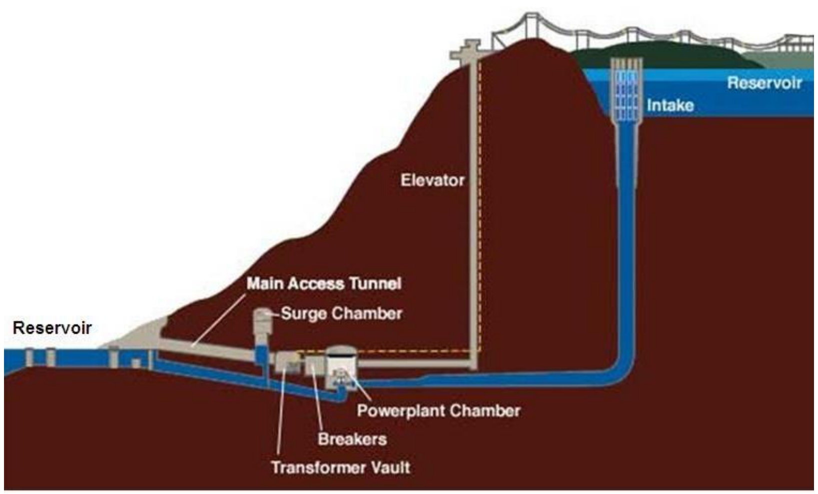
172 GW of PSH at the end of 2017

Competition Constraints



CAES

- Projects cancelled due to high cost.
- Few suitable sites.



PSH – best value, but …

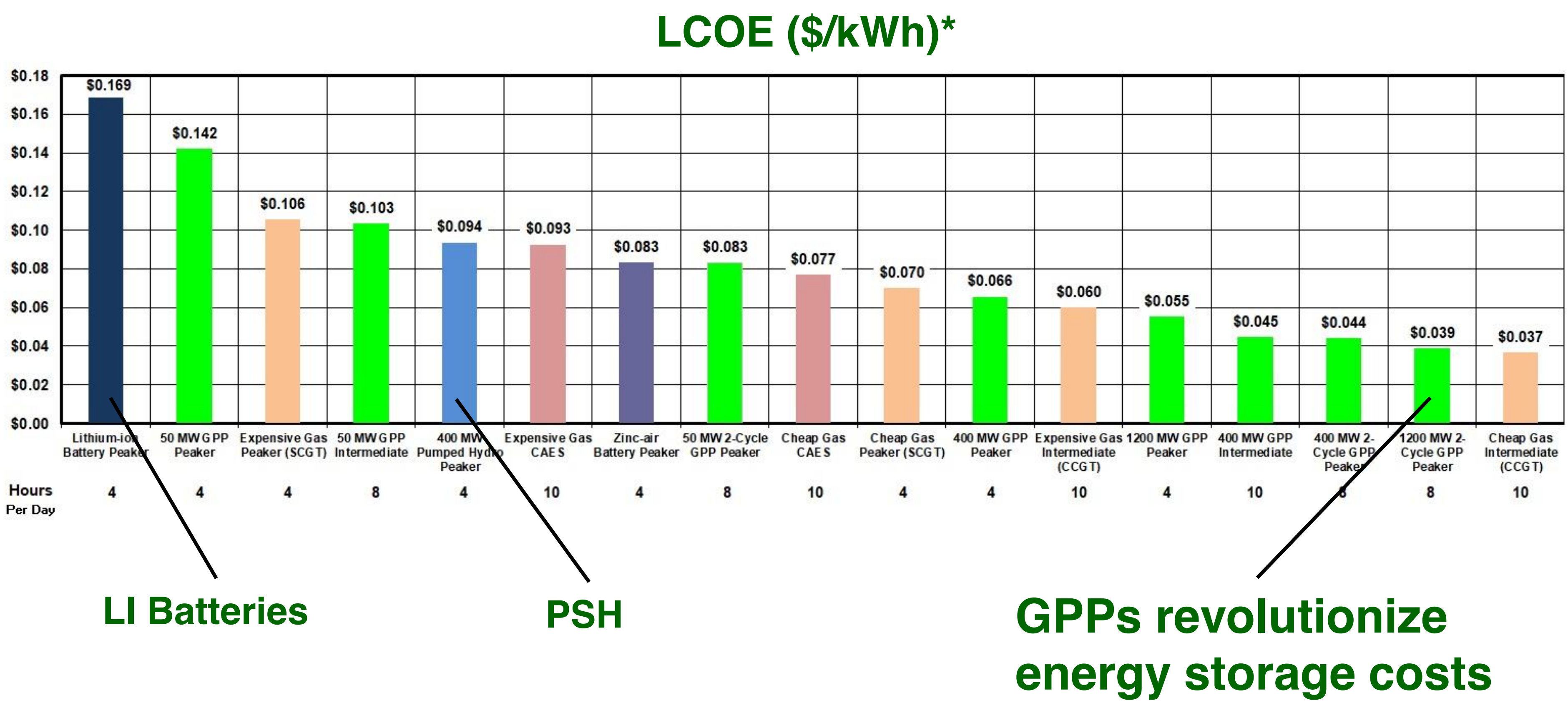
- Consume large land areas
- Limited elevation requirement sites
- Take 10-15+ years to complete
- High cost

Commercial GPP Specs & Costs

GPP Rating	output power (MW)	50	400	1,200	400
	effective energy stored (MWh)	200	1600	4800	6400
Cost	estimated overnight cost (millions)	$170	$503	$1034	$1,048
	$/kW	$3,408	$1,257	$862	$2,621
	$/kWh	$852	$314	$216	$164
Main Shaft	depth (meters)	700	700	1000	1000
	lined diameter (meters)	26.2	69.2	83.3	96
	volume (m^3)	438,630	2,788,083	5,724,356	7,514,000
Piston	height (meters)	350	350	500	500
	final diameter (meters)	23.7	66.7	80.8	93.3
	volume (m^3)	154,077	1,222,397	2,566,910	3,418,000
	mass (tonnes)	385,192	3,955,992	6,417,276	8,544,000

GPP Cost Estimates based on German labor and materials; cost could be significantly lower in MENA, Asia and elsewhere

