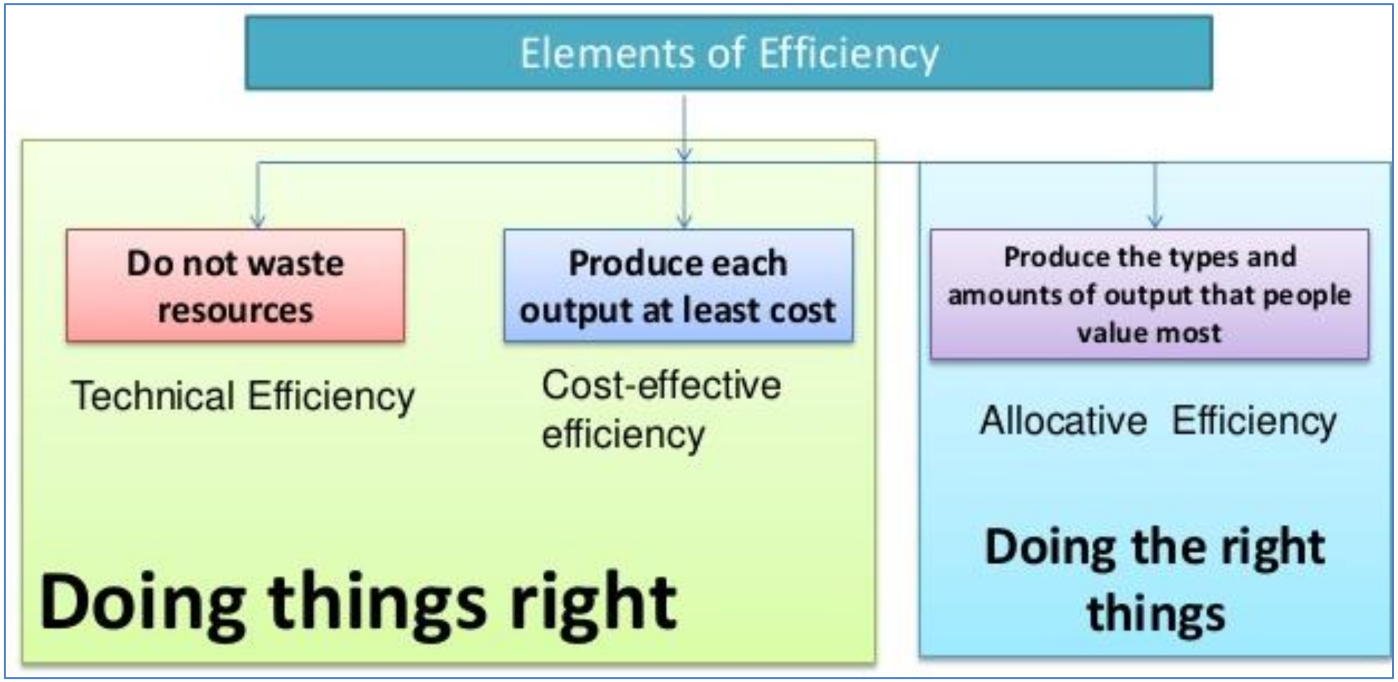
Resilient Affordable Decarbonized Energy (RADE) for Data Center (DC) - alternate prime movers for Combined Heat & Power (CHP)



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GOALS: Behind-the-meter resilient affordable decarbonized energy (RADE) for Data Center.

WHAT is the problem?:
Data Centers need energy – power & chilling. Traditional grid based power is expensive & slow to deploy.

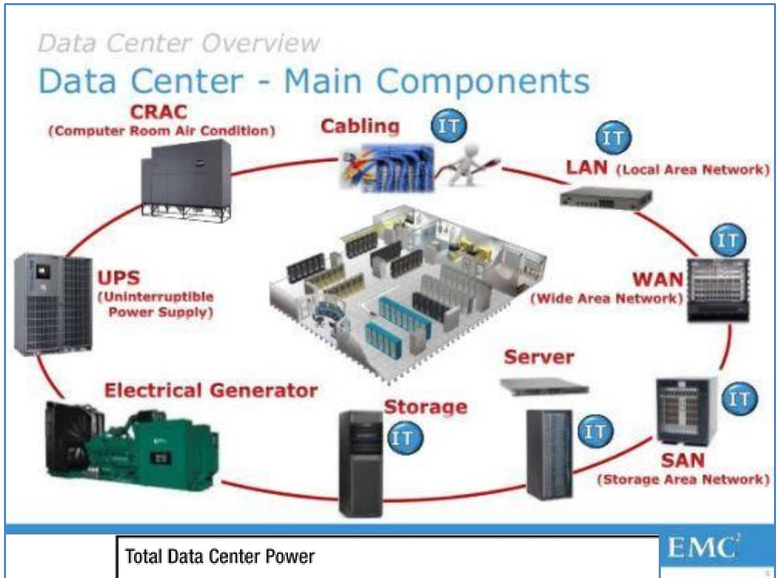
HOW & WHY can we offer an alternative?

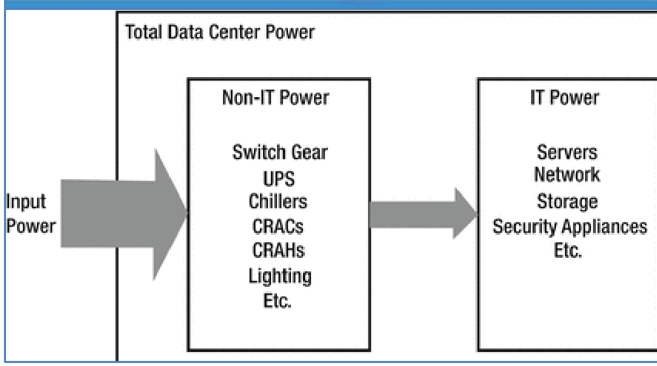
- Behind-the-meter, natural gas Combined Heat & Power (CHP) can be configured using microturbines (MT), fuel cells (FC) or conventional gas turbines (GT) with waste heat to absorption chillers.
- Each CHP configuration has characteristics –
    - CapEx, OpEx,
    - emissions, noise, vibrations,
    - energy density, technology maturity, availability, scalability, modularity,
    - fuel-to-power efficiency (aka heat rate), part load efficiency,
    - nature of waste heat (exhaust, hot water),
    - ramp rate etc…
    - Delivery schedule

PROJECT DEVELOPMENT:

- conceptual design > Limited Notice to Proceed (LNTP)
- basic engineering > Final Notice to Proceed (FNTP)
- detailed engineering & equipment procurement
- site construction > start-up

Data Center (DC): a set of 24/7/365 computers supported by electrically intensive support equipment

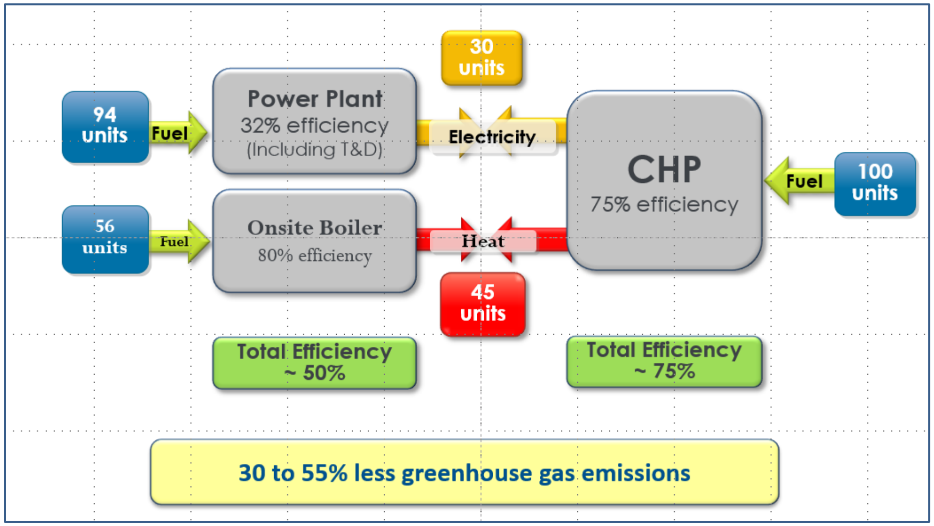


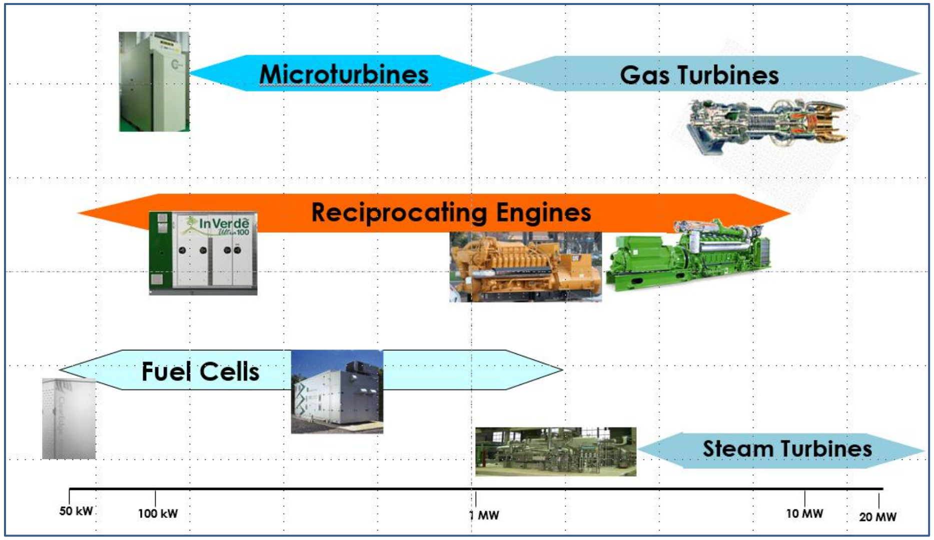


- Need (*20-60 KW/rack*) of high-quality, reliable power; more if AI-centric DC
- Use 1.5% of global electricity and responsible for 1.0% of global GHG emissions; both figures are increasing
- Need reliable (*99.9999% available*), high quality (*steady voltage, frequency*) power
- Use grid power with UPS and diesel gensets for backup. Non-core capital *parked-in-place*
- Need expensive cooling to remove resistive heat (**I^2R***)* from site computers; electric chillers are default cooling solution.
- Significant non-IT power electric loads require capital for non-IT power assets *and* parasitic power expense

