DATA CENTER ENERGY SUSTAINABILITY

Options for the Supply of Energy for the _________________, _________, NB

Notice: This report has been edited in size for distribution purposes.

Presented To: [redacted]
Presented By: **Associated Energy Developers, LLC**

January, 2021

ASSOCIATED
ENERGY DEVELOPERS

1.0 EXECUTIVE SUMMARY

1.0 About the Report

This report was undertaken at the request of [redacted] in order to provide a critical view of the options available for energy production at a Datacenter project site located in [redacted]. Management wanted to be able to examine the possibility of using various methods to achieve a redundant energy supply at the site and incorporate the use of renewable energy where possible and economical.

The report concludes that the datacenter can be served by two energy 'grids' – an existing electrical grid and an achievable gas supply main. AED has suggested that the gas main be used to run Combined Heat and Power (CHP) microturbines to produce an electrical supply on-site. The CHP units would be coupled with Absorption Chillers to create a Combined Cooling Heat and Power (CCHP) architecture to power, heat and cool the entire facility. The gas source would be considered the Primary energy source, with the existing electrical grid acting in a secondary role as a backup source.

A storage container of Compressed Natural Gas (CNG) would be located on the site and would provide backup emergency power for 96 hours in the even of an outage of both the gas and electrical lines.

Additional self-generation using both the on-site solar and wind resources are also included in the architecture. Initial investigation of the wind resource indicates that a wind turbine could operate at a high Capacity Factor and provide up to 11.8% of the datacenter's initial year's annual electrical requirements.

The scope of this report as tasked was to provide:

• *Suggestions on 3-4 potential wind/solar/CNG/Chemical/Storage strategies and energy profiles*
• *Develop first-level pricing estimates of those profiles*
• *Develop first-level operating proformas of those profiles*
• *Develop energy modeling for those profiles*

In essence, the task is to examine some energy types that could provide redundancy (N+1) with an eye towards green, renewable sources. The following scenarios were considered:

- Base Load projections – what energy will be needed?
- The nature of the existing Electrical Grid
- Combined Heat and Power (CHP) using a new gas 'grid'
- Solar Photovoltaic (on-site and off)
- Wind Energy Capabilities
- Chemical Storage (H2, CNG)

Each of these is considered in the sections to follow.

3.0 DATACENTER LOAD

3.1 Datacenter Equipment Usage

The datacenter as envisioned would be characterized as a "High End Data Service Provider" according to a Lawrence Berkeley National Laboratory report: *United States Data Center Energy Use* (2016) [1] as shown in Table 1 below. These centers are characterized as having over 20,000 square feet of floor space but below the threshold of 400,000 sf of area that characterizes the next tier of datacenters (Hyperscale datacenters). They are further characterized as a: *"Primary server location for a service provider. May be subdivided into modules for greater flexibility in expansion/refresh. Has advanced cooling systems and redundant power"*.

Table 1: Typical IT Equipment and Site Infrastructure System Characteristics by Space Type (Berkeley Labs)

Space type	Typical size	Typical infrastructure system characteristics
Internal server closet	< 100 ft^2	Often outside of central IT control (often at a remote location) that has little to no dedicated cooling.
Internal server room	100-999 ft^2	Usually under IT control, may have some dedicated power and cooling capabilities.
Localized internal datacenter	500-1,999 ft^2	Has some power and cooling redundancy to ensure constant temperature and humidity settings.
Midtier internal datacenter	2,000-19,999 ft^2	Superior cooling systems that are probably redundant.
High-end internal datacenter	> 20,000 ft^2	Has advanced cooling systems and redundant power.
Point-of-presence server closet	< 100 ft^2	At local points of presence for OSS and BSS services. Typically leverages POP power and cooling. Space is often a premium.
Point-of-presence server room	100-999 ft^2	Secondary computer point of presence for OSS and BSS services. Typically leverages POP power and cooling.
Localized service provider datacenter Including subsegment: containerized datacenter	500-1,999 ft^2	Has some power or cooling redundancy to ensure constant temperature and humidity settings. These are typically facilities set up by VARs to provide managed services for clients.
Midtier service provider datacenter Including subsegment: prefabricated datacenter	2,000-19,999 ft^2	Location for small or midsize collocation/hosting provider. Also includes regional facilities for multinational communications service providers. Has superior cooling systems that are probably redundant.
High-end service provider datacenter	> 20,000 ft^2	Primary server location for a service provider. May be subdivided into modules for greater flexibility in expansion/refresh. Has advanced cooling systems and redundant power.
Hyperscale datacenter	Up to over 400,000 ft^2	Primary server location for large collocation and cloud service providers. Based on modular designs, with individual modules of 50,000 sq ft on average in up to 8 modules. Employs advanced cooling systems and redundant power.

This category agrees with the description of the project by management, who describe the project to be that of developing a 'high end' center offering clients both security and redundancy within a context of green or renewable energy sources to the extent possible.

The suggestion was made that they believe that 96 hours of backup energy supply will suffice.

The planned datacenter will occupy approximately 54,000 sf of floor space and will run continuously (24 x7 x 365). In comparison, Dixon[2] shows that one 50,000 square feet data center (4 years older) uses about 5 megawatts, also continuously. Given advances in reductions of physical server sizes and floor space density, the amount of power suggested by management in the table below (6.2 – 9.3MW in years 3-4) appears to be a good estimate of the power requirement of this project.

PUE and DCIE: A measure of energy efficiency in datacenter design is known as the Power usage effectiveness (PUE), which is a ratio that describes how efficiently a computer data center uses energy; specifically, how much energy is used by the entire datacenter complex (including cooling, lighting, etc.) as compared to just the computing equipment.

$$PUE = \frac{Total\ Facility\ Power}{IT\ Equipment\ Power}$$

Standard	Good	Better
2.0	1.4	1.1

An average data center has a PUE of 2.0; however, several recent super-efficient data centers have been known to achieve a PUE as low as 1.1. For this study a PUE of 1.3 will be assumed.

DCiE is defined as the ratio of the total power drawn by all IT equipment to the total power to run the data-center facility, or the inverse of the PUE:

$$DCIE = \frac{1}{PUE} = \frac{IT\ Equipment\ Power}{Total\ Facility\ Power}$$

Standard	Good	Better
0.5	0.7	0.9

For this site the anticipated DCIE is .769.

Given the above, for this project we shall conservatively assume that through approximately year 3.5, 7.5MW of the estimated 8MW of grid availability shall be used without upgrading the utility conductors to the site. Given a PUE of 1.3 this would result in a power requirement of 5.77MW allocated to the servers and electronics themselves, and the balance attributed to the rest of the facility. Given a continuous load profile (which is conservative since many balance-of-facility functions such as office lighting and cooling may fluctuate over the day) an annual energy consumption estimate may be derived of:

7.5MW x 8760 hours/year = **67,500 MWhrs/year** for the entire complex, or,
67,500 x .7133 = 48,150 MWhrs (51,907,500 kWhrs) for the server electronics.

This load profile has been modeled and used as the base load in the energy and financial models of this report.