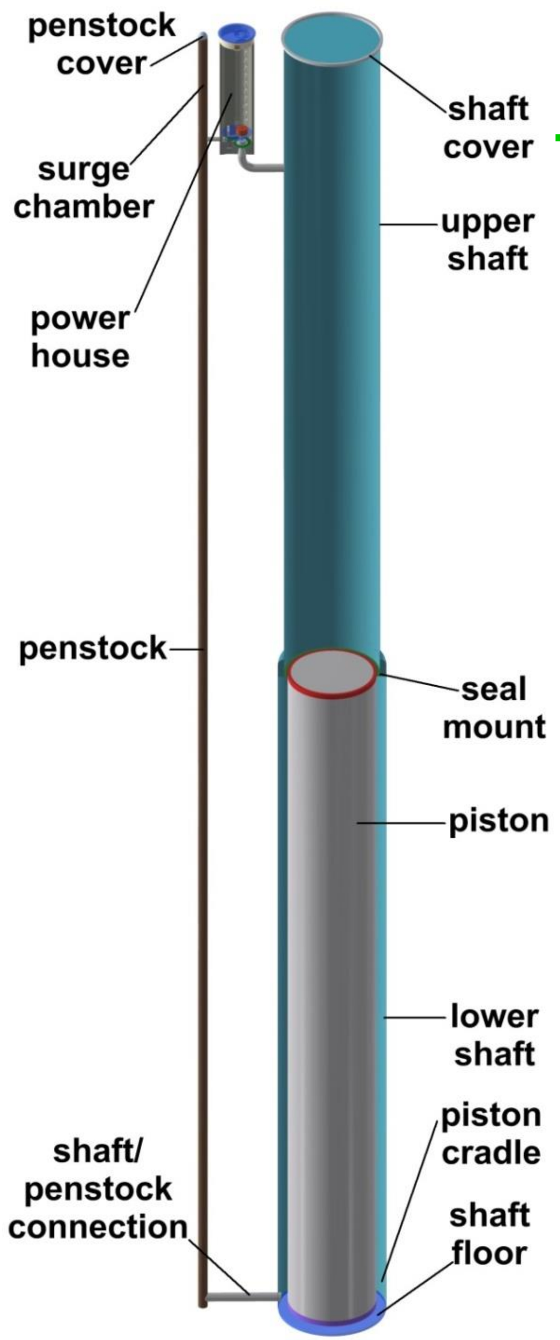
GPP vs. GT, CAES, PSH & Batteries



*Credit Suisse Model - Assumes $0.03/kWh off-peak power and $3 or $7/MMBtu Gas

GPP Parameters

- Piston diameter: 30-100 meters
- Shaft depth: 500-1000 meters
- Piston height: 250-500 meters
- Piston material:
  - Rock core
  - Concrete lining
  - Stainless steel surface
- Working pressure (500m shaft):
  - 375 meters of head (500 psi)



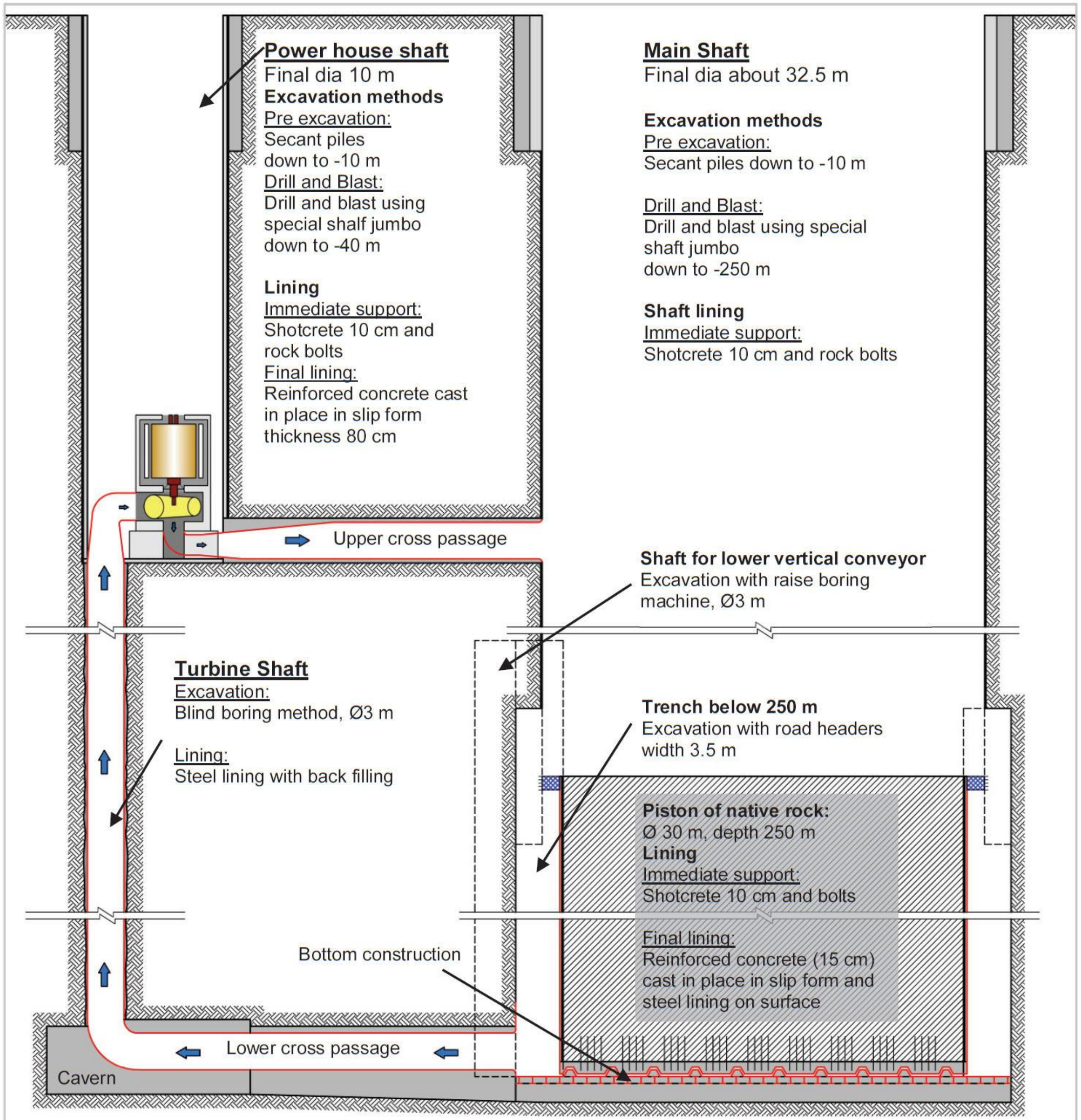
40 MW plan at correct scale

Example - 40 MW GPP

Piston diameter: 30m

Shaft depth: 500m GPM

Construction Plan



- 250m piston
- 500m shaft
- Conventional excavation
- Piston either cut from native rock or manufactured using heavy concrete
- Reinforced baseplate
- Steel-lined piston
- Steel-lined penstock
- 28 months to construct