Sources: USDOE, EMC website

What is Combined Heat & Power (CHP)? 1-input and 2 or more outputs

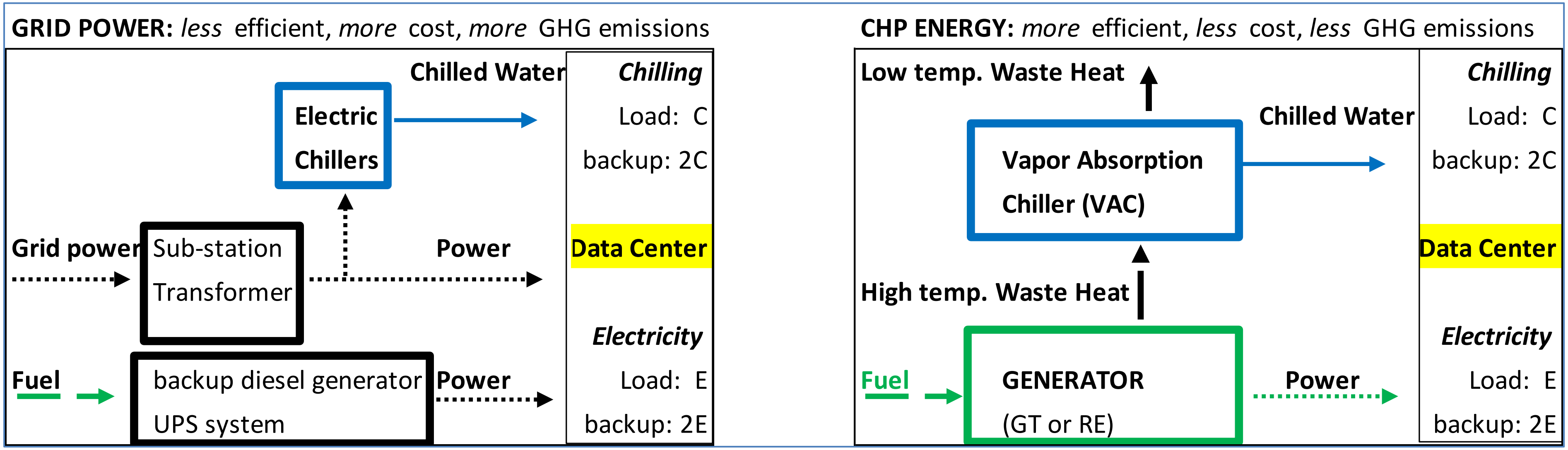




Unlike intermittent & variable renewables, CHP systems efficient generate on-demand energy in electrical and thermal form with low GHG footprint

Regular power plants generate power by burning fuel, but waste heat; hence net-net increase pollution.

CHP **complements** DC to cut cost *and* minimize GHG emissions.
Waste heat to Absorption Chilling (AC) saves Elec. Chlr CapEx, OpEx



ENERGY DELIVERY APPROACH	GHG Emissions	Efficiency	Investment	Optg. Cost
GRID power, backup generator, UPS	*MORE*	*LESS*	*MORE*	*MORE*
CHP configured with VAC	*LESS*	*MORE*	*LESS*	*LESS*

CHP waste heat *via* a bolt-on Vapor Absorption Chiller (VAC) produces chilled water that displaces chilled water from conventional electric chiller.

IMPORTANT: in a real-world system, an optimized CHP system incorporates "free-cooling" **plus** energy storage (*Battery Energy Storage System, BESS and thermal energy chilled water)* **plus** small electric chiller for "trim" chilling etc **plus** retain existing site grid tie-in.

Total Invested Capital ($TIC) of onsite CHP-VAC microgrid <= traditional energy supply (*all grid power, ECC, diesel genset etc…*)

	Energy Supply Configuration	CHP+VAC	*versus*	Traditional
	PROJECT INVESTMENT SCAFFOLD	**A**		**B**
A	**DIRECT: EQUIPMENT**			
	multiple Nat. Gas generators (MT/GT/FC/RICE)	$$$$		-
	Vapor Absorption Chillers (VAC)	$		-
	Electric Centrifugal Chillers (ECC)	-		$$
	multiple Diesel gensets sized to DC capacity	-		$$$
	Cooling Tower (wet/dry / hybrid)	$		$
	raw water treatment system	$		$
	grid power feed and/or sub-station upgrade	-		$$$
	Power conditioning: BESS/UPS	$$		$$
B	**BALANCE OF PLANT (BOP)**			
	geotechnical / site grading	$		$
	Civil/structural	$		$
	Mechanical - pipe, duct etc..	$		$
	Electrical: ATS, switchgear, Distribution Panel etc…	$		$
	Instrumentation & Control	$		$
C	**INDIRECT / "SOFT COSTS"**			
	Engineering	$		$
	Project & Construction Management (PM/ / CM)	$		$
	staff mobilization & administrative compliance	$		$
	Permits: air, water, trade, constuction & operating	$		$
	taxes / fees / duties	$		$
	equipment transport to site	$		$
	legal - contracts	$		$
	finance	$		$
	development fee	$		$
	capitalized working capital	$		$
	other	$		$
D	**CONTINGENCY**	**$$**		**$$$**
E=A+B+C+D	**PROJECT INVESTMENT**	**$$$**		**$$$$**

CapEx savings drivers for CHP+VAC configuration vs. traditional:

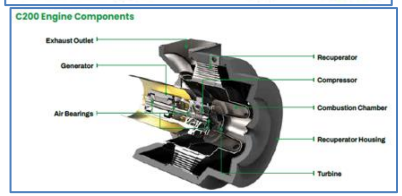
1. Reduced equipment costs

2. Shorter / more controllable delivery schedule

3. CHP CapEx grant from local utility

Select prime mover choices – leading CHP prime movers have distinct performance characteristics

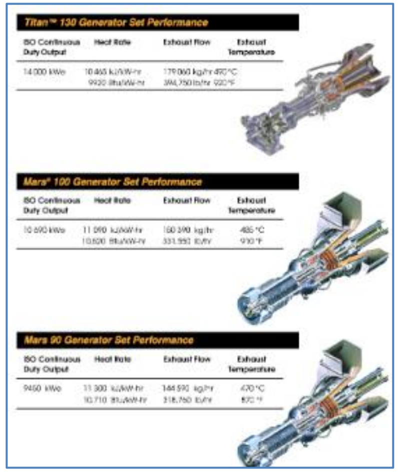
Small Microturbine (MT)



Capstone C200/C1000

- 30 kW – 1,000 kW per unit (scalable to 30 MW)
- Single moving part, air bearings, compact footprint
- Ideal for distributed CHP, district energy, and behind-the-meter applications

Gas Turbine (GT)

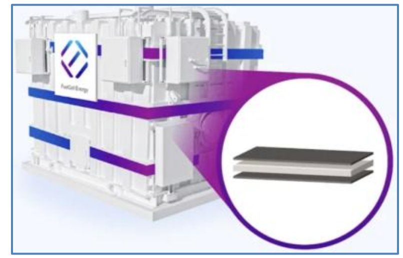


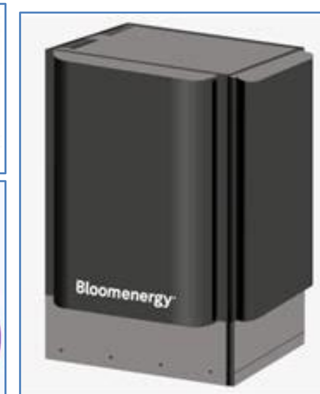
Eg: Solar C50, T60-65-70,

T130,250 etc…

- 5 MW – 70+ MW per unit
- Aircraft-engine heritage, fast start (5–10 min), high cycling capability
- Suited for utility-scale CHP and industrial cogeneration

Fuel Cell (SOFC, molten carbonate)