Transglobal management projects that the growth rate of the facility will occur as follows:

	Year 1.5	*Year 2*	*Year 3*	*Year 4*	*Year 5*	*Full*
Percent of Total Facility Capacity Built Out	20%	25%	40%	60%	85%	100%
Installed Racks End of Period (EOP)	520	650	1,040	1,560	2,210	2,600
Projected Power Need (MW)	**3.1**	**3.9**	**6.2**	**9.3**	**13.1**	**15.4**

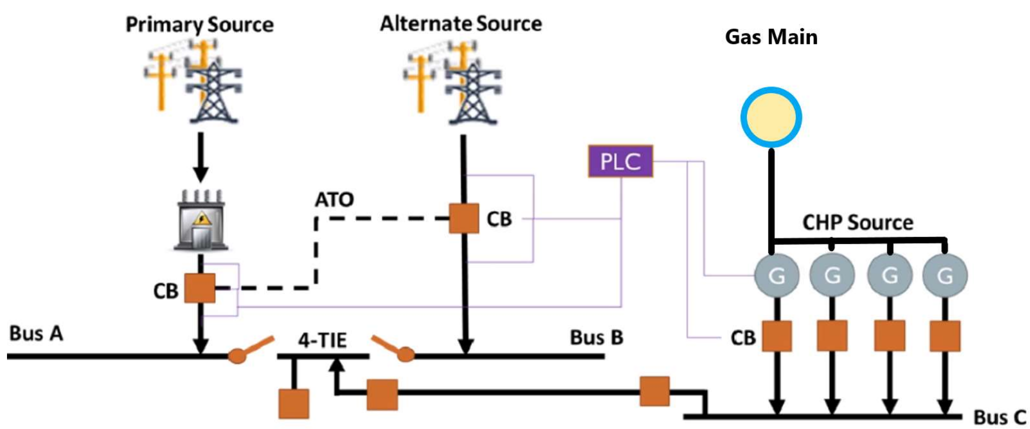
If so, then the above estimates will hold true until approximately between the years 3-4 of the projections.

6.0 SELF-GENERATION VIA CCHP

6.1 Combined Cooling Heating and Power (CCHP) Self Supply

This option provides redundancy as an electrical source to the local electric grid. It involves the use of on-site gas driven microturbines feeding a microgrid for the facility. Waste heat energy from the turbines is used to drive an Absorption Cycle Chiller to provide cooling capacity to the facility's electronics. This arrangement describes a CHP (Combined Heat and Power) or a CCHP (Combined Cooling Heating and Power) design. It is also known as 'Co-Generation'. If employed, this alternative power supply could be used to supply all of the electricity and heat needs of the site.

When employed at the datacenter, the addition of CHP driven via natural gas can be considered as the Primary energy supply for the project. The basic architecture of this energy source is shown in the following diagram, which can operate as part of a 'microgrid' arrangement within the property.



In this arrangement the Primary and Secondary sources represent the Electric and any other on-site generation employed, such as Solar PV resources (see following sections). An Automatic Transfer Operator (Switch) allows selection between the Sources and isolation of self-generation from the grid if needed for the curtailment of exports. The CHP system is driven by gas and its electrical output is also tied to Bus C. Not shown in the diagram is the waste heat loop containing the Absorption Chiller (see below).

The main elements of the proposed system are:

- CHP Generators
- Absorption Chiller Units
- Associated Switchgear and Balance of Plant

The use of CHP and CCHP in datacenters is becoming commonplace. Many whitepapers and case studies exist of similar centers, and many have been noted in the References section of this report[10,11,12,13,14].

According to the paper ***On-Site Power Generation for Data Centers***[10]

High density data centers consume megawatts of electricity for both computing and cooling. Because of the fast paced growth of data center energy demand, effective energy conservation measures must be implemented. The use of the on-site combined power generation and cooling systems for data centers that are located on campuses is discussed compared to the grid powered data centers. The placement of the power plant on site not only reduces transmission losses, but also allows the utilization of the power plant waste heat to generate cooling for the data center and both heating and cooling to adjacent campus buildings. This is why on-site power generation for data centers is an appealing option. Further, with on-site

power generation, it is possible to supply the data center with DC power, thus avoiding the cascade of waste in the multiple AC/DC conversions typical of conventional data centers.
For the purposes of this report, AED has decided to focus on the use of a specific brand and model CHP unit for illustrative and modeling purposes. This is not to say that this model must be used in any actual construction of the facility. Rather these units simply represent the state of the art and are of a well known origin.

The CHP unit selected is shown below. Additional Data Sheets and Brochures may be found in the appendix.

The C1000S CHP Power Package from Capstone Turbines

C1000S Power Package

Low-pressure Natural Gas, ICHP

Capstone

The Signature Series Microturbine provides ultra-low emissions and reliable electrical/thermal generation from natural gas.

- Ultra-low emissions
- One moving part – minimal maintenance and downtime
- Patented air bearings – no lubricating oil or coolant
- Integrated utility synchronization – no external switchgear
- Internal fuel gas compressor housed within enclosure
- Compact modular design allows for easy, low-cost installation
- High electrical efficiency over a very wide operating range
- High availability – part load redundancy
- Remote monitoring and diagnostic capabilities
- Proven technology with tens of millions of operating hours
- Various Factory Protection Plans available

C1000S ICHP Power Package

Electrical Performance(1)

Electrical Power Output	950kW
Voltage	400/480 VAC
Electrical Service	3-Phase, 4 Wire Wye
Frequency	50/60 Hz
Electrical Efficiency LHV	31%

Fuel/Engine Characteristics(1)

Natural Gas HHV	35.4–42.8 MJ/m³ (950–1,150 BTU/scf)
Inlet Pressure	1.7–34.5 kPa gauge (0.25–5.0 psig)
Fuel Flow HHV	12,150 MJ/hr (11,500,000 BTU/hr)
Net Heat Rate LHV	11.6 MJ/kWh (11,000 BTU/kWh)

Exhaust Characteristics(1)

NOx Emissions @ 15% O_2	< 9 ppmvd (18 mg/m³)
Exhaust Mass Flow	6.7 kg/s (14.7 lbm/s)
Exhaust Gas Temperature	280°C (535°F) (Heat Recovery Bypassed)

Dimensions & Weight(2)

Width x Depth x Height	3.0 x 9.1 x 4.0 m (117 x 360 x 157 in)
Weight - Grid Connect Model, dry	22,600 kg (49,800 lbs)
Weight - Dual Mode Model, dry	26,100 kg (57,500 lbs)

Reliable power when and where you need it. Clean and simple.

The CHP unit runs on Natural Gas, is available in 1MW unit modules. Eight such units would be used to run the datacenter facility, providing an on-site production capacity of 8 MW. If necessary, the datacenter could reduce CapEx by starting out operations with a smaller number of units to match projected loads, assuming that balance of plant, switchgear, pad placement, etc. was handled as part of the initial design. One additional CHP unit is suggested for coverage for when any unit needs to be taken down for servicing.

In addition to the 8MW of electric power, each of these units would also provide 1.5MW of thermal power (5.1MMBTU/hr), or 40.9MMBTU/hr of waste heat in the form of hot water which would be sent to the Absorption Chillers to produce cooling for the electronic stacks. Note that this amount of cooling capacity rivals the amount of electrical generation, insuring adequate amounts of energy for cooling and ancillary building heating requirements.

6.1 The Absorption Chiller Component

The YHAU Single Effect Absorption Chiller

For an Absorption Chiller, AED is proposing a product similar to the York YHAU series of single effect (pass) hot water chillers. More information about the product may be found in the appendix [15]. The purpose of the Absorption Chiller is to convert the waste heat generated by the CHP unit into a cold fluid stream which would be used to cool the equipment stacks. Depending on the final topology chosen in the electronic racks and floor plan, this cooling fluid could be a water/glycol mix or cold air via an air handler unit.

This product line can provide between 105 - 7,034 kW of cooling capacity, or between 30 - 2,000 Tons of Refrigeration. The actual sizing of the Chillers is left to the future when the architecture, size and quantity of the electronics in the datacenter have been established, but this capacity is considered adequate for any configuration based on 7.5MW of power requirements.

A specification data sheet for this chiller may be found in the Appendix. The final design of the microgrid and power equipment topology is left to others under an MEP design proposal, but the identification and first-order sizing of the units shown above allows us to calculate anticipated Capital Costs and determine what the cost of Electrical Production plus Cooling would be for this scenario in order to arrive at an all-in cost of self-generated electricity.