Conventional tools and equipment

Blast Hole Drilling

Roadheader

Standard equipment to perform excavation and mining

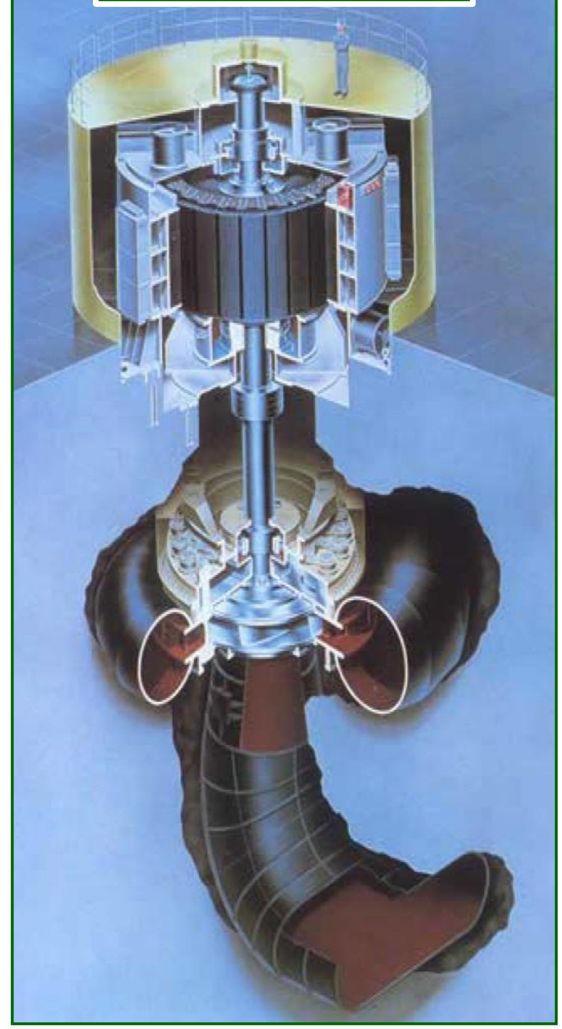
Vertical Conveyor

Vertical automated conveyor used to extract rocks from the shaft

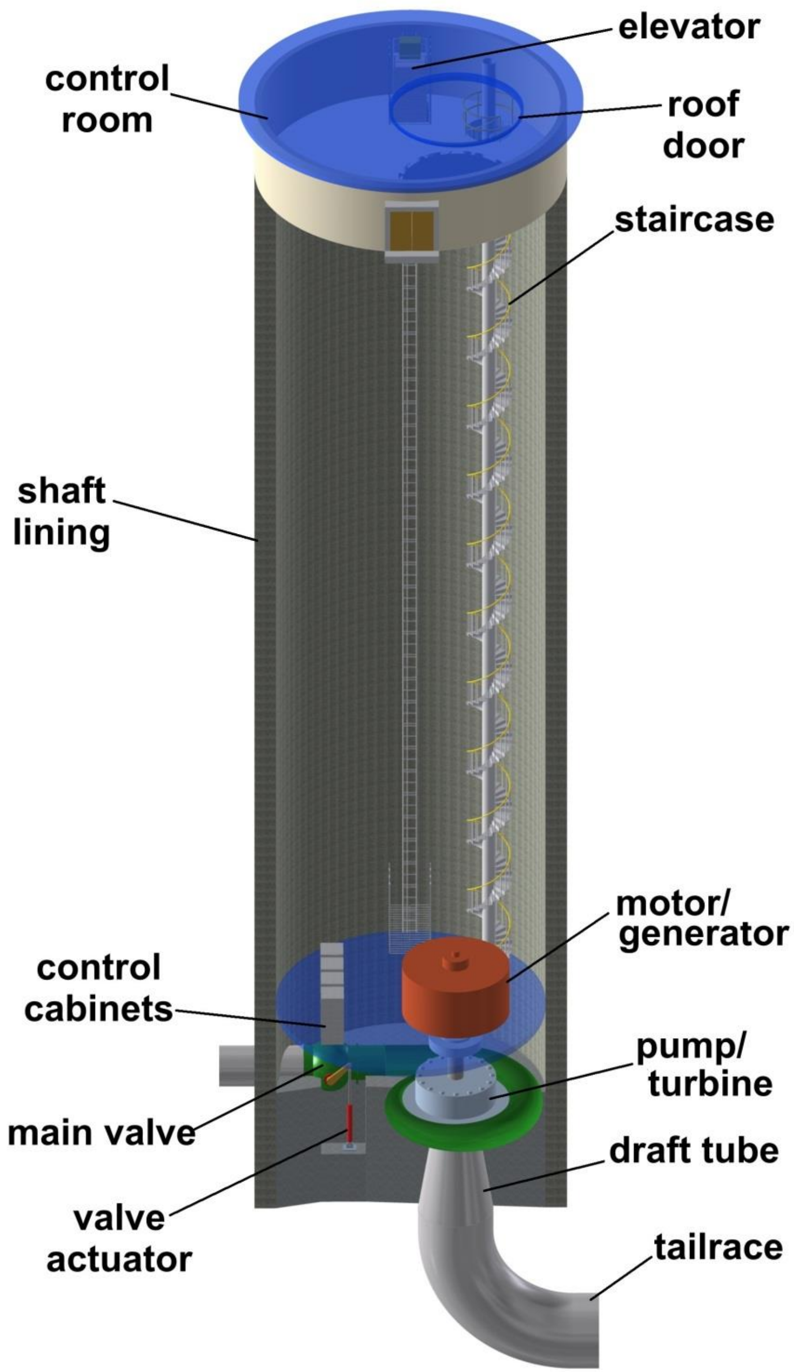
Cross-rail Project

GPP construction in an urban setting will look very similar to the Cross-rail Project in London

Motor Generator



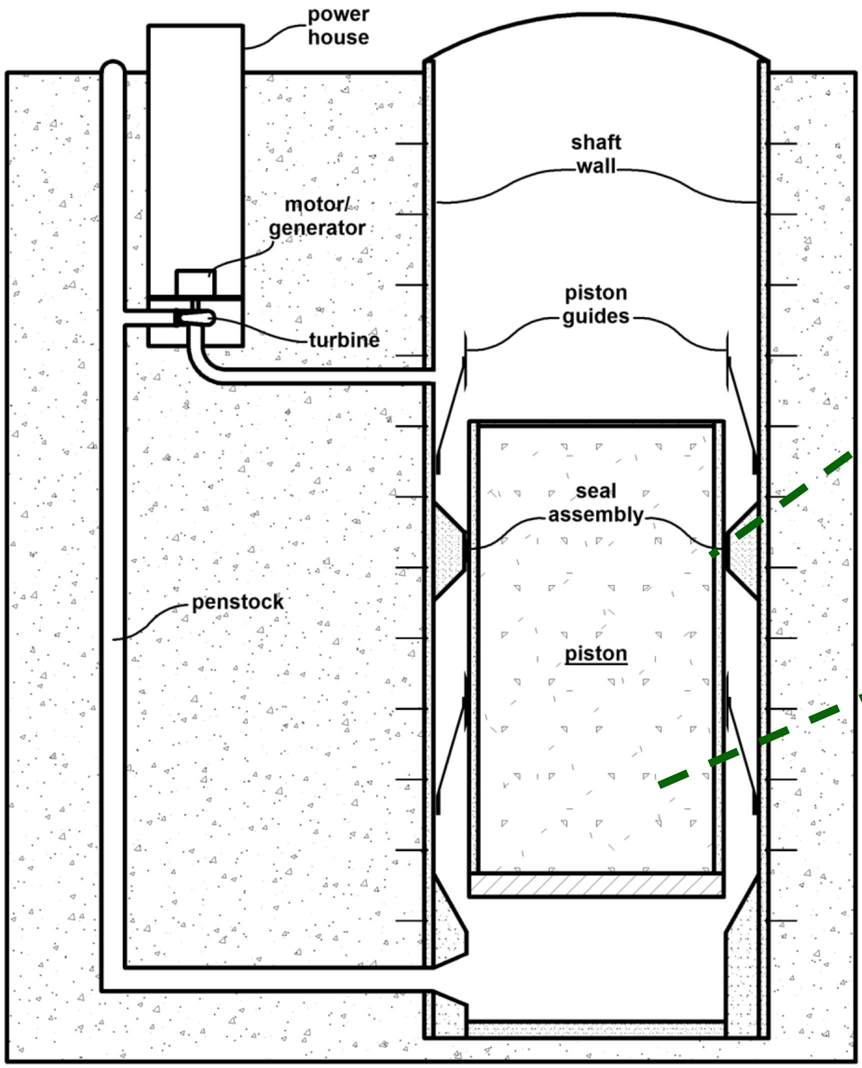
GPPs use conventional power equipment from existing manufacturers



