EIC solution to energy decarbonization – The EIC Plant

Energy Internet Corporation's (EIC) mission is to accelerate decarbonization by making renewable energy profitable with high returns. EIC's solution the EIC Plant, is a highly efficient and general purpose energy converter, that can be connected with commercially available electrical, chemical, or mechanical systems and plants today, to decarbonize electricity, fuels and industrial processes. The EIC Plant itself is assembled from repeatable modular units, per precise and standardized processes, at any scale, using only commercially available engineering components. An EIC Plant can be dynamically and programmatically configured to provide one or more simultaneous applications, all labeled as Energy internet (Ei), as described below.

1. Ei Power, *For Microgrids, substations, transmission grids, captive grids, such as, consumer data centers, steel plants, process plant*: Firm up intermittent and seasonal renewable power supply by converting and storing the surplus renewable energy in the form of compressed gases and reconverting them into electricity to deliver continuous and high-quality power.

2. Ei Ammonia & Hydrogen, *for Ammonia, hydrogen plants:* Convert intermittent and seasonal renewable power supply, to compressed gas energy and reconvert by expanding gases. It enables continuous and efficient operation of commercial ammonia synthesis plants with renewable power sources, by compressing Hydrogen and Air, to high pressures (50 MPa+) for storage and release- as needed. It also converts the excess thermal energy of gases from the ammonia reactor, as electricity and heat for Electrolyzers.

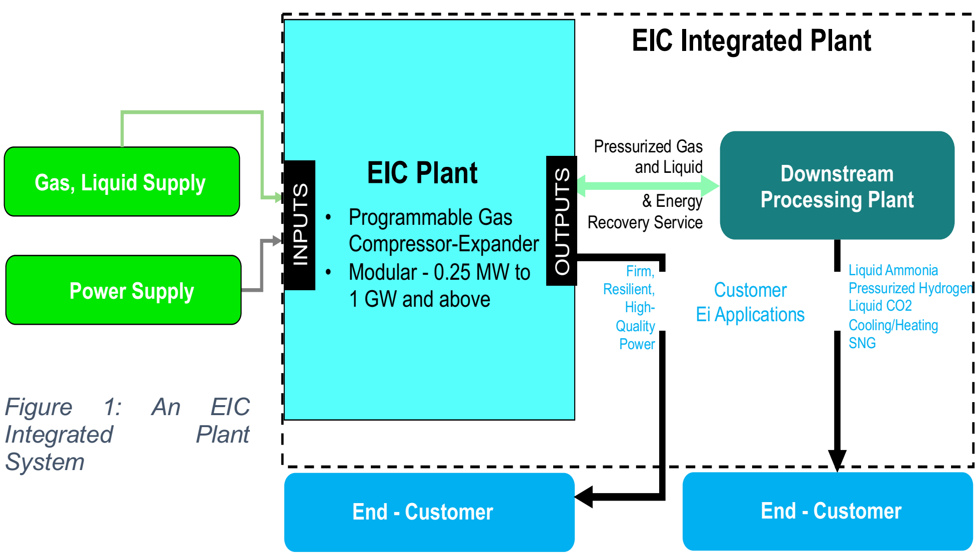

Figure 1: An EIC Integrated Plant System

3. Ei Water, *for RO plants*: Provide Sea water (or effluent) purification with a two-stage energy conversion; first from intermittent and seasonal renewable power supply into compressed air and then compressed air to pressurized sea water to different stages of an RO Plant.

4. Ei Cooler and Heater, *for Cooling and Refrigeration Applications*: A two-stage energy conversion; first from intermittent and seasonal renewable power supply into compressed gases and using the stored energy to compress the refrigerant gases.

As Figure 2 shows, the EIC Plant is a 'Programmable compressor-expander & energy converter', delivering applications, as noted above, by appropriately integrating and interfacing with third party processes, through its standardized control and physical interfaces. The EIC Plant scales from its smallest size, 0.25 MW to a GW and above, by repeating unit modules as needed.

EIC Plant

An EIC Plant, a programmable platform, comes with preinstalled features at commercial deployment. Customers can customize and programmatically add features as they scale, enhance, or upgrade their system or integrate their plant with downstream plants, along with associated physical devices, interfaces, and systems. Figure 2 shows an EIC Plant. It's four modular components (labeled #1 to #4), are integrated and assembled at site, per a precise and standardized process. Supply systems (#5) and the downstream and customer systems (#6 and #7), can each be interfaced in a modular fashion, enabling systems from different vendors, generation, and types, to seamlessly interoperate with each other. We describe below the four standard services provided by the EIC Plant.