System Costs and Cost of Power

With respect to the CHP and Cooling system it is assumed that management will decide to purchase the system and own it outright. An alternative however, is to enter into a Power Purchase Agreement (PPA) with an Independent Power Producer (IPP) who would own and operate the generation equipment and charge the project by the kilowatt hour, like the electric company. Each option has its own merits. Regardless of the option selected however, the operating cost of the system can be determined by modeling the capital expenditure plus annual operating costs and adding costs of financing. That is the process this report uses to determine the cost of energy for the options shown. To do this, AED uses a proprietary software named FOCUS© which can model each of these energy production scenarios.   The FOCUS© modeling for each option in the report may be found in the Appendix.

Based on recent discussions with the product manufacturers and distributors, the system costs (Capex) for the CHP and Chiller option have been derived as follows:

- CHP Units - $1,450/kW
- Absorption Chillers - $900/kW
- Balance of Plant (Data Control, piping, etc.)~ 28% of above, or $660/kW

Assuming that management would want to procure at least enough generation to reach the 3^{rd} year of growth projections (6.2MW), then the following CapEx would apply:

- Total CapEx - $3,010/kW
- Total size of system: 7,600kW (7 units plus 1 reserve)
- Total Capex - $22,876,000 USD

An estimate of $.02/kWhr was suggested as a close approximation of actual Operational Expenses per year. This includes a rebuild of the microturbines every 7 years. This value has been used in the financial model.

Given the above, it is estimated that between the 4^{th} and 5^{th} year, a combined CCHP system sized for the facility would produce electricity ($9{,}300^{+}$kW) at about the same price that it could purchase it from the power company. At that time the annual gas bill would be approximately $5.9M, and the annual electric bill would be approximately $5.5M/yr, based on a projected average $.0675/kWhr from the electric company. This is the equivalent of producing electricity from gas at $.072/kWhr, with NO demand charges. The entire CCHP system would have a Capital cost of $22,876,500, which would add less than $.008/kwhr to the cost of energy produced over a 20 year lifetime for the generation plant.

This indicates that a gas supplied self-generation system can be a cost effective secondary resource to provide redundancy to the datacenter.

8.0 RENEWABLE ENERGY OPTIONS

8.1 Solar PV

Concept and Use at the site:

Since Solar (Photovoltaic) is an intermittent resource, and since the datacenter has a primary goal of having power available all the time in a redundant mode, the use of solar at the site must be viewed critically. On the one hand, solar does provide an ultimately reliable resource – the sun will come up tomorrow, or the next day, and thus the renewable resource does provide some degree of longer term reliability when other network resources may not be available. But to truly be relied on as a secondary energy resource for the redundancy issue, it must be combined with some sort of storage in order to be effective.

Solar is also part of the evolving political and social energy landscape and helps tell a good 'story' for the datacenter. The goal is to explore ways to include solar where it can either be relied upon as a stable second energy source or include solar as a resource for a business reason (such as saving money during operations), or treating the solar energy as a backup resource to be relied on if BOTH of the other main supplies were not available. Losing both the electric AND gas grids at the same time does not happen often but is possible. So, to have a short backup supply of energy held in reserve might provide an additional redundancy.

Completely solar?

The ability to provide solar would be more important if the site did NOT have the capability to be serviced with both an electric and gas grid with additional gas storage. Then the strategy employed for the design of a solar system would change. Our goal would be to design a large solar array, perhaps off site on neighboring land, that could generate the daily needs of the data center should the electric utility be lost. Given a daily load of 7.5 MW (PUE, in projected years 3-4) for 24 hours, the site would consume 180,000 kWhrs every day. Providing a solar array and a storage system to service this load in the winter months (lowest solar insolation) would require an estimated 75MW of solar array-

180,000kwhrs/day x 30.4 days/mo = 5,472,000kWhrs/month

5,472,000kWhrs/mo / (729.6 hrs/mo * .1 capacity factor (typ winter month)) = 75,000kW

where the .1Capacity Factor (10%) is an approximation of the Capacity Factor in the winter months.

This system would require approximately 300 acres of land to be covered by solar panels. At an estimated cost of $3.00/watt installed (including a storage system), such a system would cost approximately $225,000,000 USD!

Given this size investment, the array would need to be the primary source of energy for the facility, and not function in an 'adjunct' mode so as to not strand the investment. Financing a project of this size is no small task, and probably rivals the cost of the datacenter itself. If that route were to be taken, management should explore the use of an Independent Power Provider (IPP) to develop and build out the array under the terms of a Power Purchase Agreement (PPA).

As the world develops an increasing number of datacenters which use a rapidly increasing share of our global power supply, there are other important intrinsic values attributable to this solar option, such as carbon reductions from fossil fuel emissions and the savings in water from central power plants. But given the current financial incentives and energy pricing structure in Nebraska and across the USA, many of these intrinsic values cannot be fully realized yet. Unless supported further by the new administration and Congress, the major solar incentive – the Solar Investment Tax Credit (ITC) of 26% - will be declining to 10% in another 2 years, perhaps when this project is being built.

In short, given the availability of extending the natural gas grid to the site for less than $2M, we view the role of solar as a resource to supply the FULL load as a second energy source in this case to be less critical. Instead, we now look to see if solar be added to the project, but in a supplemental fashion to be available as a standby, 'last resort' option, but one that does 'pay its own way' to be a part of the datacenter's story.

A smaller supplemental solar system?

Another solution examined is to use a smaller solar array, perhaps to 'trickle charge' a storage facility and keep it 'topped off' in order to be able to supply the facilities needs when both other primary systems are not available. In this scenario, the storage energy produced by the solar array would need to provide a tertiary redundancy for a period of 96 hours. When the storage is full, any power produced by the solar array could be used 'behind the meter' to supplement the existing primary operating grid and reduce electric or gas consumption.

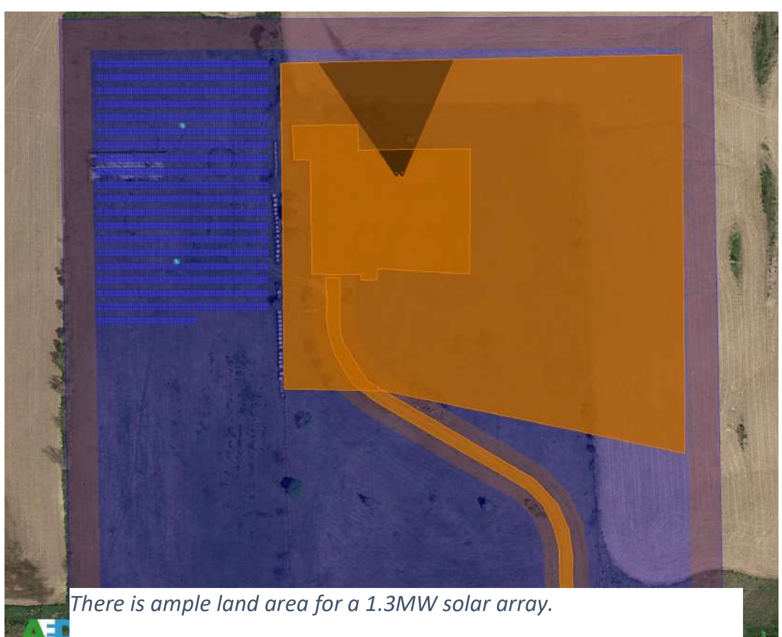
Because of the tertiary nature of the situation, we also recommend designing the datacenter circuits to allow a switchover to a 'maintenance' mode during catastrophic situations that involve the loss of both the gas and electric grids, rather than full operation, in order to reduce the energy and power required in this mode. All non-essential loads would be curtailed, such as offices, most lighting and perhaps some of the stacks on a rotational basis. Although it is beyond the scope of this report to design such circuits, it is estimated that a reduction of 50% of full operation could be achieved (note that this exceeds the PUE somewhat).

If a Maintenance Mode load reduction of 50% to 3750kW/hr could be achieved, then we need to design a solar array and storage system to accommodate the smaller load. If the intent is to supply a full 96 hours of operations at 3750kW, then we need to store (3750kW x 96 hours =) 360,000kWhrs of solar energy storage.