GPP Power House

- Control room at ground level
- Power equipment 30 - 40m below ground to provide required inlet pressure for pump
- Easy access for maintenance
- Quiet & invisible

GPP Seal Configuration



The stationary seal assembly is **attached to the shaft wall** at a depth halfway from the surface

The piston has a **steel skin** for a smooth, hard surface

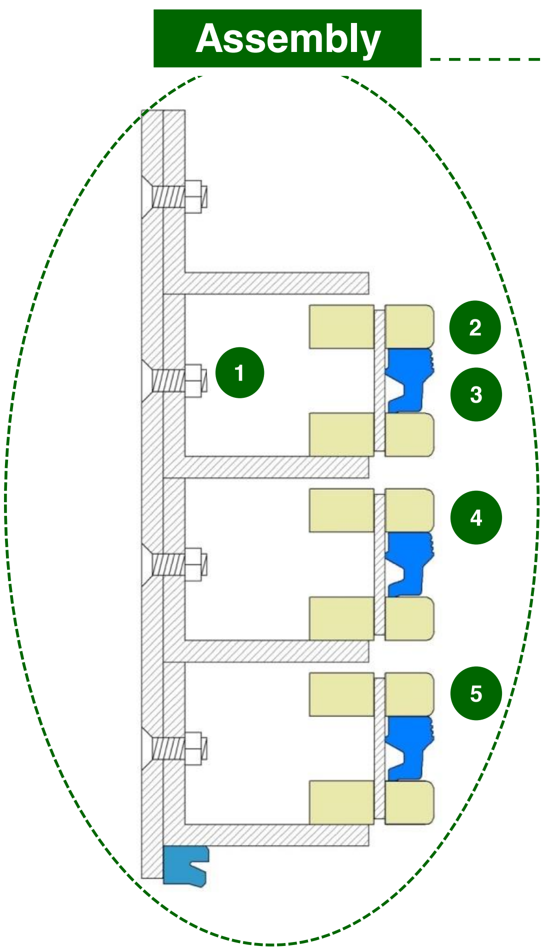
Peterborough Lift Lock

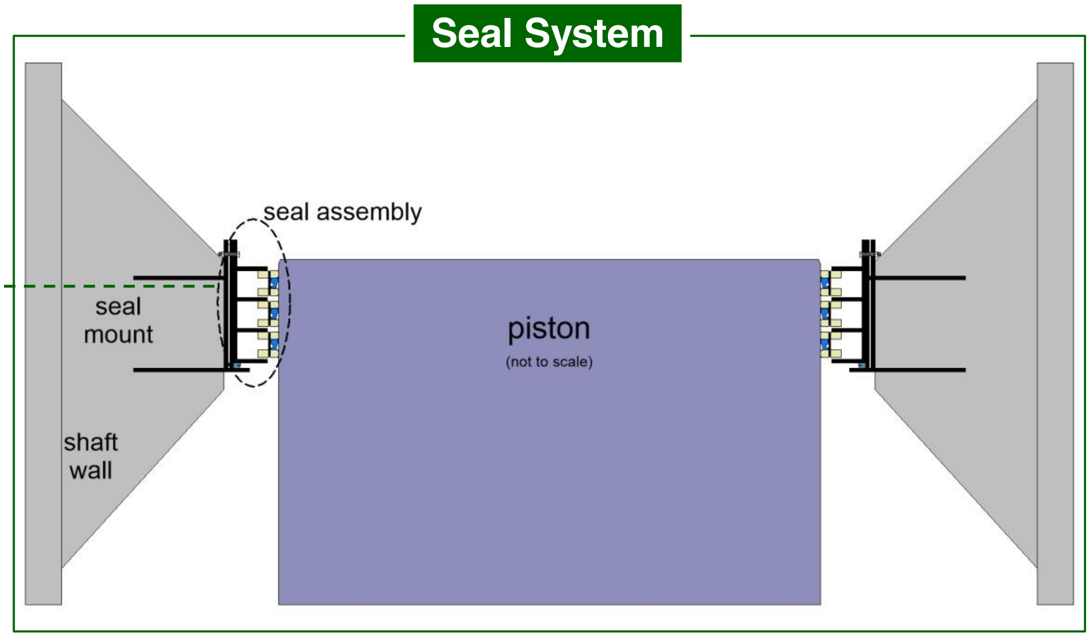
Details

- Built in **1904** in Peterborough, Ontario, Canada
- **20 meter** vertical lift
- **Steel skin** piston for a smooth, hard surface
- **Coil of rubber** seal squeezed between two disks

Peterborough		GPP
20 cm/sec	**Piston speed**	2 cm/sec
600 PSI	**Pressure across seal**	750 PSI
2.3 m	**Piston diameter**	13 m (demo plant)