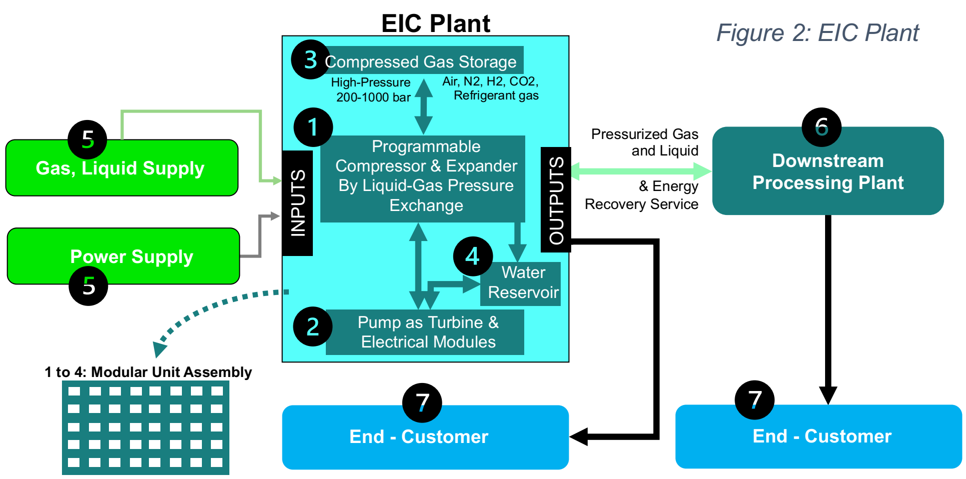

Figure 2: EIC Plant

I. The P*rogrammable Gas Compressor – Expander,* is the core 'mechanical processing unit building block' of the EIC Plant (#1). Its 250 kW modules, are arrays of pressure vessels, connected to each other on manifolds. They plug in with each other to form a Liquid Piston Heat Engine (LPHE) Assembly of the size and pressure range needed. Each module performs one of four processes of energy exchange at any one time.
   a. Water to Gas energy exchange – Pressurized water from water pumps (#2) are admitted into an array of pressure vessels (in a segment of an LPHE module), filled with a gas,

through a circuit of hydraulic valves. The water acts as a piston and pressurizes the gas. The hydraulic energy (pressure head plus kinetic energy) is efficiently transmitted to the gas, normally under near-isothermal (with little change in temperature) conditions. Specialized insulated LPHE modules provide adiabatic or polytropic compression. The gas when it reaches a certain pressure (and temperature) is either delivered to a downstream processing plant (#6) or to a storage unit (#3) through a circuit of pneumatic valves.

b. Gas to Water energy exchange – Pressurized gas from a stored gas unit (#3) pressurizes water in an array of pressure vessels, to run a turbine that generates electricity (#2). It can also pressurize any liquid to send the pressurized liquid to another segment of the LPHE module or to an array of other LPHE modules, or a downstream processing plant (such as, pressurized sea water to an RO plant). Again, this energy transferred generally isothermally, but can also be adiabatic/polytropic.
c. Gas to Gas energy exchange – Pressurize gas from a stored gas unit (#3) or from a set of other LPHE modules, pressurize a liquid in an array of pressure vessels, that in turn pressurize another gas, safely, in a connected array of pressure vessels.
d. Liquid to Liquid energy exchange – Pressurized liquid in an array of pressure vessels pressurize a gas that in turn pressurize another liquid in a connected set of pressure vessels.

The LPHE's versatility with any gas or liquid, its operation at desired pressure and temperature ranges, and flow rates, is effectively leveraged by its programming environment. Standardized programming scripts can be effectively employed to leverage the four energy exchange features, to deliver the desired Ei Applications indicated.

II. *Pump (often also) as a Turbine (PaT) and electrical modules* (#2) provide the electrical to hydraulic energy conversion. Surplus (power that cannot be directly distributed to a customer) intermittent and seasonal renewable power, drives pumps to deliver water at desired pressure and flow levels. This through its intelligent valve assembly (in Valve rooms) distribute water in appropriate manifolds into select LPHE modules (#1), where the earlier described pressure energy exchange transpires. In the reverse, pressurized water flows from the LPHE, directed to the relevant turbines (through the valve assembly) produce electrical power. Electrical subsystems, including capacitor and battery systems are used to regulate and modulate the power supply, both in the pumping phase and the turbine phase of its operations.

III. *Compressed Gas Storage (#3)* provides efficient long duration energy storage. The largest form factor of storage, at TWH of energy scale, is in the form of compressed air in subsurface reservoirs- spent oil/gas, aquifers, or hard rock formations. This can also store hydrogen, SNG or other such gases at scale. The range of gas pressures can be upwards of 15 MPa. At surface gas storage is often held at high pressures, to minimize the cost of storage per ton, KWH or BTU. The range of gas pressures can be upwards of 50 MPa.