Depending on how long of a timeframe management is willing to risk between 'catastrophic' events that require the use of ALL of the stored energy, a solar array can now be sized to charge up the storage between events. For instance, if we are willing to allow 4 months between catastrophic events (2,920 hrs) requiring the tertiary energy supply, then we can size a solar system as follows:

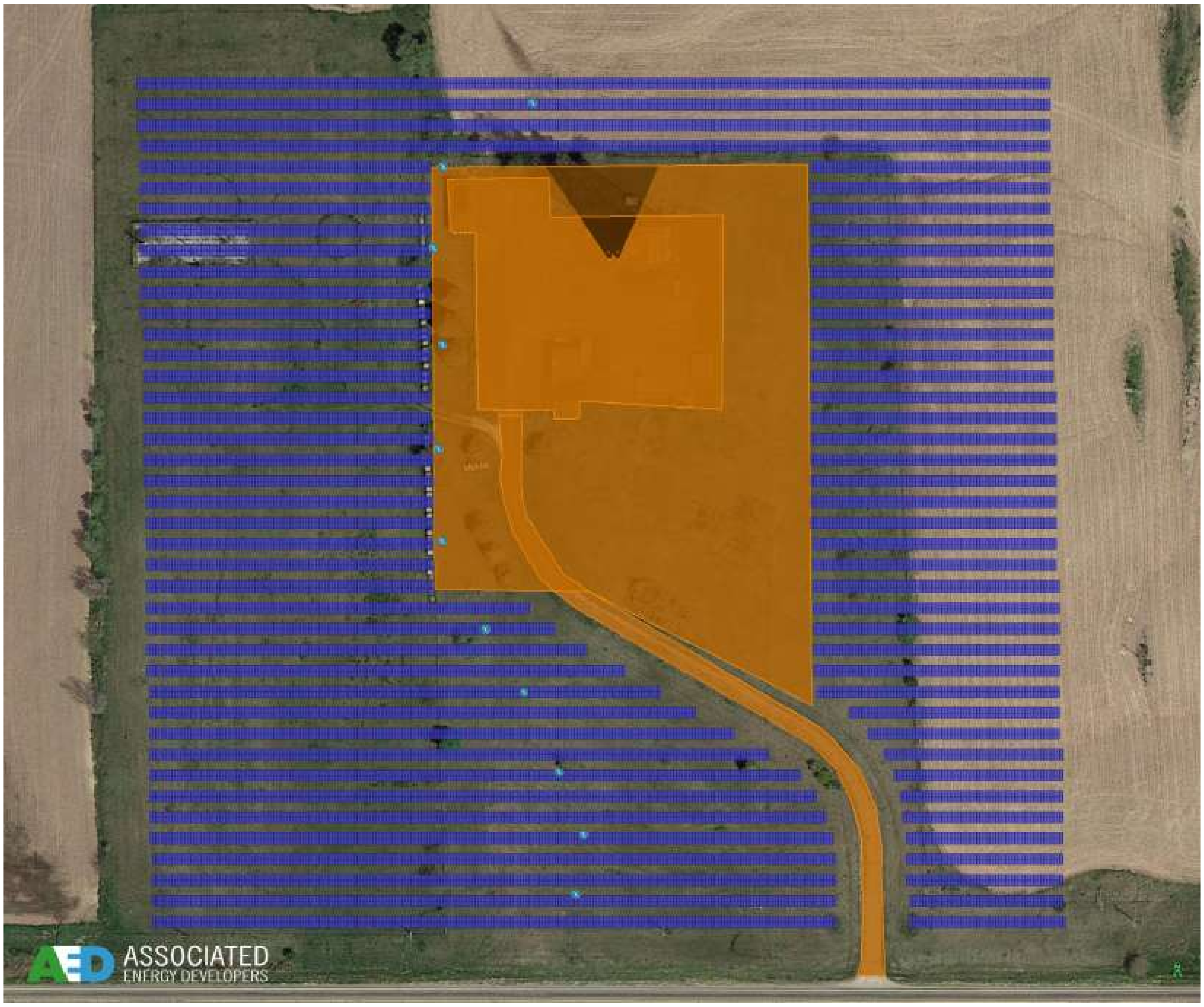
> To achieve 360,000kWhrs / (2920 hrs * .12 Capacity Factor (over 4 months) = 1,027kW
> Plus energy conversion for storage: 30% = ~1.3MW solar array.
>
> where a 12% Capacity Factor is assigned to the greater 4 month period than in the equation above.

In other words, a 1.3 MW array operating for 4 average months in Nebraska would produce about 360,000kWhrs of energy which could be stored (excluding storage or conversion losses). This array easily fits on the property, as can be seen from the diagram below.



There is ample land area for a 1.3MW solar array.

Viewing the problem from another direction, we can alternatively calculate how large of a solar array could be contained on the site, and then use that to determine how fast the solar storage could be recharged between catastrophic events. AED has determined that the land area of the site – excluding parking and other estimated needs – could contain a solar PV project of approximately 6.5 MW in size. This is depicted in the diagram below.



A 6.5 MW solar project could lso fit on the property.

This would lead to a recharge period of just 25 days between catastrophic events.

Recharge period = (360,000kWhrs x 1.3 (for storage conversion)) / (6500kW * .12 CF) = 600 hours

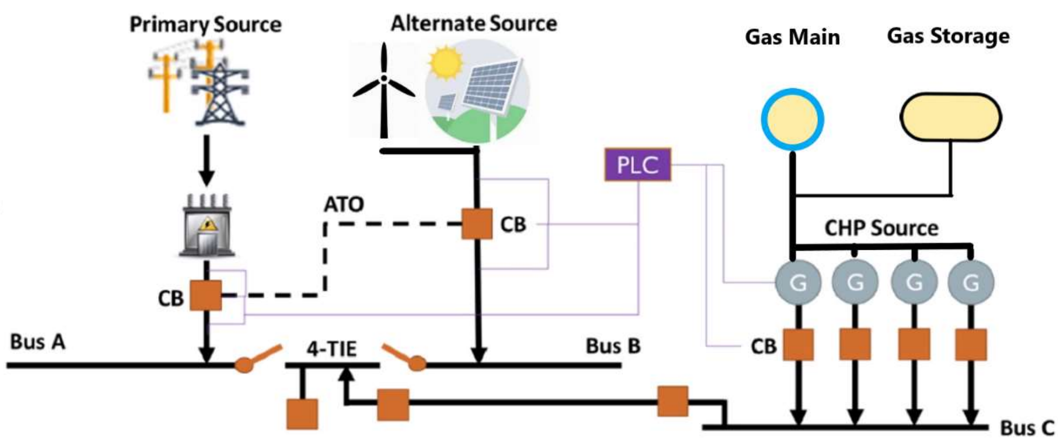
In either of these scenarios, once the storage has been filled, the DC or inverted AC current could be used to directly power the facility during normal operations, saving energy purchased from either the electric of gas grids. This allows the solar array to function as a 'recharger' for its storage, and as an intermittent contributor for overall operations.

AED has created a 'Helioscope' design for each of the sized arrays mentioned above, which may be found in the Appendix. In addition, a financial cash flow model was created for each scenario in order to depict what the solar economics would look like from the viewpoint of the owner of the solar array. It is assumed that a smaller 'supplemental' solar project like those shown above may wish to to be owned directly by the client, so a detailed analysis was performed to show all costs involved in operating a solar project. Alternatively, management could contract out the ownership of the array and storage to an Independent Power Producer under a Power Purchase Agreement.

Key metrics of each of the 2 solar arrays mentioned above are shown in the table below. Reference is made to the appendix for the complete FOCUS© financial model and assumptions.