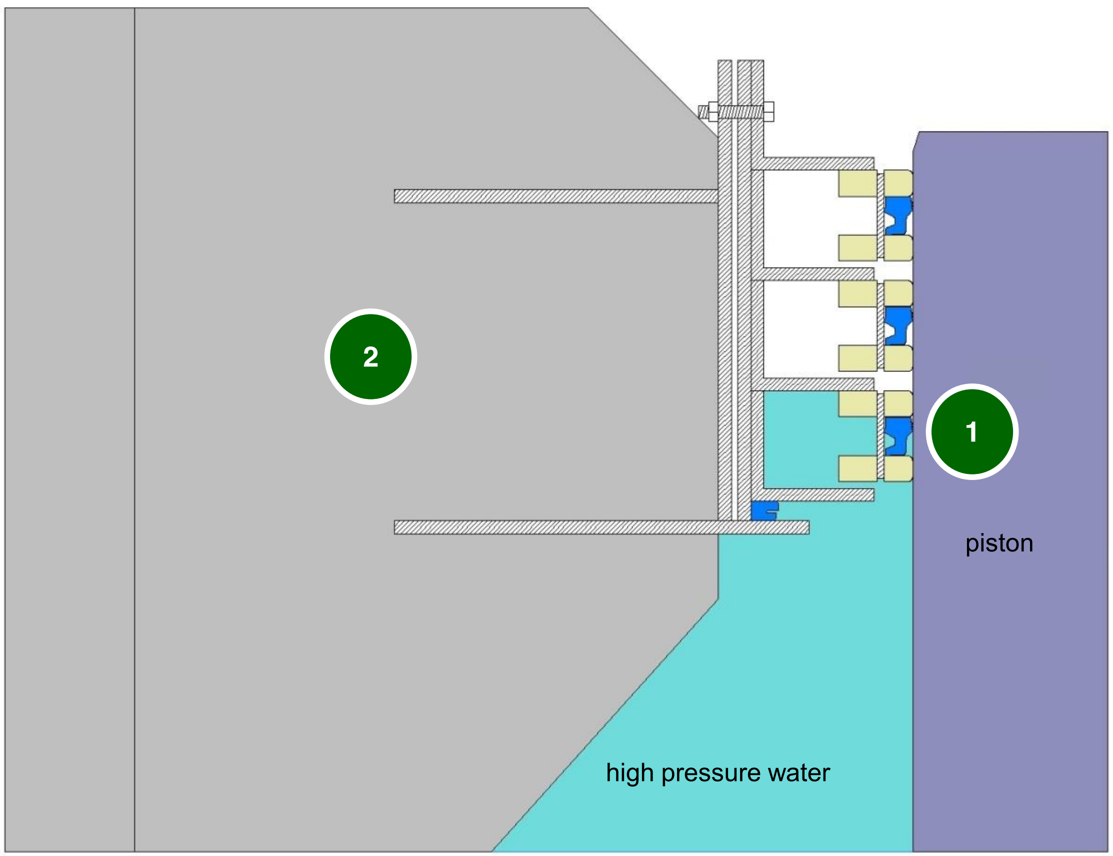
Piston





1	Seal carrier
2	Top seal guide ring
3	Seal
4	Second seal guide ring
5	Bottom seal guide ring

Seal operation

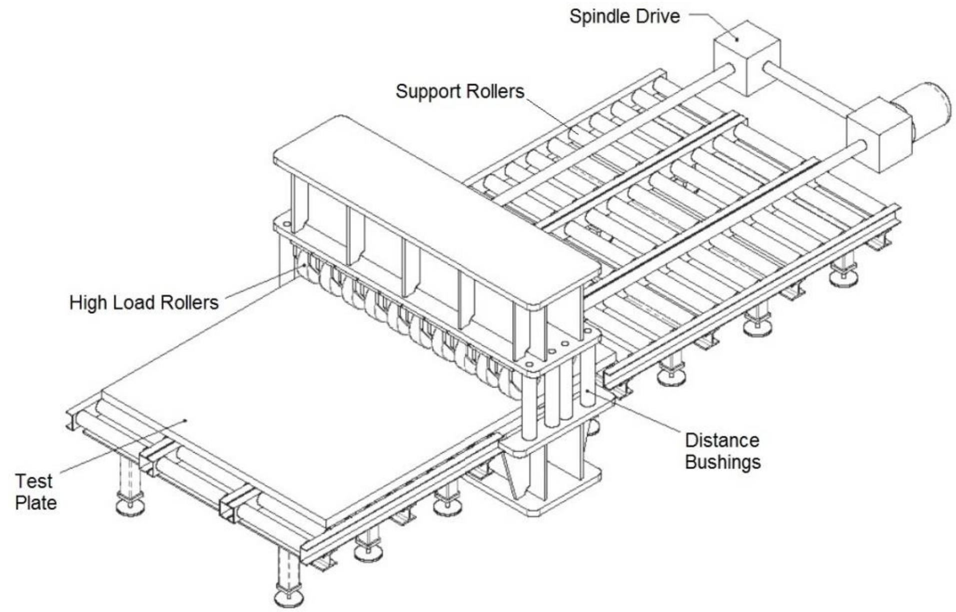


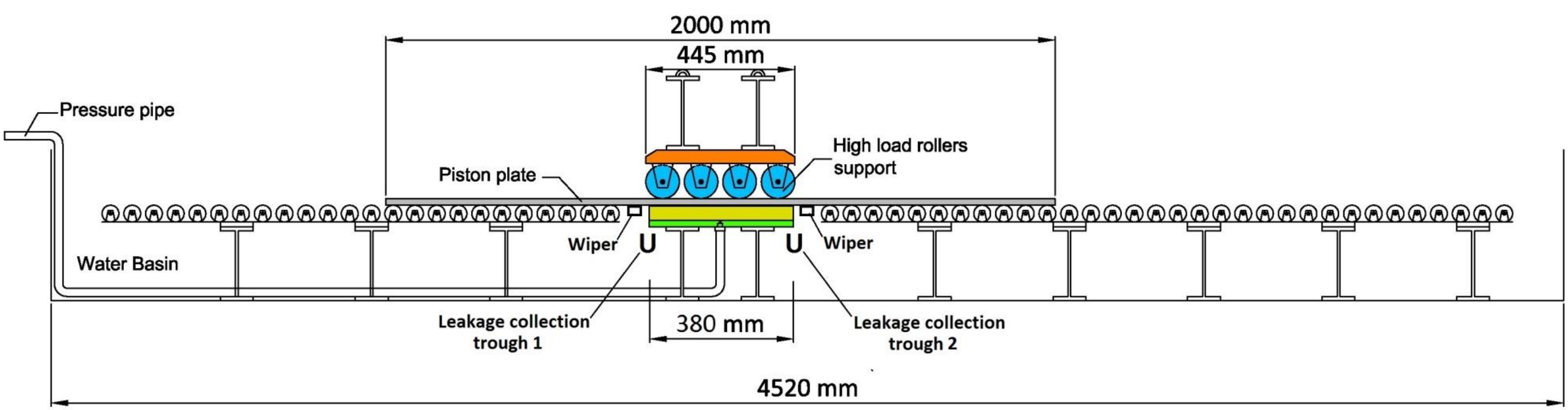
1 In normal operation **only the primary seal** is subject to high pressure

2 The seal mount **must withstand large forces** resulting from the operational water pressure

Seal Tester

- Seal test for demo GPP at full pressure and speed
- Simulated piston tolerance imperfections tested
- Completion forecast late 2018