Eg: Fuel Cell Energy, / HyAxiom

/ Bloom etc…

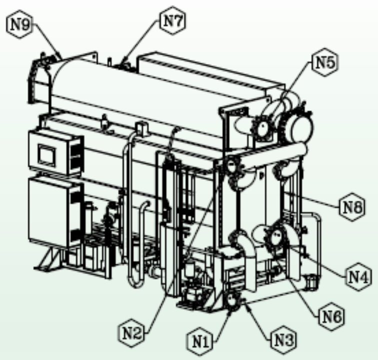
- 200 kW – 2500 KW (modular)
- Electrochemical conversion, no combustion, near-silent operation
- Best for premium power, data centers, and zero-emission mandates

Key equipment: Vapor Absorption chiller available as modular, factor built, skid-mounted units ==➔ reduced risk

Chiller Rear Side

Control Panel Side

G A Drawing



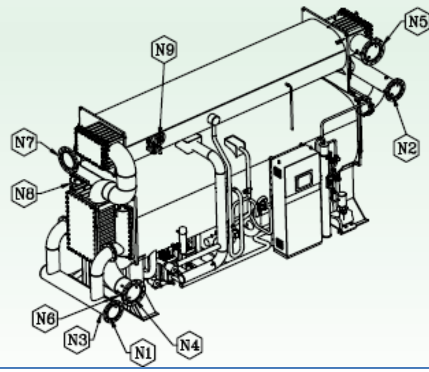
NOZZLE SCHEDULE		
NOZZLE	NOZZLE FL. RATING	DESCRIPTION
N1	ASA 150	CHILLED WATER INLET
N2	ASA 150	CHILLED WATER OUTLET
N3	–	CHILLED WATER DRAIN PLUGGED
N4	ASA 150	COOLING WATER INLET
N5	ASA 150	COOLING WATER OUTLET
N6	–	COOLING WATER DRAIN PLUGGED
N7	ASA 150	STEAM INLET
N8	ASA 150	CONDENSATE OUTLET
N9	ASA 150	RUPTURE DISK OUTLET

NOTES :

1) ✦ INDICATES THE POSITION OF ANCHOR BOLTS.
2) ↑ INDICATES THE POSITION OF THE POWER SUPPLY CONNECTION ON CONTROL PANEL
3) MINIMUM INSTALLATION CLEARANCE.
CONTROL PANEL SIDE :50"
TOP : 10"
OTHERS : 20"
4) MACHINE TOLERANCES :

L (INCH)	TOL. (INCH)
0–100	0.2
100–200	0.3
200–300	0.4
300–400	0.5
OVER 400	0.7

5) RUPTURE DISK OUTLET TO BE PIPED OUT ACCORDING TO THE LOCAL RULES AND REGULATIONS. MAXIMUM PIPING ELEVATION SHALL NOT EXCEED THE HEIGHT OF M/C.



Select CHP prime movers: more technical + economics considerations

INPUT	UNIT	VALUE	COMMENT
Deliv. Nat. gas	$/MMBtu, HHV	**$4.0**	assumed
CHP Chilling Required	TonsR/MW_e	284	thermodynamics

PARAMETER	UNIT	MICROTURBINE	GAS TURBINE	FUEL CELL
Electrical efficiency	%LHV	30.0%	33.0%	48.0%
Heat rate	LHV Btu/KWh	11,377	10,342	7,110
Available Waste Heat	Btu/KWh	7,964	6,929	3,697
COP of VAC unit		1.30	1.30	0.90
Chilling delivered	TonsR/MW_e	431	375	139
CHP-VAC chilling adequate?		yes	yes	no
CHP VAC chilling deficit	TonsR/MW_e	0	0	(145)
Accept opportunistic grid power?		yes	yes	no
NOISE		quiet	high	ultra-quiet
VIBRATION		very low	medium	approx. zero
STACK: AIR EMISSIONS				
NOx. CO, UHC/VOC, PM		very low	low	ultra-low
Emissions Control reqd?		usually no	sometimes	No
Nominal availability	%	97%	96%	95%
Nominal availability	full-load hrs/yr	8,497	8,410	8,322
Ramp rate	% full load/min	35%	35%	5%
Part-load performance: efficiency		poor	poor	acceptable
22 MW CHP SYSTEM- INSTALLED ROM ECONOMICS:				
CapEx - **before** incentives	$/KWe	$4,500	$4,000	$6,000
CapEx - before incentives	$MM	$99	$88	$132
Fuel Cost of Power (FCP)	$/MWh	$50.0	$45.5	$31.3
NON-FUEL OpEx	$/MWh	$25.0	$20.0	$30.0
Sub-total: FCP + NF OpEx	**$/MWh**	**$75.0**	**$65.5**	**$61.3**
Fuel Cost of Power (FCP)	c/KWh	5.0	4.5	3.1
NON-FUEL OpEx	c/KWh	2.5	2.0	3.0
Sub-total: FCP + NF OpEx	**c/KWh**	**7.5**	**6.5**	**6.1**
Delivery: PO to site	months	8-to-10	12-to-24	10-to-15
INCENTIVES:				
Investment Tax Credit		no	no	yes
Bonus depreciation		yes	yes	yes
New Market Tax Credit (NMTC)		location dependant	location dependant	location dependant
Local utility (elec, gas) grants		site specific	site specific	site specific

CHP configured with VAC influenced by factors as tabulated

ENERGY FACTS & EQUIVALENCES:

1-KWh = 3413 Btu *quantity*

1-MWh = 3,413,000 Btu *quantity*

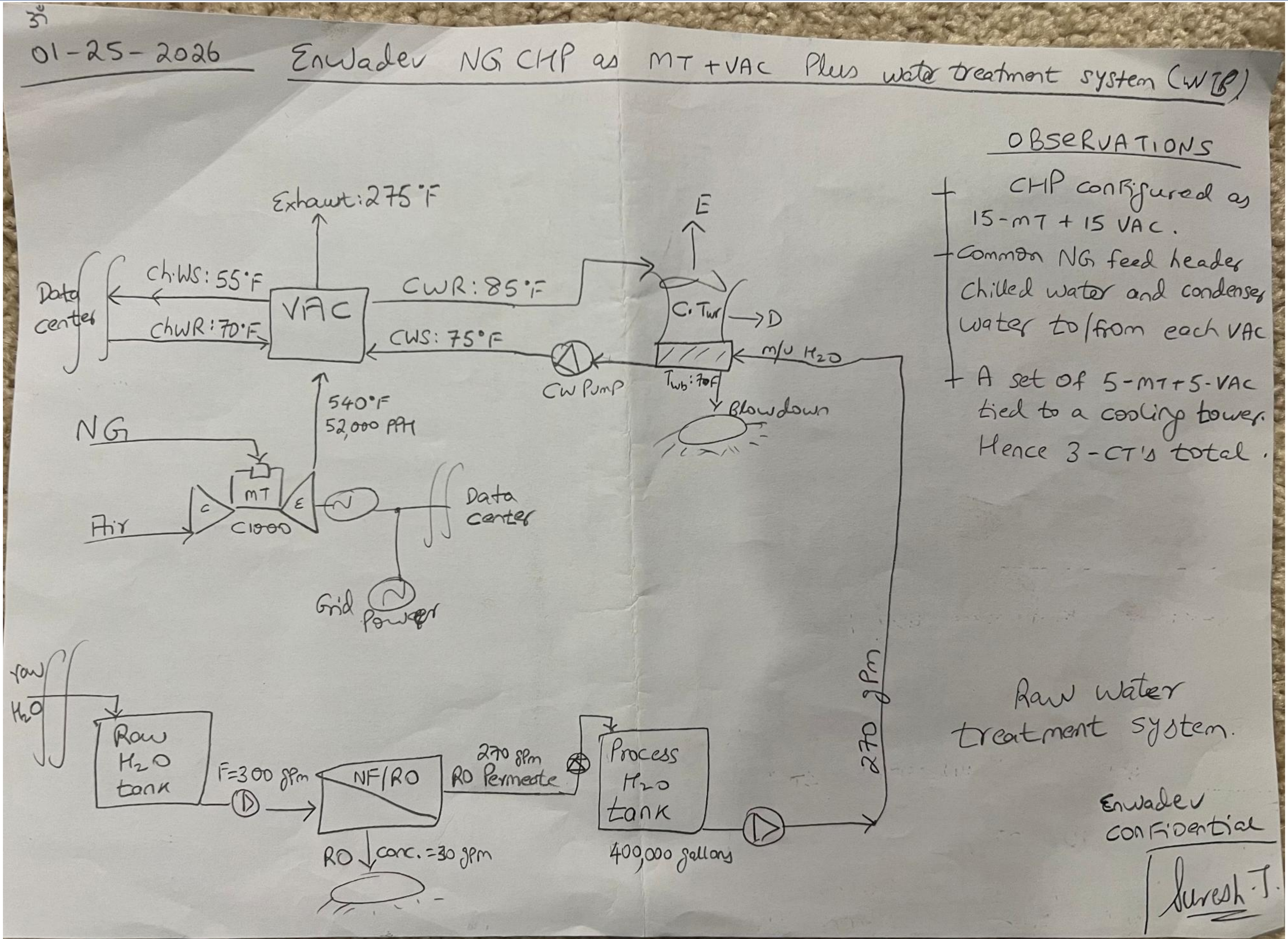
1 MW = 3413,000 Btu/hr *rate*

1-TonR =12000 Btu/hr *rate*

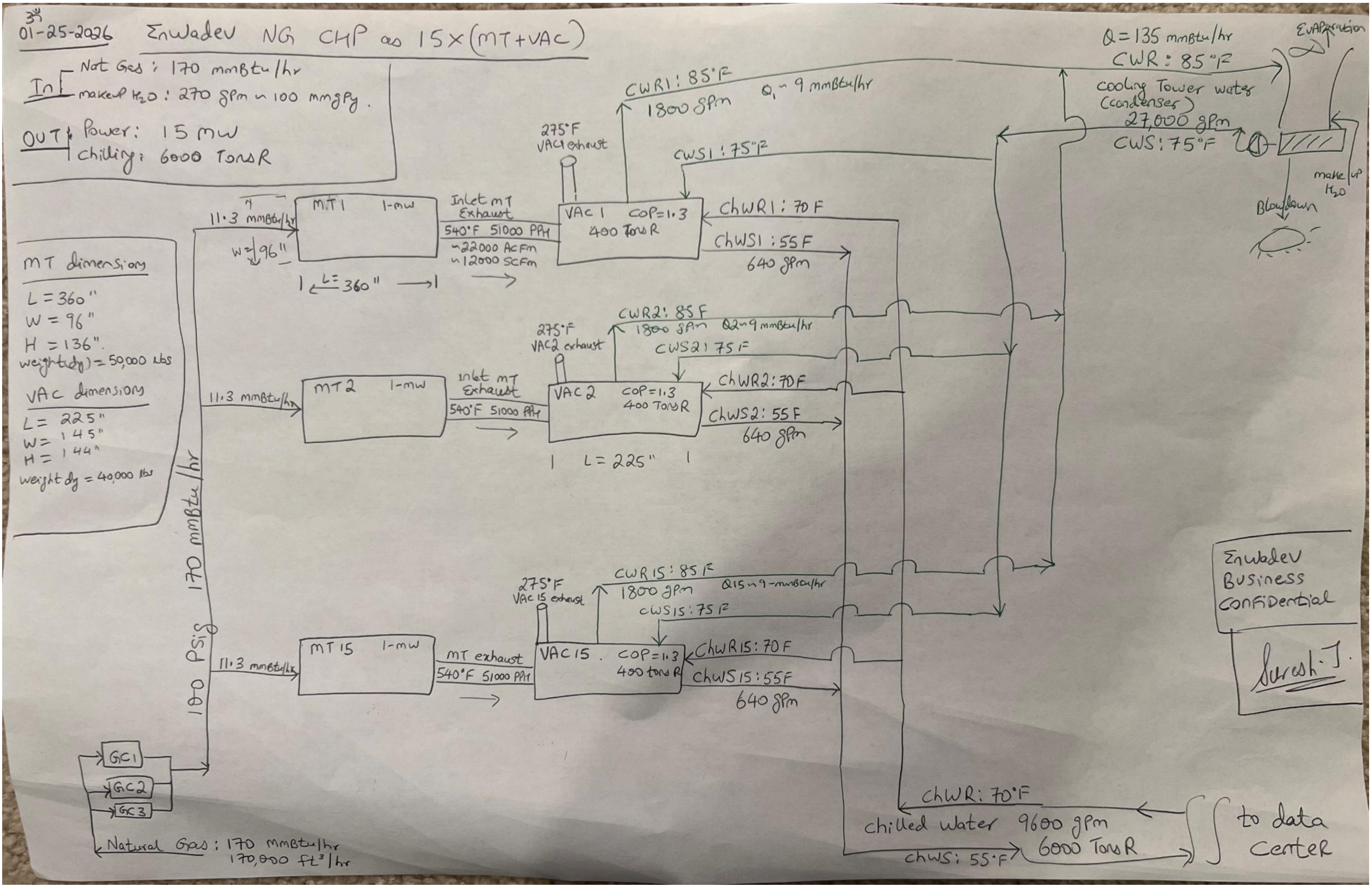
hence:

1 MW = 284 TonsR *rate*

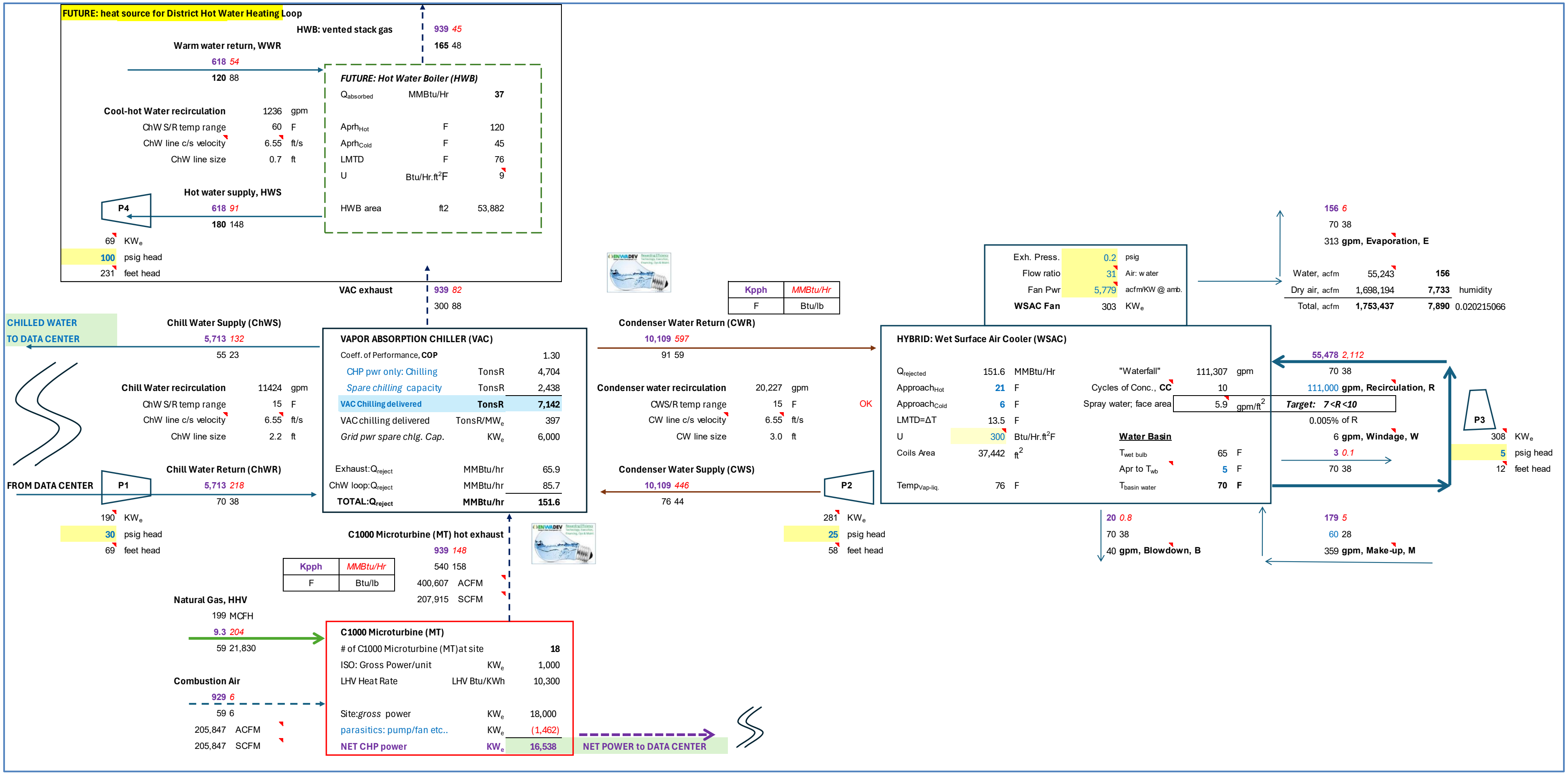
Phase 1 concept: modular CHP configured as gas turbine and exhaust waste heat to absorption chilling. Energy (power, chilling) to data center



Phase 1 CHP sized per available Nat. gas: modular parallel units with common supply / return lines. Easy constructability=reduced scope creep risk



Technical basics 1: Process Flow Diagram + Heat Mass Balance (PFD+HMB) for CHP+VAC + assumed available grid power



IMPORTANT: CHP+VAC provides option for hot water district heating loop using available *medium-grade* waste heat exiting Vapor Absorption Chiller (VAC).