Key Metrics:	**1.3MW Supplemental Array**	**6.7MW Supplemental Array**
kWhrs/yr produced:	1,703,000	8,790,000
Capital Cost:	$2,530,000	$12,395,000
Ground area required:	Approx 3.5 ac	Approx 14 ac

In terms of electrical topology, the arrays and storage would be constructed as follows:



8.2 Wind Energy Potential

The Wind Resource

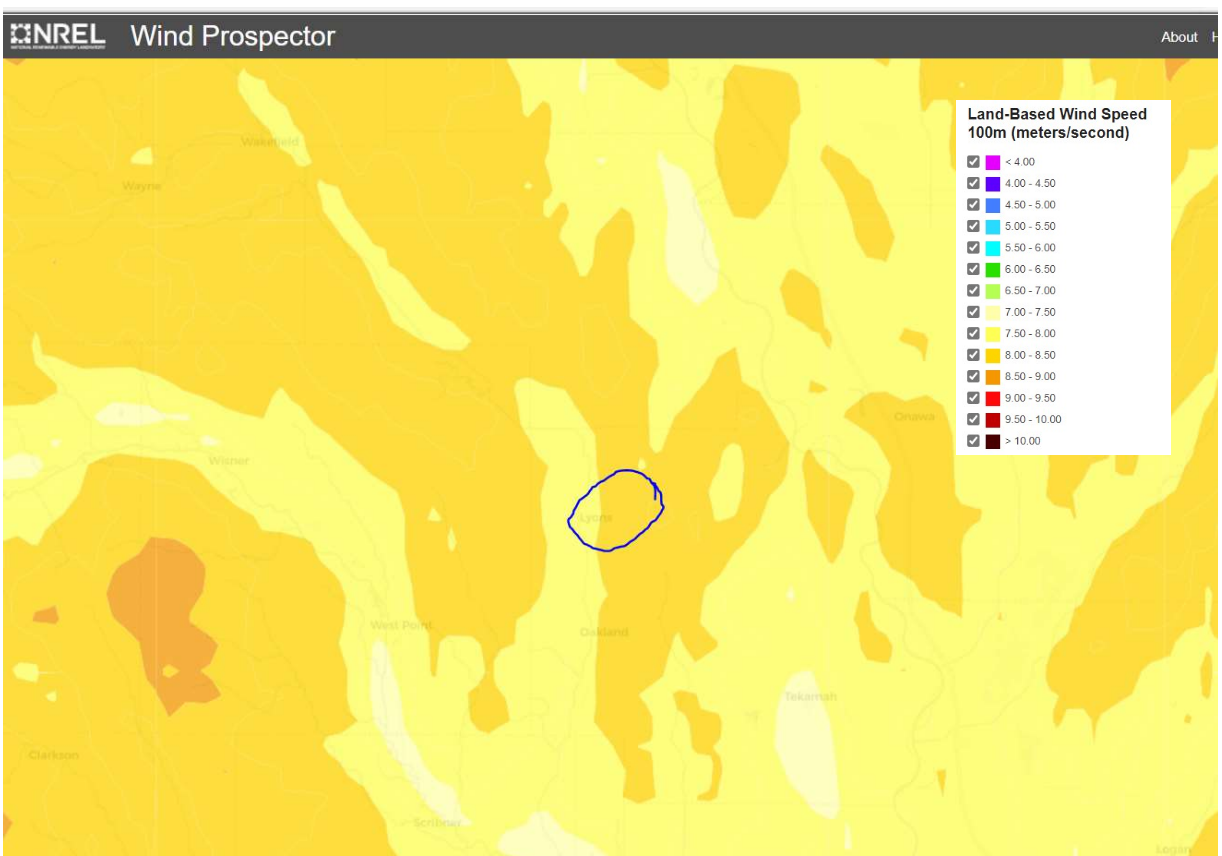
Most commercial wind project requires a wind study to be performed, including a met tower or LIDAR measurements of the wind field for a period of at least one year to be financeable. A first-order analysis may be made however by examining data collected over the past few decades and condensed into 'Wind Maps' published by the National Renewable Energy Labs, or NREL. A good understanding of the wind resource is especially critical as compared to the solar resource, since wind speeds can vary greatly over relatively short distances and be affected by topography. And since the power from a wind turbine varies as the cube of the wind speed, a small increase in annual wind speed creates a large increase in output power and energy. Given the relative flatness of this site and its surrounds, the Wind Map values are probably quite accurate. The NREL 'Wind Prospector' does show the wind speed at 100meters hub height for this location to be in the range of 8.0m/s. This is generally regarded as a very good commercial wind speed.

Concerns: Low-Level Military Airspace

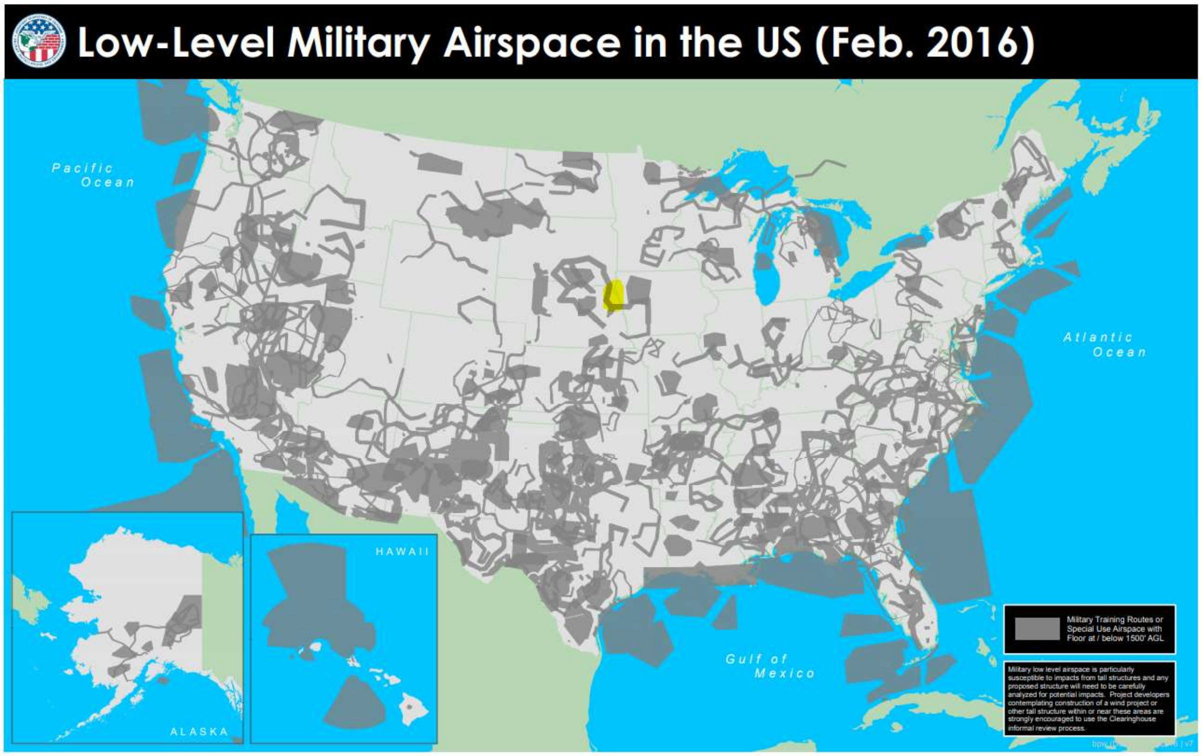
The site appears to be located in proximity to a pathway of concern for low-level Military training flights.

According to the DOD Low Level Military Airspace website[5]:

Military training routes and special use airspace with a floor of 1500 feet or below is considered low-level military airspace. Low-level military airspace is particularly susceptible to impacts from tall structures and any proposed structure will need to be carefully analyzed for potential impacts to DoD.