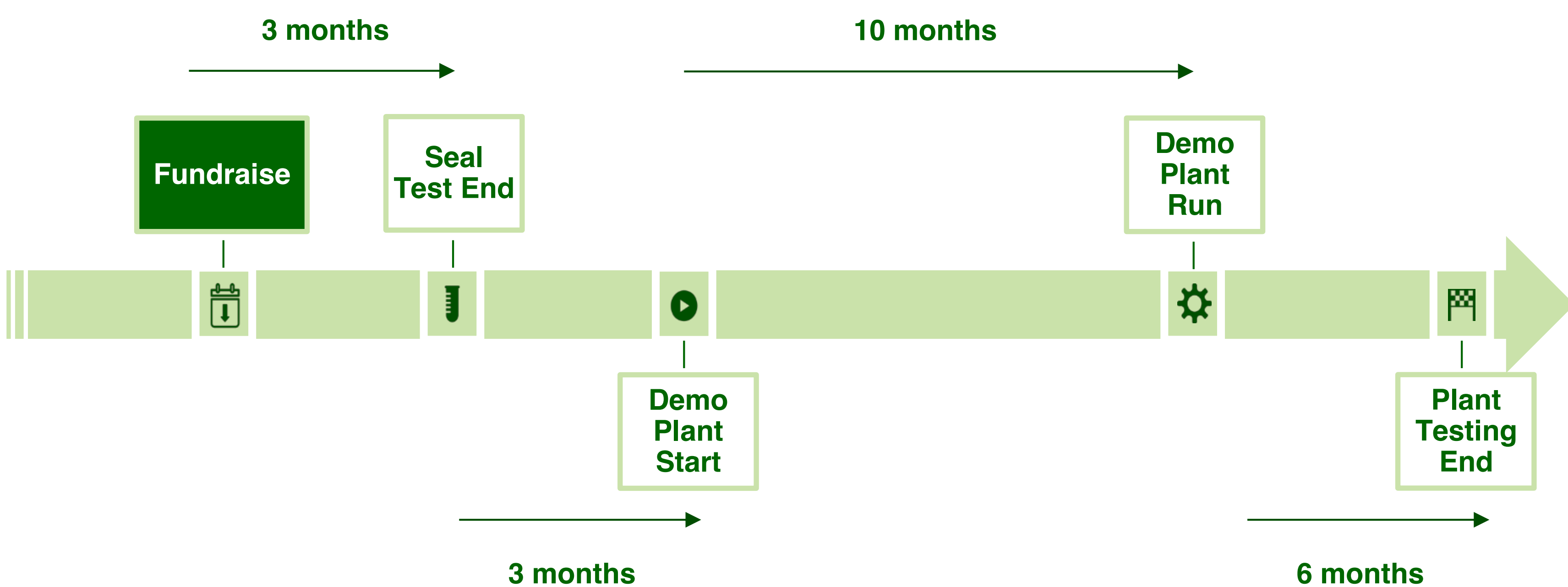


Demo Plant in Kansas

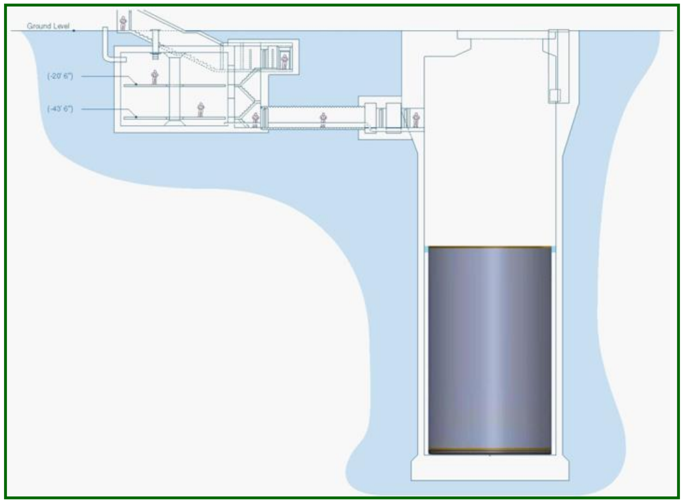
Wilson Demo

- **Atlas F Missile Silo** Technology
- Site Owner "Plan B" signed **MOU**
- **Bibb** Engineers, Architects and Constructors
- **Babendererde** Engineers
- Rolling Hills Electric Co-op, Kansas Electric Power Cooperative, Sunflower Electric Power Corporation

Demo plant construction and operation timeline (less than 2 years)

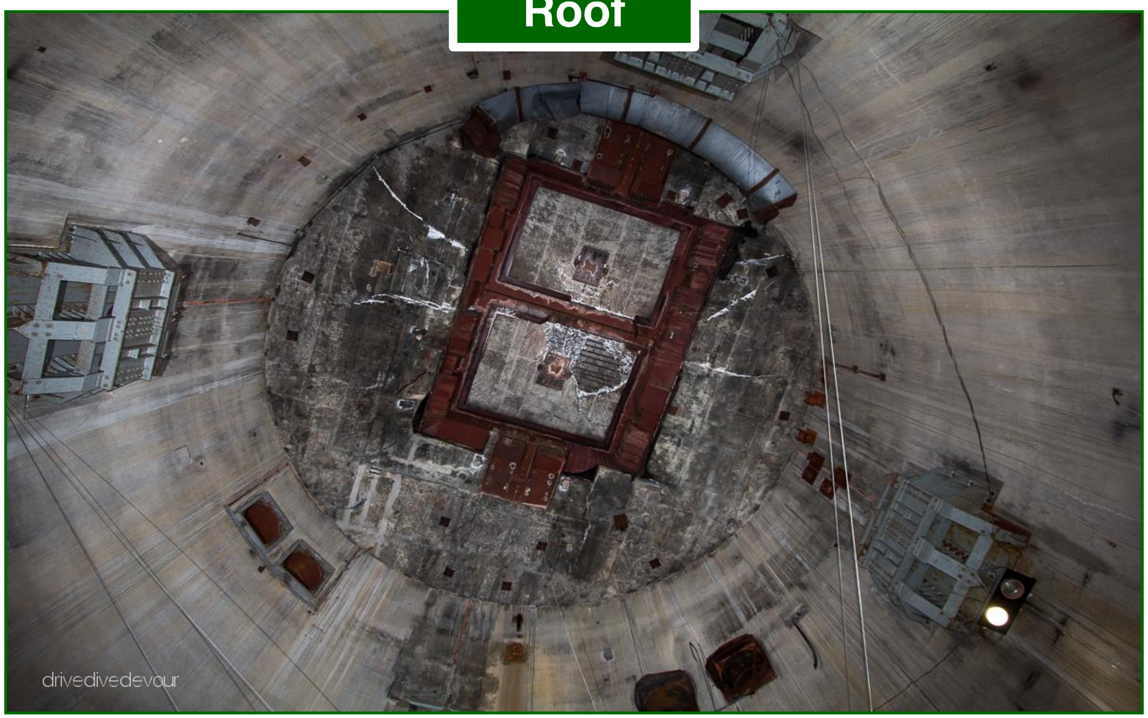


Wilson Missile Silo Demo Plant

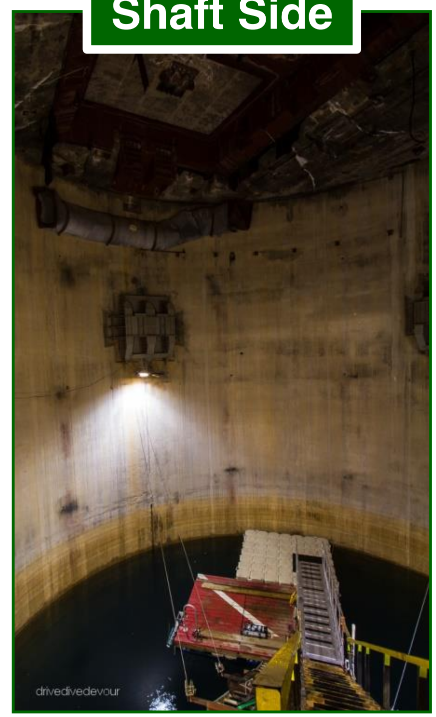


- **1 MW**, 30-minute discharge
- **Shaft:** 15.85m ID, 65m deep
- **Piston:** 10,823 tons,
  12.9m OD, 33m long
- **Estimated demo system cost**: $11M