Overall system efficiency, % HHV:

- CHP+VAC only: ~ 70%
- CHP+VAC + hot water heat ~ 85%

Select risks & mitigants. Project success = managing risk

RISKS	MITIGANTS
Variance from	
CapEx estimate	scope freeze = *avoid* scope creep. Immediate permits line-of-sight. Quickly execute key contracts, make down payments to secure production slot, parall site preparation
OpEx estimate	Execute Equipment Agreements, hire key staff, share select resources with city
Fuel reqd. estimate	Equipment performance ("heat rate") guarantees at design & off-design conditions
design / process performance	1st principles heat & mass balance; pass-thru equipment performance guarantees
Permit delays	Concept scope freeze, immediately engage permit authorities for permit *line-of-sight*
Spark-spread Ratio (SSR) squeeze.	unlikely - local and ISO grid is heavily gas marginal
Gas supply	Uninterruptible supply contract, onsite fuel storage ("CNG bullets"), virtual gas pipeline
Grid power supply	grid connect exists & desirable as backup. But........ grid power not required. CHP can be 100% nat. gas fueled
Tariff / taxes / duties	continually update CapEx estimate; maintain healthy contingency
Engineering delays	freeze conceptual design; rapidly advance to engineering
Construction delays	scope freeze > rapid engg. Deliverables to construction contractor. Payments tied to milestone completions; insurance and/or bonding

Tradeoffs: Cost Vs. Accuracy Vs. Time

ESTIMATE CLASS	ESTIMATE TYPE	PURPOSE	ACCURACY	PROJECT COMPLETION	COST & TIME
5	Order of Magnitude (OOM)	Initial Feasibility or screening	-50% to 100%	0%-to-1%	Free-to-$10,000 2-hours-to-3 days
4	Preliminary	Concept study or feasibility	-15% to 50%	1%-to-15%	$5,000-to-$50,000 2-days-to-5 weeks
3	Definitive	Budget, authorization or control	-10% to 30%	10%-to-40%	3%-to-5% of final CapEx 4-weeks-to-4 months
2	Detailed	Control or bid/tender	-5% to 20%	30%-to-70%	4%-to-10% of final CapEx 2-to-6 months
1	Check (Construction)	Bid/tender	-3% to 15%	50%-to-100%	5%-to-20% of final CapEx 3-to-12 months

FRONT END LOADING (FEL) & PROJECT DEVELOPMENT

FEL STAGE	FEL1: Business Assessment	FEL2: Alternatives Selection. *Conceptual Engineering*	FEL3: Scope Definition. *Basic Engineering*	FEL4: Engineering, Procurement & Construction Management (EPCM). *Detailed Engineering+*	FEL5: Commissioning & Operations & Evaluation
PURPOSE	Identify projects aligned with business objectives	Select preferred process & technology options	Complete scope definiton: validate business premises, ensure project execution with a degree of certainty	Implement Project Execution Plan (PEP)	Meet design nameplate; evaluate against business objectives
OBJECTIVES	Define business premises	Validate business premises	Finalize scope of work, schedule and cost	Complete Detailed Engineering	Achieve nameplate production
	Define project objectives	Analyze alternate process & technology options; select best alternative	Value engineering for cost reduction	Secure required permits	
	List assumptions - technical & commerical	Develop Process scope of work	Mitigation of risks & uncertainties	Create equipment procurement plan	
	Identify risks & state mitigants	Process Flow Diagram with Heat & Mass Balance (PFD + HMB)	Project Execution Plan (PEP)	Mobilize construction resources - project / construction manager, prime contractor & sub-contractors	
	Preliminary economics	Utilities availability ("gap analysis")	Gather project team	EHS management	
	Justify & prioritize projects	Identify uncertainties & risks	Secure project funding	Checkout & commissioning	
DELIVERABLES	FEL 1 deliverables check list	FEL 2 deliverables check list	FEL 3 deliverables check list	Commissioned project	
	Abstract / objectives statement	Basic economic model	Major equipment list & specifications with firm quotes	Purchase & receive equipment & bulk materials, manage construction to support PEP	Collect operating data
	Resource assignment	PFD + HMB, basic plot plan	Finalize plot plan	Manage change orders	Capture formal lessons learned
	Project manager	Permitting requirements & strategy	Issue for design: P&ID, control lists, electrical 1-line diagrams		
	Project Engineer	O&M strategy	Conduct HAZOP review	Final HAZOP review	Capture process improvements for future projects
	Other	EHS requirements & strategy	EHS requirements & strategy		
		Technical risk assessment	Project Execution Plan (PEP) with Work BreakDown Structure (WBS) & sub-contracting plan		Prepare for project close-out
		Major equipment list and key vendors			
	CapEx: Order of magnitude. ± 50%	CapEx: Conceptual estimate +35% -20%	CapEx: quasi-investment grade estimate +15% -5%		
	O&M, G&A: Order of magnitude. ± 50%	O&M, G&A: conceptual estimate. ± 25%	O&M, G&A: estimate ± 15%		
	FEL2 plan with milestone schedule	FEL3 plan with milestone schedule	Detailed construction schedule		
COSTS	$1,000 <= co$t <=$5,000	0.3% <= $ TIC <= 1.0%	0.7% <= $ TIC <= 3.0%	3.0% <= $ Engineering <= 15.0% rest for Procurement & construction	Funded from O&M,G&A budget
FUNDING SOURCE	Owner expensed	Owner expensed	Owner expensed or capitalized	Capitalized	
DURATION	1 <= days <=5	2 <= weeks <=12	6 <= weeks <=18	6 <= months <=24	

GLOSSARY

O&M, GA	Operations & maintenance, General & Administrative	TIC	Total Installed Cost
PFD+ HMB	Process Flow Diagram + Heat & Mass Balance	HAZOP	Hazard & Operability Analysis

APPENDIX

Questions?

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Who is Energy & Water Development LLC ("EnWaDev")

Assertions:
1. Efficiency *hedges* energy & water price volatility.
2. *Profitably* reduce Greenhouse Gas Emissions.
3. *No conflict* between your wallet and your conscience.

A. Consulting:
Energy & Water optimization strategy ("Demand Reduction", then "Supply Optimization") Investment grade financial analysis encompassing concept development, project structuring, contracting strategy, technology assessments, bid management, environmental impact, project schedule and constructability etc…

B. Development:
Design-Build and Own projects. Deliver as full-wrap Engineering Procurement & Construction (EPC) or part-wrap Engineering, Procurement & Construction Management (EPCM).

C. Operations & Maintenance:
Reliable energy & water to the customer and maintain asset value for the owner

Preferred partnerships with equity funding group, design-engineering-construction group plus O&M support team

ASSUMPTIONS: gas turbine CHP+VAC sized to currently available natural gas: waste heat recycled into Vapor Absorption Chilling (VAC)

INPUT	INPUTS IN BLUE	UNIT	VALUE	COMMENT	
OPERATING ECONOMICS: Delivered cost of				**$K in yr1**	**c/KWh,yr1**
Grid power	*use spare CHP VAC chilling*	cents/KWh	**14.0**	**$7,656**	**14.3**
				CHP only, year 1 = full operation	
Fuel & Water EXPENSE				**$K**	**c/KWh**
Natural gas		$/MMBtu HHV	**$4.00**	$7,427	4.71
Reclaimed water - Cooling Tower		$/Mgal	**$0.00**	$0	0.00
City water - Cooling Tower		$/Mgal	**$8.00**	$985	0.62
O&M SG&A EXPENSE					
Eqp. Maintenance: Long Term Service Agreement (LTSA)					
C1000 Microturbine (MT)	*CHP gen. pwr*	cents/KWh	**1.5**	$2,461	1.56
VAPOR ABSORPTION CHILLER (VAC)		cents/Ton-hr	**1.0**	$651	0.41
HYBRID: Wet Surface Air Cooler (WSAC)		$/MMBtu	**$0.25**	$346	0.22
FUTURE: Hot Water Boiler (HWB)		$/MMBtu	**$0.00**	$0	0.00
Staff: (Mgr, Ops, Maint. Admin etc...)	*CHP gen. pwr*	cents/KWh	**1.0**	$1,641	1.04
Consumables & miscellaneous	*CHP gen. pwr*	cents/KWh	**0.3**	$492	0.31
				$14,002	**8.88**

INPUT to CHP	UNIT	PEAK	UNIT	ANNUAL
Natural Gas	MMBtu/hr	204	MMCF/yr	1,741
makeup water to Clg. Twr	gpm	359	MMGal/yr	121
Grid power	MW_e	6.0	MWh/yr	52,560

OUTPUT to Data Center	UNIT	PEAK	UNIT	ANNUAL
Chilled water	TonsR	7,142	MMTon.hr/yr	62.6
Net CHP Power	MW_e	16.5	MWh/yr	144,871
Grid power	MW_e	6.0	MWh/yr	52,560
NET Power to DC	**MW_e**	**22.5**	**MWh/yr**	**197,431**

OUTPUT		UNIT	VALUE
Efficiency: CHP + VAC only		**%HHV**	**70%**
Efficiency: CHP-VAC + *future Hot Water*		%HHV	88%
Power Usage Effectivenss (PUE) and Data Center Infrastrucure Efficiency (DCiE)			
A. Power: IT Equipment = **net** CHP power + grid power		KW_e	22,538
B. Power: full site = ***gross*** CHP power + grid power		KW_e	24,000
B/A:	**PUE**		1.06
A/B	DCiE	%	94%

INPUT	INPUTS IN BLUE	UNIT	VALUE	COMMENT
CHP-VAC stack emissions				
NOx		lb NOx/MMBtu HHV	**0.0362**	C1000
CO		lb CO/MMBtu HHV	**0.0247**	C1000
UHC		lb UHC/MMBtu HHV	**0.0097**	C1000
VOC		lb VOC/MMBtu HHV	**0.0097**	C1000
$PM_{10}/PM_{2.5}$		lb PMx/MMBtu HHV	**0.0009**	C1000
GHG Emissions				
CO2: Nat. Gas combustion		lb CO_2/MMBtu HHV	**117**	stoichiometric
CO2: marginal grid emissions		lb CO_2/MWh	**1,100**	https://www.epa.gov/avert/avert-web-(

OUTPUT	VALUE	VALUE
CHP-VAC stack emissions	**pph**	**mt/yr**
NOx	7.4	29
CO	5.0	20
UHC	2.0	8
VOC	2.0	8
PM10/PM2.5	0.2	1
GHG Emissions		
CO2: Nat. Gas combustion	23,837	94,915
CO2: marginal grid emissions	6,600	26,280
TOTAL Project related emissions	**30,437**	**121,195**

IMPORTANT: Optimized CHP system incorporates "free-cooling" **plus** energy storage (*Battery Energy Storage System, BESS and/or UPS* **plus** retain existing site grid tie-in.