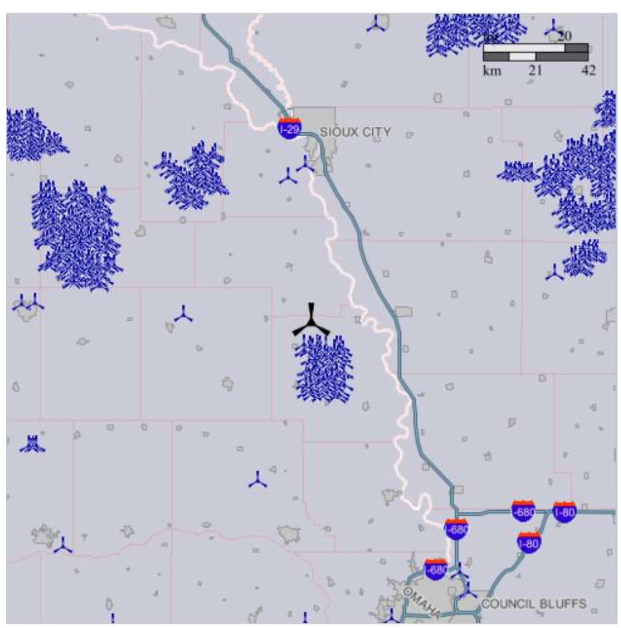


This would only be a concern for the siting of any wind turbines at the site. The risk of interference may be considered small however, due to the presence of the existing microwave tower. This needs to be examined further in an Aeronautical study.



Concerns: FAA Screening Tool for Wind Turbines

Investigation into the FAA's 'Wind Turbine Buildout' web site[3] shows that no significant obstructions or hazard areas exist for the subject site. Any further investigation of the feasibility of wind energy supply and permitting for the site would need to include an FAA form 7460 analysis in order to determine other concerns of the FAA or DOD. This is standard procedure for any wind turbine project.

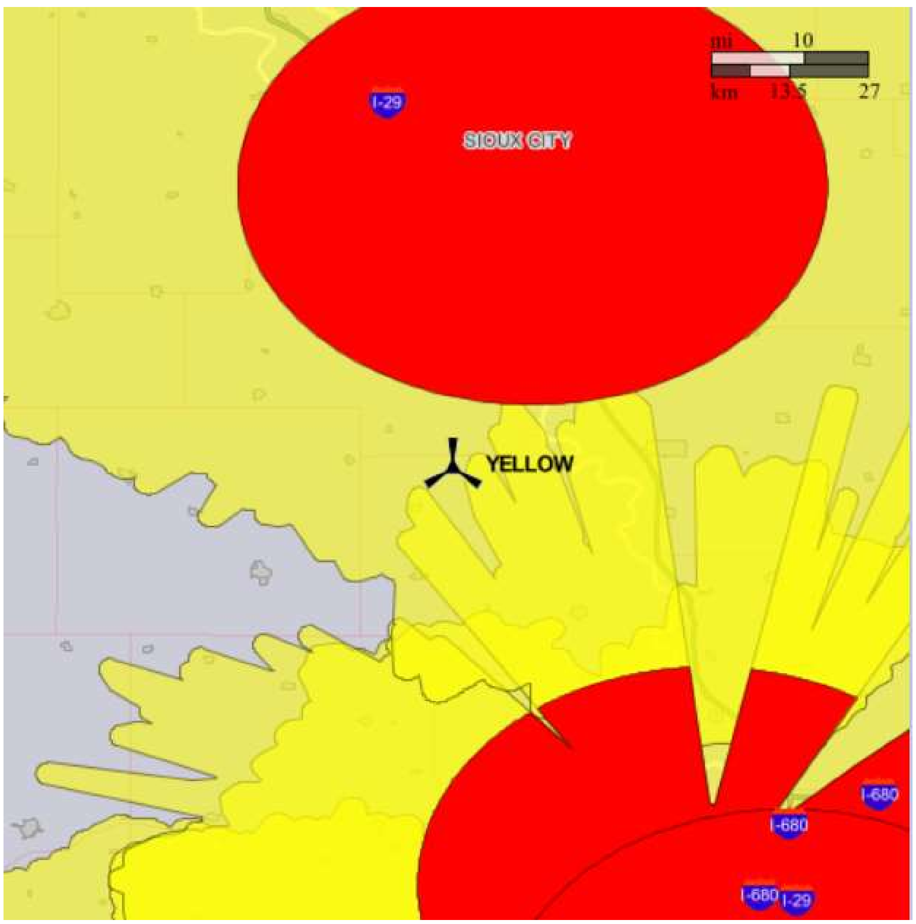


Map Legend:

- **Red:** Hazard- cases that exceed obstruction standards and/or have an adverse effect upon navigable airspace or air navigation facilities.
- **Yellow:** Proposed-cases that are being evaluated by the FAA.
- **Blue:** Determined-cases that have a completed aeronautical study and an FAA determination.

DOD Screening Tool for Wind Turbines

Further investigation into the DOD Screening tool[4] reveals that the site is located within an area 'likely to impact Air Defense and Homeland Security Radars. An Aeronautical Study will be required if a wind turbine permit is sought.



Map Legend:

- **Green:** No anticipated impact to Air Defense and Homeland Security radars. Aeronautical study required.
- **Yellow:** Impact likely to Air Defense and Homeland Security radars. Aeronautical study required.
- **Red:** Impact highly likely to Air Defense and Homeland Security radars. Aeronautical study required.

Given the above, AED considers this site worth further investigation as a potential wind energy site, pending a further Aeronautical study by the DoD and FAA as first gating items. These studies usually indicate a 'go/no go' decision for the wind project developer. Given the current tower on the site, we believe there is a strong likelihood that a turbine(s) could be located on site.

Under the assumption that the study would allow a wind project on the site, AED has modeled what a wind project on the site might produce.

To begin, we will assume that only the property owned by Transglobal would be used for siting the turbines. It is understood that additional surrounding farmland might be available to the client or to a wind project IPP working with the client, but we will limit our initial investigation into how many turbines might be located on the owned site, and what those turbines could produce.

In order to avoid wake related turbulence and buffeting of the blades which cause undue maintenance and wear on a wind turbine, a heuristic rule has been established which limits the 'inter-rotor spacing' between machines to be greater than 3x the rotor diameter in a direction perpendicular to the predominant wind direction, and 5 rotor diameters in a direction parallel to the predominant wind direction. Given the size of a modern 2 or 3 MW wind turbine to be on the order of 100meters in diameter, one can calculate that such machines would need to be spaced 984 feet apart. Even if one turbine was placed in the center of the property, there is no room for a second turbine on the site.

Best practice, and many town zoning ordinances and governing officials, also consider a 'clear zone' around the turbine equal to the height to the tip of the blade, so that in the unlikely event of a collapse, the machine falls within the owner's property. It has not been established that Lyons would impose such a limit in such a rural area, but given a typical tip height of +/- 400' for most machines of this size, it can be concluded that if held to a 'clear zone', there IS room at the center of the property where a wind turbine can be located, although at this time AED has not studied the proximity of the underground bunker in relation to the topography of the land. We will therefore assume that a single 2-3MW wind turbine could be placed on the property.

A representative sample of such a wind turbine is given by a 2.05MW machine by Wind-2-Energy GmbH of Germany, of which AED is familiar. We will use this machine as a representative machine, although there are many others which should be considered when appropriate. The basic specifications of such a machine are shown below.

A W2E 2.05MW wind turbine.

2.0 MW

TECHNICAL DATA

Rated power	2.0 MW
Rotor diameter	93 m | 100 m
Wind class	IEC 2a | 3a
Cut-in wind speed	3.5 m/s
Rated wind speed	12 m/s | 11.5 m/s
Cut-out wind speed	25.0 m/s
Capacity factor	3,701 h, 42% | 3,975 h, 45%
Sound power	104.5 dB(A) | 105.8 dB(A)
Hub height tubular tower	70 m | 85 m | 100 m
Hub height lattice tower	117 m | 141 m

AED has modeled the output of the 2MW machine using the 8m/s wind speed found on the NREL wind maps[19]. The model shows that such a machine at this site would produce approximately 7,781,814 kWhrs/yr given such an average wind speed. This represents as much as 11.8% of the facility's projected year 3-4 load (7500kW) under normal conditions.