Roof

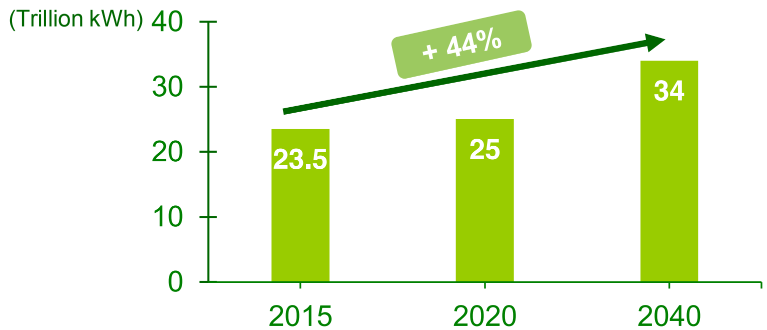


Shaft Side



Addressable market

World electricity demand is expected to grow over the next 20 years



Global Energy Storage Investment by 2050

$590B

Energy storage market will grow from 195 GW in 2018 to more than 500 GW of capacity by 2050

Note: This is limited to USA, China, European Union and India in an average scenario built by the IEA

Energy Storage market addressable (in TWh)

2 TWh of PSH energy storage to be built, representing 88% of global storage capacity in 2030 *(reference scenario of IRENA)*

Intermittent renewable energy is rapidly increasing the need for energy storage

Dropping cost of solar and wind renewable energy coupled with storage option will lead them to become the low-cost capacity options

Governments continue to **encourage reductions in fossil fuel use**

Utilities are **increasingly procuring energy storage** through Request For Offers ("RFOs") and other solicitations

Source: IRENA, IEA, US DOE Global Energy Storage Database, Specialized press

Commercial Markets

The Kingdom of Saudi Arabia

Crown Prince Mohammed bin Salman, in his Saudi Vision 2030, called **for cutting fossil generation and expanding solar generation** creating a huge market for GPPs. Multiple meetings with strategic parties have occurred.

China

China **has 39 GW of new PSH under construction**, which will more than double their current 29 GW of installed capacity - a massive market for GPPs with talks ongoing.

Morocco

The Moroccan Agency for Sustainable Energy is **pursuing solar generation coupled with storage to meet peak loads**. PV plus GPP is the lowest cost offering for this need - parties there await a GP demo.

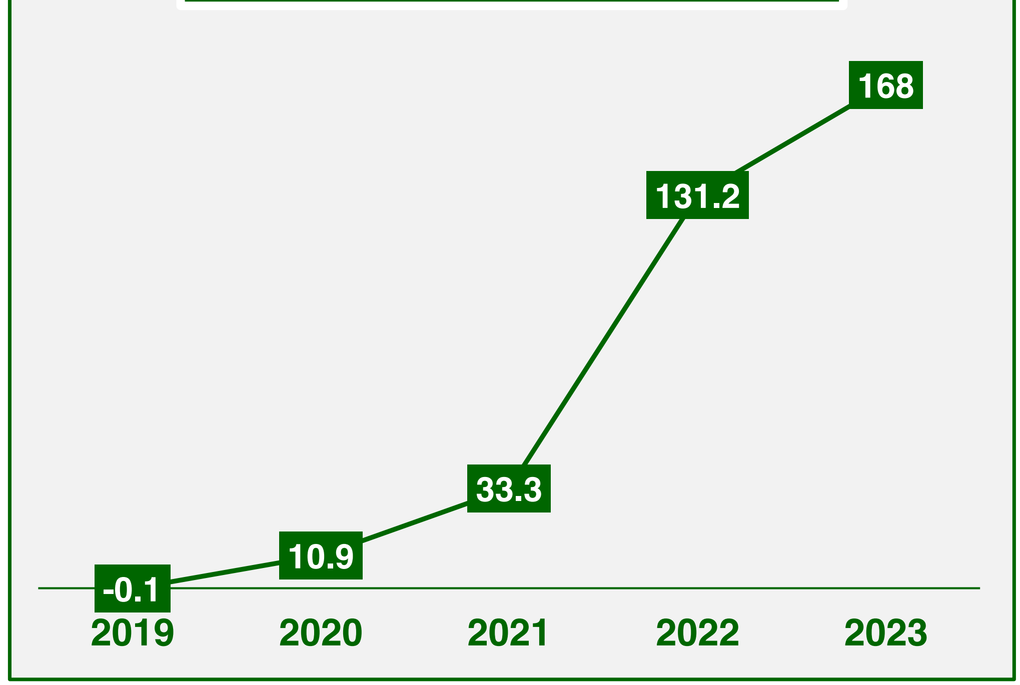
The United States

There is a need to balance the burgeoning solar PV and wind capacity additions. There is now **51 GW of PSH** in the FERC queue. With easier permitting and faster construction GPPs could be operational far sooner than traditional PSH.

Europe

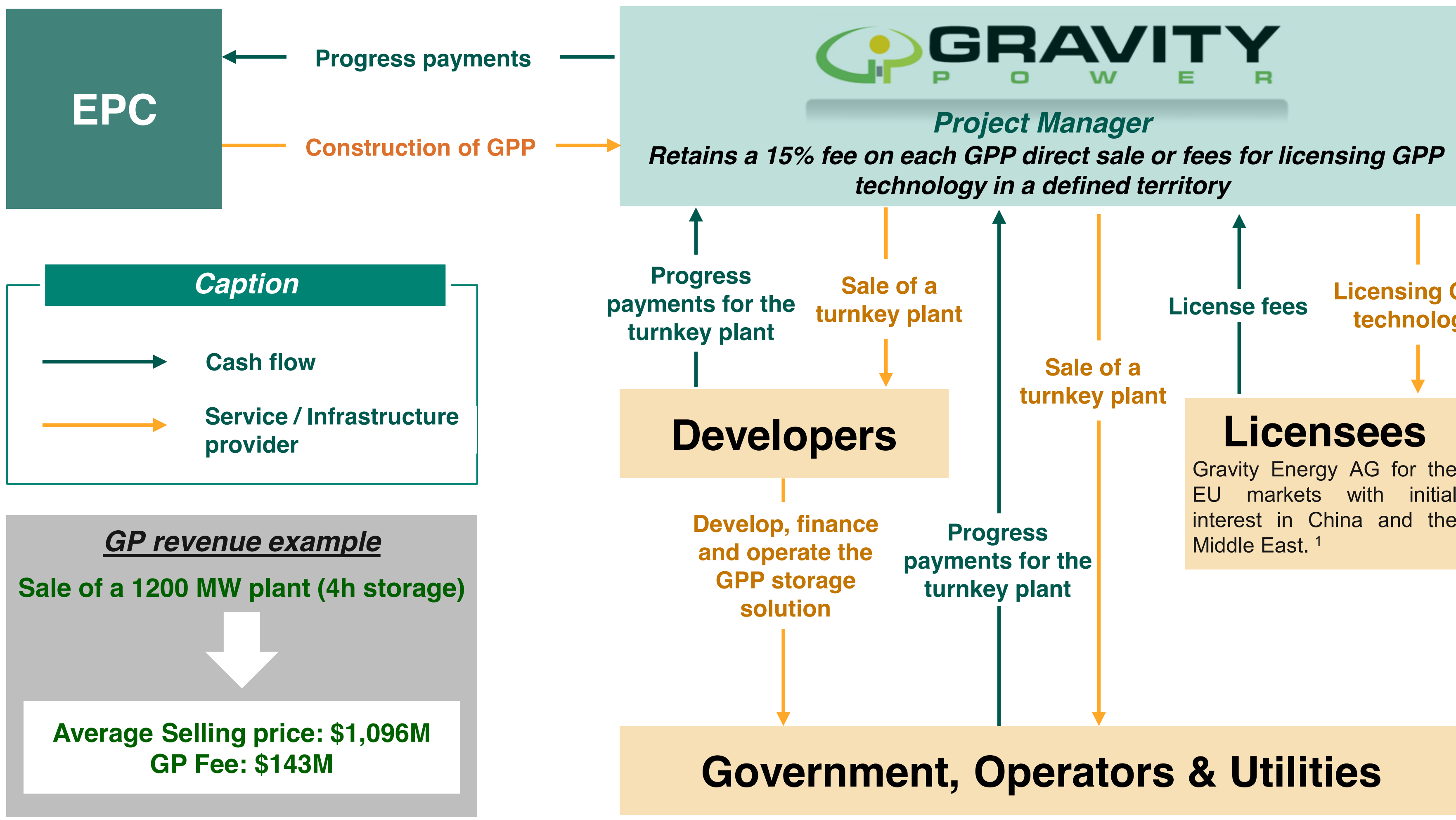
With fervent support for renewables and environmental opposition to traditional PSH, GPPs are a compelling alternative. **Licensee Gravity Energy AG** is working to address this market. GP has strong interest in commercial projects in the UK.