IV. *Water Reservoir (#4*) provides the water that is used by the PaTs and LPHEs in a closed loop. Water is stored in standard sized modular tanks at surface. Appropriate water quality is maintained through every cycle of operation.

How EIC Plants are deployed at customer sites

EIC deploys 'EIC Integrated Plants', integrating its EIC Plants with suitable energy and gas supply as input, and third-party downstream processing plants as necessary, to meet a customer's requirement (Figure 1)

Inputs

An EIC Plant has one or more inputs of

- Electrical power feed,
- Gases, such as purified hydrogen from electrolyzers, or purified flue gas from thermal power plants, purified and syn gas from biodigesters, and air, de-particularized where appropriate, from the ambient environment;
- Liquids, such as sea water or brine or effluent water.

Input side interfaces convert the supply from third-party sources into EIC plant supply streams.

Respectively they are:

- Electrical – EIC Plants operate on 4 KV. Input interfaces - Transformers and electrical systems as appropriate.
- Gases and Liquids – EIC Plants operate within a prescribed maximum pressure and flow. Input sources need to provide appropriate safety and expose real time key parameter operational data.

Outputs

The EIC plant delivers its outputs through standardized interfaces as below:

- *Electrical Power* – Firm, resilient, high-quality electricity through an output interface that matches customer voltage and frequency requirements.
- *Pressurized Gas and Liquid and Energy Recovery Services* – This an output and return service, to deliver customer end-products such as Liquid ammonia, pressurized hydrogen on-demand, Liquid CO2, SNG or services, such as, cooling and heating. To illustrate the

pairs of outgoing and return service to/from EIC plants:

- *An Ammonia Downstream Process Plant* receives compressed gases, nitrogen, and hydrogen, at the appropriate pressure, temperature and flow rates from the EIC Plant. In turn, it sends back to EIC Plant the hot gas mixture of ammonia, and unreacted nitrogen and hydrogen to cool, and recompress; the thermic/ionic fluids from heat recovery in the ammonia reactor, for electricity generation; and the refrigerant gas for compression and condensation. The Ammonia Plant's output is eventually liquid ammonia, at the desired temperature. An additional ammonia cracker plant can then crack ammonia to deliver hydrogen at the desired pressure on demand.

- *A Liquid CO2 Downstream Process Plant*, cycles liquid CO2 from its store, into the EIC Plant, to receive back in return an additional stock of freshly condensed CO2 from flue gases. The process plant may perform some upstream or input functions, where missing, in terms of the purification and de-particularization necessary before it sends flue gases into the EIC Plant in the first place.

- *A Synthetic Natural Gas Process Plant* receives the pressurized hydrogen and CO2 from the EIC Plant at the appropriate pressures and temperatures necessary for its catalytic reaction and performs similar cycling of gases to the EIC plant and energy recovery services as the ammonia process plant above.

- *An RO Plant* – receives pressurized sea water (or effluent) from the EIC Plant. It also sends back the concentrated brine back to the EIC Plant for energy recovery.

Integration with third-party systems through Programmable Control & Physical Interfaces

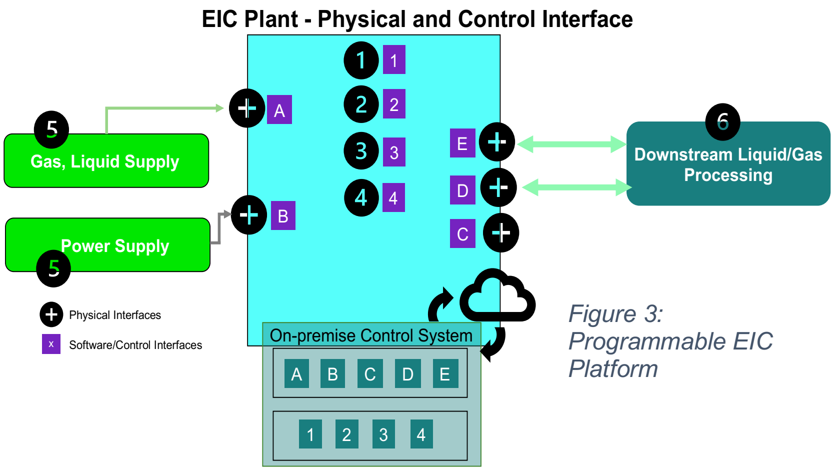

Figure 3: Programmable EIC Platform

The programmable (A to E & 1 to 4) and physical interfaces (shown +) are illustrated in Figure 3. Features 1 to 4 are preprogrammed into the EIC Plant (on-premise) based on customer requirements, identified in project planning stages. Respective physical interfaces connect into relevant input (A and B) and output ports (C, D and E). Customers can use an EIC cloud environment to securely update, upgrade, or develop custom applications.