The total CapEx for the wind project -without storage - would be approximately $3.42M USD. Annual operating costs would be about $40,000/yr. No Renewable Energy Credits have been included in the calculations, nor has the Production Tax Credit, which will only increase profitability but has been left out due to the unknown nature of the entity's tax status and how the project will be owned.

It was determined in the model that at this wind speed and at an average price of $.061/kWhr – midway between what is expected to be charged by the local electric utility (see section 3 - $.046 <> $.076) - the 25 year Pretax Internal Rate of Return for the turbine project would be a respectable 13.5%. It was further determined that an internal cost of electricity as low as $.048 could be achieved while still earning an 11.8% IRR and maintaining Debt Service Coverage Ratios over 1.1 under a fully (100%) financed scenario. It should be noted that these numbers all are derived from the wind speed of 8m/s, which needs to be validated. But even at an internal price of $.052/kWhr, the project turns positive cash flow from year one under a fully leveraged financial model when viewed in a 'P-99' method, which is often used by banks for wind project financing. This bodes well for using wind energy at the site in at least a supplemental form.

25 year Financial Proforma

Project: ***Transglobal***

Revenue Proformas - Cash Basis - w/out Tax Implications, P Value = 50

	Revenue (Cash Basis)							SG&A Expense					EBITDA	Financing Costs			Results		
Yr	Retail Revenue	Resale Revenue	*Ancillary Revenue*	REC Revenue	Federal Tax Grant [(a)]	Other Grants/Inc.	*Gross Revenue*	O&M	Insurance	Land Costs	Mgt	Other Exp.	*Net Rev.*	Loan Interest	Loan Principal	Tot. Pmts. (CMLTD)	*Net Cash after CML TD*	*Cum Net Cash Flow*	DCS w/RECs
0			*(see breakout)*												Down Pmt.>	0	*0*		
1	474,691	0	*0*	0	0		*474,691*	-25,000	-15,000	0	0		*434,691*	-170,900	-158,398	-329,298	*105,393*	*105,393*	1.32
2	481,811	0	*0*	0			*481,811*	-25,250	-15,150	0	0		*441,411*	-162,980	-166,318	-329,298	*112,113*	*217,506*	1.34
3	489,038	0	*0*	0			*489,038*	-25,503	-15,302	0	0		*448,234*	-154,664	-174,634	-329,298	*118,936*	*336,442*	1.36
4	496,374	0	*0*	0			*496,374*	-25,758	-15,455	0	0		*455,162*	-145,933	-183,365	-329,298	*125,864*	*462,306*	1.38
5	503,819	0	*0*	0			*503,819*	-26,015	-15,609	0	0		*462,195*	-136,764	-192,534	-329,298	*132,897*	*595,203*	1.40
6	511,377	0	*0*	0			*511,377*	-26,275	-15,765	0	0		*469,336*	-127,138	-202,160	-329,298	*140,038*	*735,241*	1.43
7	519,047	0	*0*	0			*519,047*	-26,538	-15,923	0	0		*476,587*	-117,030	-212,268	-329,298	*147,289*	*882,530*	1.45
8	526,833	0	*0*	0			*526,833*	-26,803	-16,082	0	0		*483,948*	-106,416	-222,882	-329,298	*154,650*	*1,037,180*	1.47
9	534,736	0	*0*	0			*534,736*	-27,071	-16,243	0	0		*491,421*	-95,272	-234,026	-329,298	*162,123*	*1,199,303*	1.49
10	542,757	0	*0*	0			*542,757*	-27,342	-16,405	0	0		*499,009*	-83,571	-245,727	-329,298	*169,711*	*1,369,014*	1.52
11	550,898	0	*0*	0			*550,898*	-27,616	-16,569	0	0		*506,713*	-71,284	-258,014	-329,298	*177,415*	*1,546,429*	1.54
12	559,161	0	*0*	0			*559,161*	-27,892	-16,735	0	0		*514,535*	-58,384	-270,914	-329,298	*185,237*	*1,731,666*	1.56
13	567,549	0	*0*	0			*567,549*	-28,171	-16,902	0	0		*522,476*	-44,838	-284,460	-329,298	*193,178*	*1,924,844*	1.59
14	576,062	0	*0*	0			*576,062*	-28,452	-17,071	0	0		*530,538*	-30,615	-298,683	-329,298	*201,240*	*2,126,084*	1.61
15	584,703	0	*0*	0			*584,703*	-28,737	-17,242	0	0		*538,724*	-15,681	-313,617	-329,298	*209,426*	*2,335,510*	1.64
16	593,473	0	*0*	0			*593,473*	-29,024	-17,415	0	0		*547,035*	0	0	0	*547,035*	*2,882,545*	
17	602,376	0	*0*	0			*602,376*	-29,314	-17,589	0	0		*555,472*	0	0	0	*555,472*	*3,438,017*	
18	611,411	0	*0*	0			*611,411*	-29,608	-17,765	0	0		*564,039*	0	0	0	*564,039*	*4,002,056*	
19	620,582	0	*0*	0			*620,582*	-29,904	-17,942	0	0		*572,737*	0	0	0	*572,737*	*4,574,793*	
20	629,891	0	*0*	0			*629,891*	-30,203	-18,122	0	0		*581,567*	0	0	0	*581,567*	*5,156,360*	
21	639,340	0	*0*	0			*639,340*	-30,505	-18,303	0	0		*590,532*	0	0	0	*590,532*	*5,746,892*	
22	648,930	0	*0*	0			*648,930*	-30,810	-18,486	0	0		*599,634*	0	0	0	*599,634*	*6,346,526*	
23	658,664	0	*0*	0			*658,664*	-31,118	-18,671	0	0		*608,875*	0	0	0	*608,875*	*6,955,401*	
24	668,543	0	*0*	0			*668,543*	-31,429	-18,857	0	0		*618,257*	0	0	0	*618,257*	*7,573,657*	
25	678,572	0	*0*	0			*678,572*	-31,743	-19,046	0	0		*627,782*	0	0	0	*627,782*	*8,201,440*	
	14,270,637		*0*	*0*	*0*	*0*	*14,270,637*	*-706,080*	*-423,648*	*0*	*0*	*0*	*13,140,909*	*-1,521,469*	*-3,418,000*	*-4,939,469*	*8,201,440*		

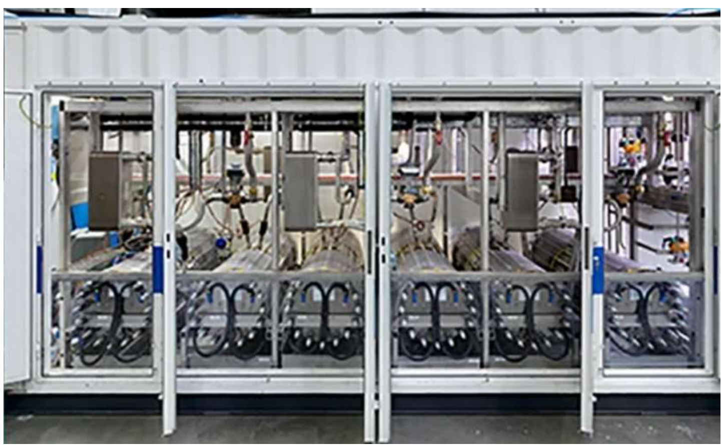
It should also be noted that a single wind machine located at the center of the facility can be co-located along with the solar projects mentioned above. Although there will be some flicker from the wind turbine shadows, it has been shown that this is a manageable event at other sites with both solar and wind present.

8.3 Storage for Solar or Wind

Because of the potential of bringing natural gas to the site as a redundant electric supply via CHP, and the ability to store a quantity of the gas on site for emergencies, it will be hard to economically justify any storage capacity for renewables on the site. This report does, however, briefly investigate potential measures for storage of renewable energy as a baseline for management.