GP Projected 5Y EBITDA (M$)



Business Model

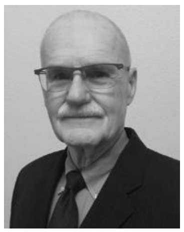
Gravity Power becomes cash-flow positive at the start of construction of the first commercial plant.



[1] License not included in the financial model

Management

Gravity Power is led by a highly experienced management team



Tom Mason l CEO - Expert in power generation and gas turbine technology

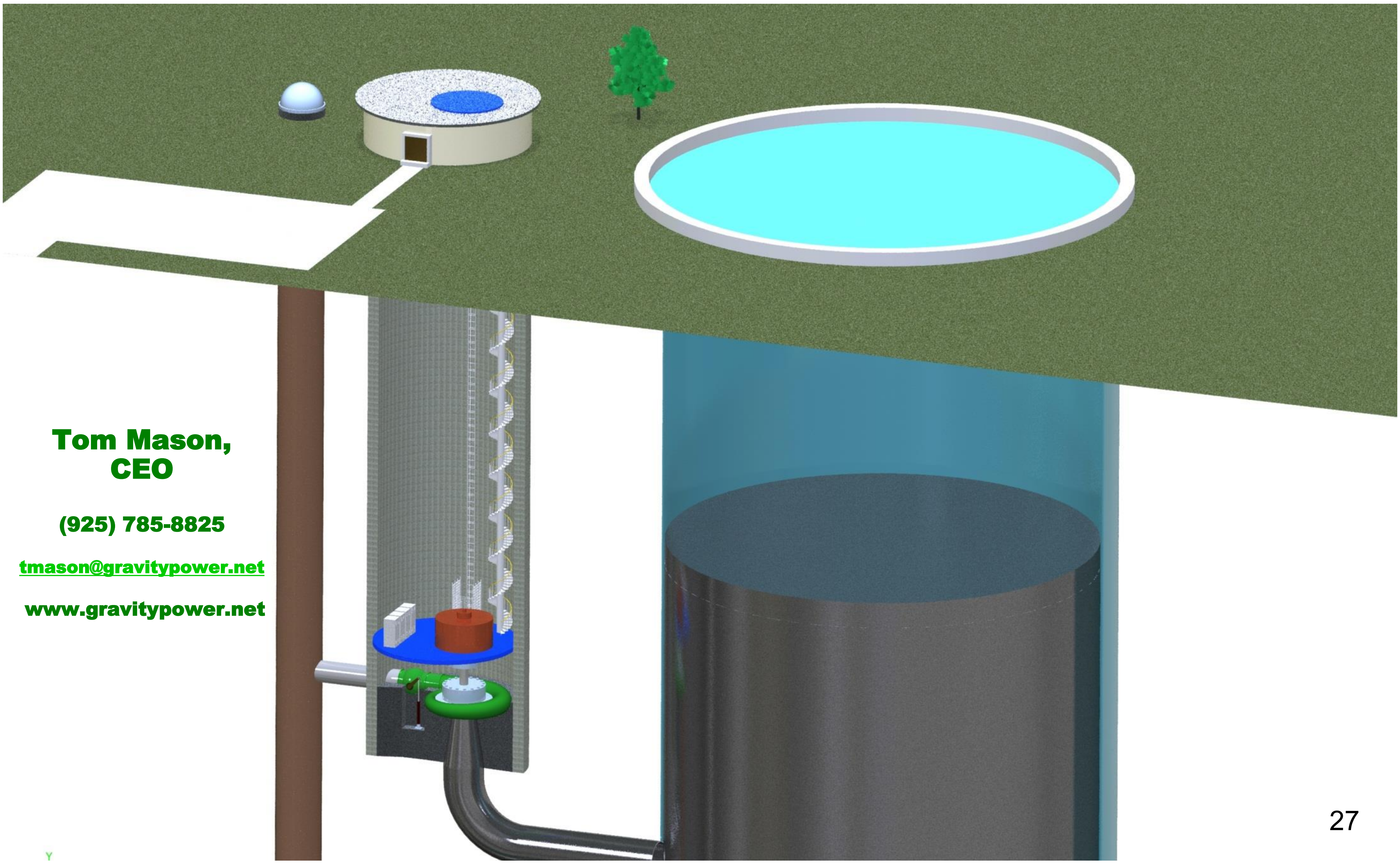
Tom was Executive Vice President of Calpine and President of Calpine Power Company, responsible for the largest fleet of gas-fired power plants in the world and the world's largest geothermal facility. While at Calpine he managed the simultaneous construction of 30 power plants, most of which were 500 MW or above. Prior to that, Tom was President and COO of CalEnergy and prior to that with Solar Gas Turbines and Commonwealth Edison. Tom is an Electrical Engineering graduate of Purdue University and holds an MBA from the University of Chicago.

James Fiske l Founder & CTO - 30 years in technology R&D and commercialization

Jim leads the team developing the new Gravity Power Plant (GPP) and has spent over 30 years in technology R&D and commercialization. Jim founded three venture-funded companies and led R&D efforts in fields ranging from high speed digital electronics to electromechanical energy storage systems. Jim won research grants from organizations including the National Science Foundation, the Department of Energy, and the Air Force Office of Scientific Research. Jim received his Electrical Engineering & Computer Science degree from the Massachusetts Institute of Technology.

Christopher Grieco l EVP - 25 years of experience in power generation, energy storage and transportation

Chris brings over 25 years of experience in power generation, renewable energy, energy storage and transportation. Chris served as Head of Technology for Dehlsen Associates, LLC. As COO, Chris also spent 3 years building a startup company. Chris spent his first 12 years with the Ford Motor Company in engineering and mergers and acquisitions. He received the Henry Ford Technology Award, Ford's highest technical achievement for new technology commercialized. Chris received a BS degree in Mechanical Engineering from The Ohio State University and a MS in Mechanical Engineering from the University of Michigan.



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