Technical-financial 1: OpEx + primary fuel savings of CHP-VAC *versus* traditional energy supply (*power, chilling*) for nominal 22.5MW data center

Net power to Data Center (DC)	MW_e	22.5	22.5
Configuration		C1000 Microturbine (MT)	Elec. Centr. Chlr
Configuration		VAPOR ABSORPTION CHILLER (VAC)	b/u diesel genset
Configuration		Grid pwr spare chlg. Cap.	All grid power
Configuration		**CHP+VAC**	**traditional**
PARAMETER	**UNIT**	**A**	**B**
Net CHP Power	MW_e	16.5	-
Grid power	MW_e	6.0	22.5
parasitics (ECC, pumps etc..)	MW_e	1.5	6.6
Site gross power	MW_e	**24.0**	**29.1**
PUE		**1.06**	**1.29**
Natural Gas	MMCF/yr	1,741	-
Diesel	gal/yr	-	42,867
Reclaimed water - Cooling Tower	MMGal/yr	*0*	*0*
City water - Cooling Tower	MMGal/yr	*121*	*78*
makeup water to Clg. Twr	**MMGal/yr**	**121**	**78**
OPERATING ECONOMICS: Delivered cost of			
grid power	$K	$7,656	$37,166
natural gas	$K	$7,427	-
diesel — $3 per gallon	$K	-	$129
Reclaimed water - Cooling Tower	$K	$0	$0
City water - Cooling Tower	$K	$985	$640
O&M SG&A EXPENSE			
Eqp. Maintenance: Long Term Service Agreement (LTSA)			
C1000 Microturbine (MT)	$K	$2,461	-
VAPOR ABSORPTION CHILLER (VAC)	$K	$651	-
HYBRID: Wet Surface Air Cooler (WSAC)	$K	$346	$346
Electric Centrifugal Chiller (ECC)	$K	-	$976
Diesel backup gensets	$K	-	$291
FUTURE: Hot Water Boiler (HWB)	$K	-	-
Staff: (Mgr, Ops, Maint. Admin etc...)	$K	$1,641	$1,641
Consumables & miscellaneous	$K	$492	$492
TOTAL Fuel + O&MSGA EXPENSE	**$K**	**$21,657**	**$41,680**
TOTAL Fuel + O&MSGA EXPENSE	**cents/KWh $_{to\ DC}$**	**11.0**	**21.1**

EXCLUDES Capital recovery. Total Invested Capital: $TIC A <= $TIC B

O&M, SGA plus primary fuel (*gas, grid power*) savings are drivers for CHP+VAC vs. traditional configuration.

1. On an energy-normalized basis, $Natural Gas: $4/MMBtu <<<< Grid power: 14 c/KWh = $41/MMBtu

2. CHP+VAC more efficient than traditional configuration;
PUE manifests efficiency advantage.

3. OpEx + fuel savings ~$20 MM/yr of CHP+VAC Vs. traditional config. pays for CapEx investment.

4. CHP+VAC CapEx estimate is work-in-progress. Needs scope and sizing *freeze* to tighten current Total Installed Cost ($TIC) guesstimate $75-to-$85 MM.

Effective Project Development Contract

Decide Commercial structure based on simple contracts, open book costing & equal alignment of interests

- Commercial Operations Date (COD)
- Milestones – Engineering completed, issue PO's for equipment, start construction, Equipment delivery, start commissioning
- Commercial: EPC or EPCM, rates, cost caps, profit percentage, other
- Performance guarantees for generator heat rate, VAC perf. (TonsR), availability etc…
- Warranties – part load performance, perf. Degradation, outage rates, component costs
- Acceptance criteria
- Bonus or penalties for over / under performance
- Project Execution Plan and critical path to completion

OTHER benefits of CHP-VAC versus grid power only

- Superior energy supply resiliency = *Redundancy* + *Availability*
- CHP systems are scalable; i.e. modular, skid-mounted and easy delivery to site
- Simple tie-ins for fuel, chilled water and power
- Reduce stranded asset risk; dis-connect and move modular CHP systems if needed
- Predictable data center load is a perfect fit to CHP; several avenues to optimize
- If possible, the project can
    - monetize value of superior energy supply resiliency
    - monetize GHG emissions
- Stand-alone nature of CHP assets lends itself to non-recourse project financing
- Data Center (DC) developer can avoid investing in critical, but non-core energy supply; instead redirect all available capital into the DC

Key equipment: Gas turbine (microturbine or aero-derivative) available as modular, factor built, skid-mounted units ==➔ reduced risk

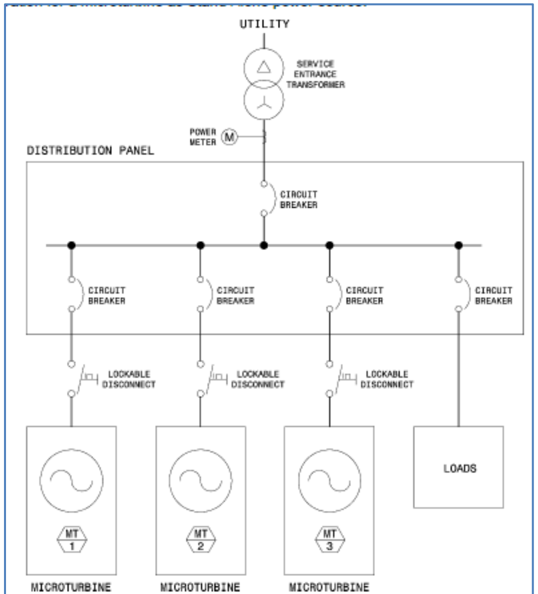


Figure 37. Recommended Device Layout – Grid Connect

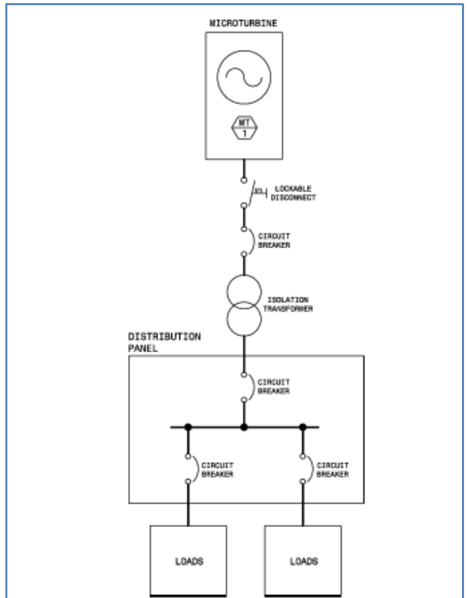


Figure 38. Recommended Device Layout – Stand Alone

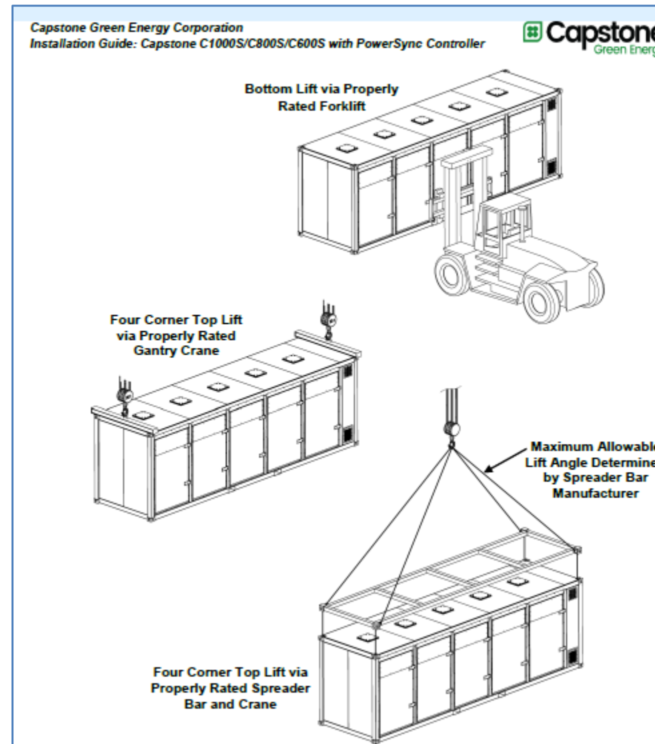


Figure 4. C1000S/C800S/C600S Lifting Example (C1000S Shown)