The use of Hydrogen generation was initially considered for the datacenter, but then rejected. The conversion of water to Hydrogen gas through the use of electrolysis units such as the 'Hydrogenics' product line[20] which was recently purchased by Cummins is bringing the production of Hydrogen out of the laboratory phase it seems to have been stuck in for decades and into more industrial use. The process requires very clean, essentially using distilled water, necessitating a source of water on site, a Reverse Osmosis plant and associated energy requirements. Once the H2 is created it can be stored in tanks similar to CNG tanks for later use. In order for the Hydrogen process to be considered as 'Green' Hydrogen, renewable energy must be used to produce the gas. The gas can then be either combusted in an engine or put through a Proton Member (PEM) type fuel cell and created back to electricity directly. If burnt, Hydrogen is not a very good choice for the environment, as it releases a high amount of NOx emissions. The fuel cell process creates only electricity and water vapor, and is the more environmentally clean process. There is also a process in which the H2 is combined with other gases in a pipeline, like natural gas, in order to 'green up' the gas.

All of these methods require energy and equipment to create the gas, and additional equipment to convert the gas back to energy again. Discussions with Hydrogenics and Cummins indicated that this cost is on the order of $1500-2000 per kW to create the gas, and $1500/kw to convert it back to electricity again using fuel cells. Annual operating costs would be approximately 2-3% of CapEx/year.



This process will become more widespread over the next few decades. But two factors need to be realized.

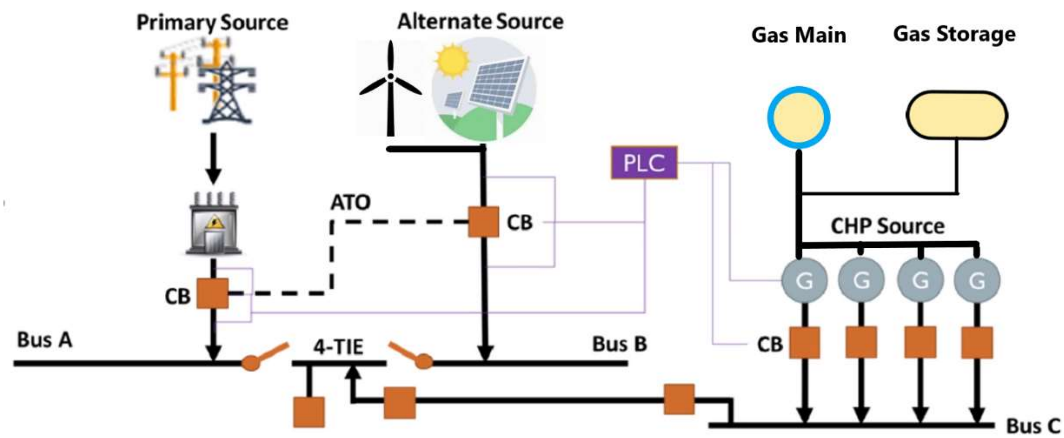
First, once Hydrogen has been created from water to create an energy 'carrier', it becomes transportable and has a high 'energy density'. Although this is ideal for energy storage, it is also the goal of the transportation industry. In fact, once created, H2 has a greater value as a transportation fuel than simply turning it back to electricity for on-site use! Transglobal would be better off selling off any H2 produced to that marketplace and using the earnings to offset other energy costs.

Second, in the case of this energy center specifically, the presence of the second energy grid of natural gas makes it very difficult to economically justify the Capital cost and expanded operations of a full H2 production and storage facility at all.

8.4 Conclusions about Renewables and Storage at the site.

Due to the availability of gas storage and the costs involved in storage, AED believes that the datacenter should simply use 'run of the sun' or 'run of the wind' energy as it is available to offset electric or gas consumption from either of the grids, and not worry about storing energy from these sources. The same sized renewable systems depicted above can simply be run 'behind the meter' to defer operating costs. The amount of energy self-generated from the site by either sun or wind plants running at full capacity is still lower than the consumption of the datacenter, so there need be no exporting of power in either case, unless a larger wind farm or solar farm is contracted for on neighboring land. And if this occurs, Transglobal needs to decide how it wants to be involved with these efforts from a business standpoint – what business should they concentrate on?

These conclusions lead to the final suggested system topology, as represented in the diagram below.



8.5 Virtual Green Power Procurement

It also bears mentioning that the Transglobal development team may achieve its goal of adding to the 'green story' of the datacenter simply through the procurement of wind or solar electricity from the local electric utility, which offers such rate structures.

However, if the choice is made to self-generate via CHP self-generation, then the electric grid becomes the redundant, secondary grid as the investment in the cogeneration equipment must be maximized. That would eliminate the procurement of green electricity from outside sources.

In many ways the procurement of green power from outside sources resembles what could be achieved using neighboring land for a larger, closely held wind farm or solar farm.

9.0 CONCLUSIONS

AED is pleased to provide this report to Transglobal management, and draws the following conclusions regarding the choice of energy solutions for this datacenter site:

1. Due to the availability of a natural gas pipeline being brought to the datacenter location from a nearby location, a competitively priced, redundant energy supply in the form of natural gas can be established.

2. A tertiary redundancy, in the form of on-site storage of Compressed Natural Gas (CNG) is viable.

3. The use of natural gas to drive a Combined Heat and Power (CHP) system as a primary electric resource is suggested. Depending on the year of operation and load, electricity and cooling capacity for the electronics can be created on-site at a cost competitive with the electric company, including the elimination of costly 'demand charges'. The CHP system should be considered as the primary source in order not to 'strand' the required capital investment of the CHP equipment. The existing electric grid should be considered the 'backup' to the facility.

4. Operated in this fashion, with the gas serving as the primary energy supply, there should be no need for a UPS or Flywheel momentary storage during a cutover event from gas to electric. Reversing the priority to make electric the primary source creates not only more expensive kilowatt-hours, but also creates the need for a UPS or Flywheel during cutover events.

5. A 96 hour supply of stored CNG can easily be stored on site for immediate use if the gas grid supply was diminished or curtailed. Cutover to the reserve gas supply would have no effect on electrical generation. The use of multiple CHP units (plus a reserve unit) to provide the generation provides both 2N+1 redundancy for the energy stream and also provides for proper servicing of the CHP units over time.

6. There does exist an opportunity to use self-generated green power from the site. It would appear that a single 2-3MW wind turbine could be located on the site. This one device could supply between 5.77% and 28.6% of the projected annual on-site load over time (3.1MW > 15.4MW) at a competitive cost of electricity. Initial wind mapping indicates a commercially viable annual wind speed of 8m/s at the site. Further investigation into the permitting is required, including an aeronautical study by the FAA and Dept. of Defense.

7. Up to 6MW of solar photovoltaics could also be located within the property borders and generate power to offset gas or electric grid supplied power. Both the wind and solar resources could be co-located at the site. This would result in the possibility that the wind and solar resources could actually supply more than 100% of the on-site load of the datacenter if each were operating at rated capacity. If this were the case, one of the CHP units (or the electrical grid being used as the primary source) would still be needed for voltage and frequency control.

8. The ability to provide additional solar or wind energy to the site exists through the use of additional abutting land. However, unless large amounts of exported power can be negotiated with the local power company (questionable if the site is using the electrical grid as a secondary, or backup resource), these energy resources need to be tightly designed and managed to constrain energy use to the site. Without using the grid as a 'storage' device through financial mechanisms such as net metering, or even unbalanced buy/sell transactions at some net cost, solar or wind systems will need to be balanced with large amounts of battery or gas storage.

9. Storage methods for the site were examined, and due to the scale of energy requirements it was concluded that the solar and wind resources, if built, should function at the present as a supplemental resource without storage involved. This project serves to illustrate the fact that since natural gas is available at low capital cost to serve as both a primary electrical resource AND a source of stored emergency energy, the investment of capital in storage for renewables is hard to justify. This may change if management philosophy were to value all inherent aspects of renewables, such as carbon costs and ESG (Environmental, Social and Governance) type values.