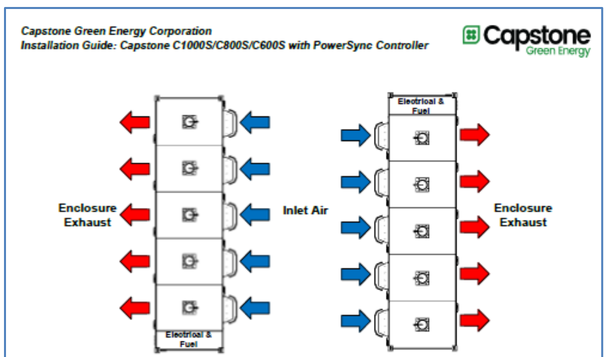
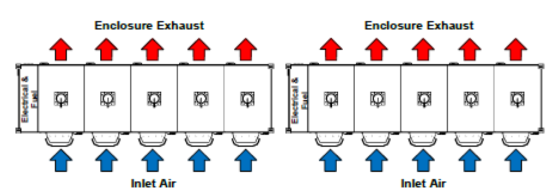


Figure 26. Microturbine Orientation Example #2



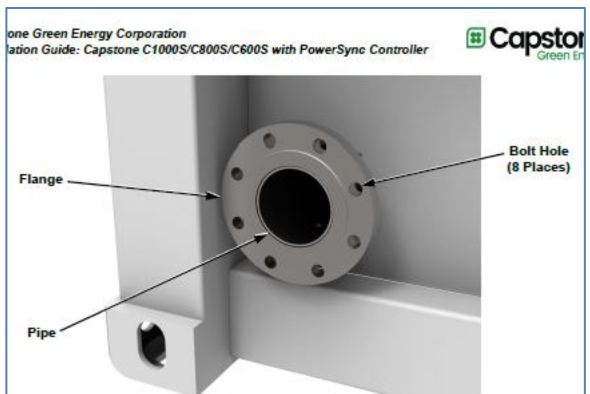


Figure 7. Gaseous Fuel Connection

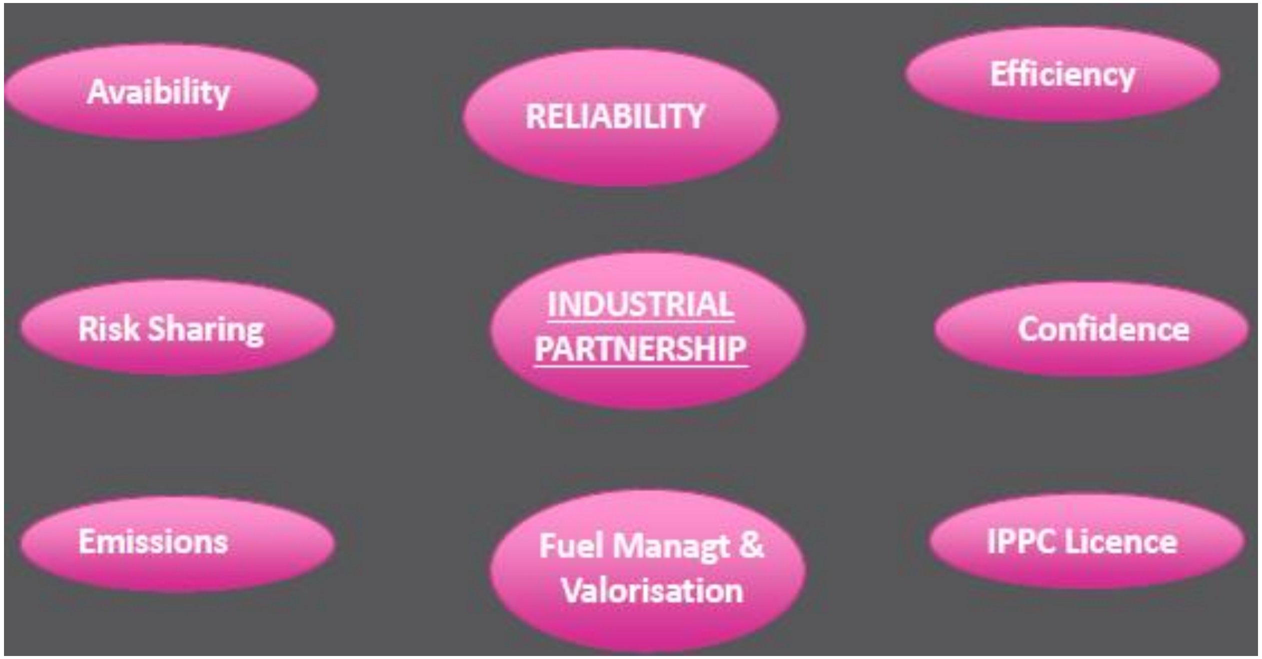
Project planning

Set objectives & gather data

Conceptualize configurations + appraise economics

<u>Project development</u>

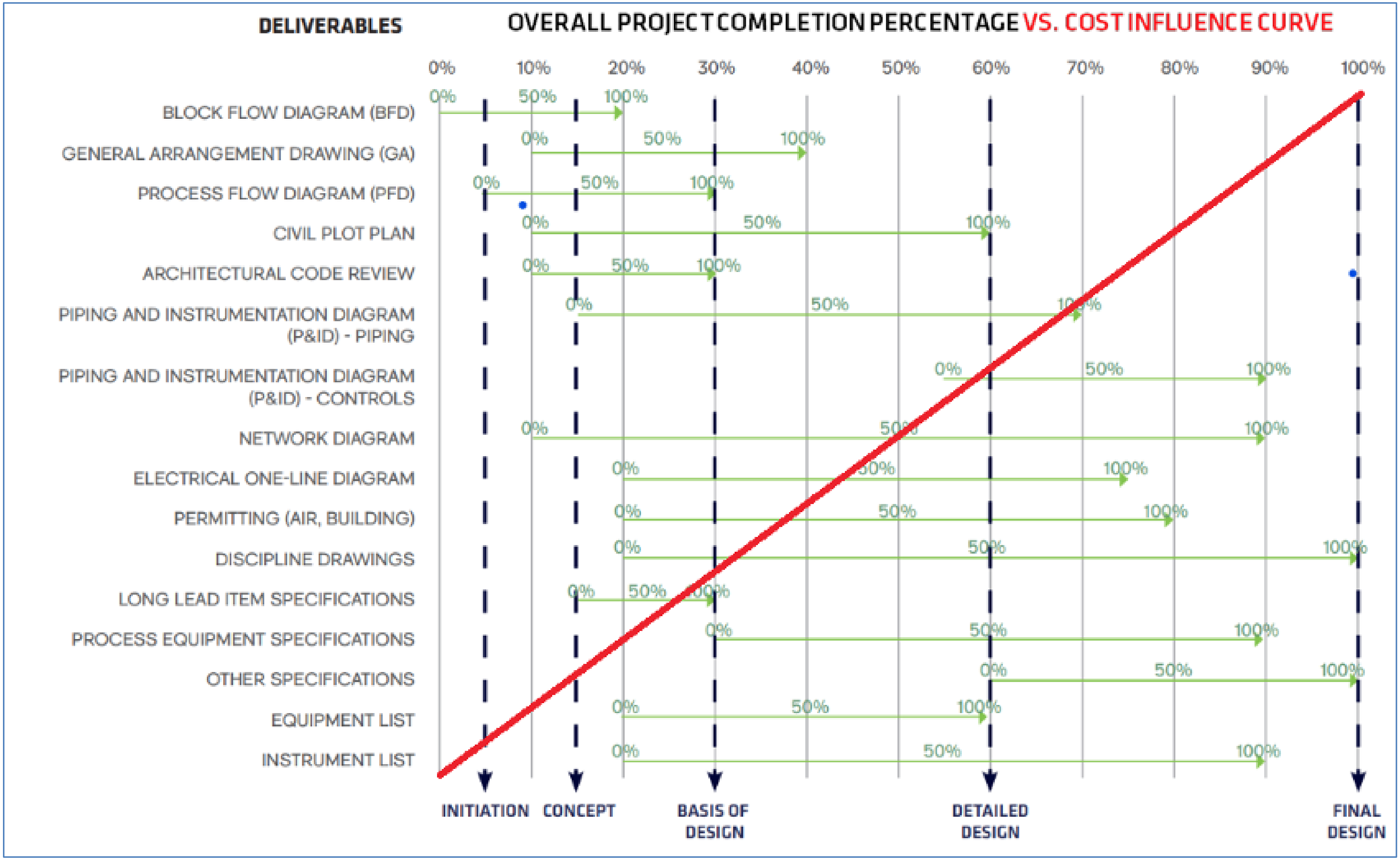
Technical:	Configuration, Engg; Procurement, Constr.
Legal:	Structure (LLC, S or C Corp etc…)
Commercial:	Contracts for fuel, power/steam, O&M
Environmental:	Permits
Financial:	Financial models, equity & debt
Risks & Mitigants:	Project Execution Plan (PEP)



Alternate Energy supply project financing models

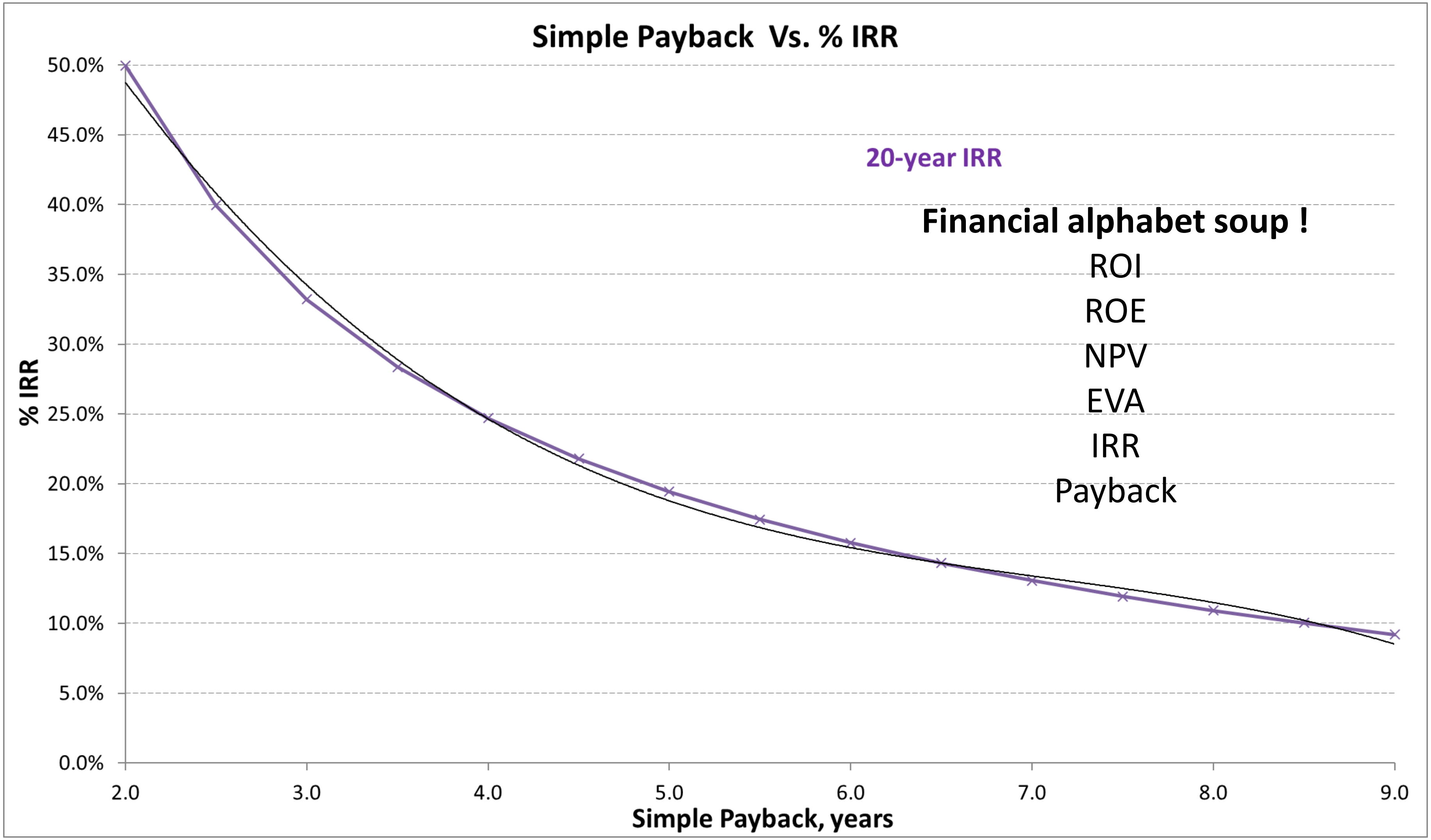
ECONOMIC MODEL	DESCRIPTION
Energy as a Service (Eaas)	The EaaS provider delivers energy (heat, cool) *up to limit of customer needs*. The EaaS provider takes Finances-Designs-Builds-Owns-Operates-Maintains (FDBOOM) the HP assets per a long term Energy Services Agreement (ESA) typically comprising a monthly capacity payment *plus* pass-thru variable charge indexed to cost of power, consumables etc...
Energy Service Performance Contract (ESPC)	Energy Service Company (ESCO) will FDBOOM the project and share savings or provide guaranteed energy savings
Pay for Performance	Customer pays a fixed rental fee for HP equipment based onn actual energy saved
Conventional equipment lease	The HP is leased to the energy customer over a pre-determined lease term. At end of lease term, the HP asset can be returned or the lease is renewed or customer can opt to buy asset at a negotiated cost
Property Assessed Clean Energy (PACE) financing	The HP assts is financed by a long-timer, lower cost loan issued by a bank / financing source. Repayments are an add-on charge to property tax bill, thus enabling easier transfer of the site to new owners.

Think *thrice*, prelim.-design *twice*, detail design-construct *once*



Project Execution Plan (PEP) for schedule-budget-resource expectations

Financials: simple payback or IRR? Empirically related



Indicative performance: thermodynamics, GHG emissions and economics: GT and RE based CHP-VAC *versus* grid power

INPUT	INPUTS in BLUE	UNIT	VALUE	COMMENT
Data Center loads (servers etc..)		MW_e	**25**	assumed
Efficiency of offset Elec chiller		KW_e/TonR	0.70	typical
Delivered Grid power		**cents/KWh**	**10.0**	**assumed**
Delivered Natural Gas		$/MMBtu, HHV	**$3.00**	assumed
CHP system Reqd. Payback		years	8.0	assumed
GHG emissions				
CO_2 from Grid power		Lb CO_2/MWh	1,200	site specific; **eGRID**
CO_2 from Nat. Gas combustion		Lb CO_2/MMBtu	116.0	stoichiometry

OUTPUT	UNIT	VALUE	COMMENT
Elec. Chlr to cool servers	MW_e	5.0	calculated
Servers cooling Load	TonsR	7,110	calculated
DATA CENTER: Peak LOAD	**MW_e**	**30.0**	$26.3 MM/y
Data Center Grid electricity reqd	**MWh/yr**	**262,601**	calculated

PARAMETER	INPUTS in BLUE	UNIT	CHP-VAC SYSTEM GT-CHP	RE-CHP
CHP generator capacity		MW_e	**22.7**	**25.5**
Generator Heat Rate		HHV Btu/KWh	10,497	8,600
CHP Fuel reqd.		HHV MMBtu/Hr	238	220
CHP-VAC sizing		TonsR/KW_{gen}.	0.46	0.25
VAC size		TonsR	10,439	6,383
CHP SYSTEM EFFICIENCY		% HHV	82%	75%
Elec. Chlr offset by VAC		MW_e	7.3	4.5
CHP supply to Data Center load		MW_e	**30.0**	**30.0**
Does CHP meet DATA CENTER LOAD?			**YES**	**YES**
OpEx (*Gen + VAC*)		$/MWh	**$13**	**$22**
CHP Prime mover		$/$KW_e$	**$700**	**$700**
CHP VAC		$/TonR	**$1,100**	**$900**
CHP Prime mover		$MM	$15.9	$17.9
CHP VAC		$MM	$11.5	$5.7
CHP - Bal of Plant		$MM	$24.6	$23.6
CHP INVESTMENT		**$MM**	**$52.0**	**$47.2**

PARAMETER	INPUTS in BLUE	UNIT	CHP-VAC SYSTEM GT-CHP	RE-CHP
OVER-SIMPLIFIED ECONOMICS (assumes 8760 hrs/yr)				
OpEx		$MM/yr	$2.6	$4.9
CapEx recovery		$MM/yr	$6.5	$5.9
Fuel		$MM/yr	$6.3	$5.8
TOTAL CHP-VAC EXPENSE		$MM/yr	**$15.3**	**$16.6**
TOTAL CHP-VAC EXPENSE		cents/KWh	5.8	6.3
DIRECT SAVINGS		$MM/yr	$10.9	$9.7
versus		cents/KWh	4.2	3.7
Grid Power		% saved	42%	37%
Additional CapEx saved - electric chiller, diesel genset, UPS systems etc..				
CHP Grid power offset				
Generator		MWh/yr	198,790	223,660
VAC offset elec. Chlr		MWh/yr	64,010	39,140
TOTAL		**MWh/yr**	**262,800**	**262,800**
GHG emissions				
offset CO2 from Grid power		met.tonne/yr	(143,345)	(143,345)
CO2 from Nat. Gas combustion		met.tonne/yr	110,028	101,419
NET change GHG emissions		**met.tonne/yr**	**(33,317)**	**(41,926)**
NET change GHG emissions		**% decrease**	**-23%**	**-29%**