Enhanced Cooling Tower Technology for Power Plant Efficiency Increase and Operating Flexibility

Award # FE0031833

Project Status Review

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Project Description

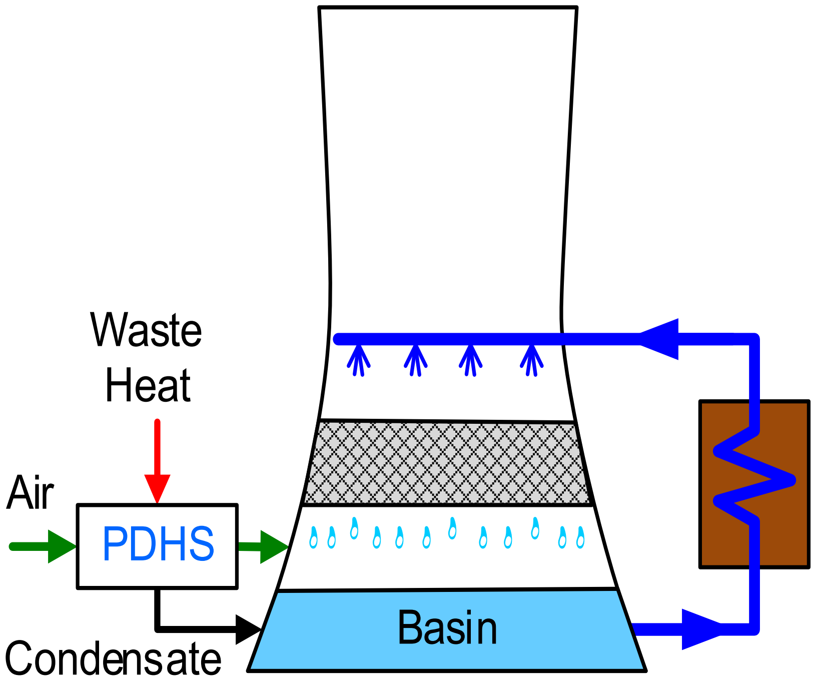
Purpose of project

- Develop and demonstrate a prototype (up to 100 kW) of "all weather" Sub-Dew Point Cooling Tower (SDPCT) enhancement technology
- Demonstrate an inlet air dehumidification including testing in controlled environment for simulating various ambient conditions

Strategic alignment of project to Fossil Energy objectives

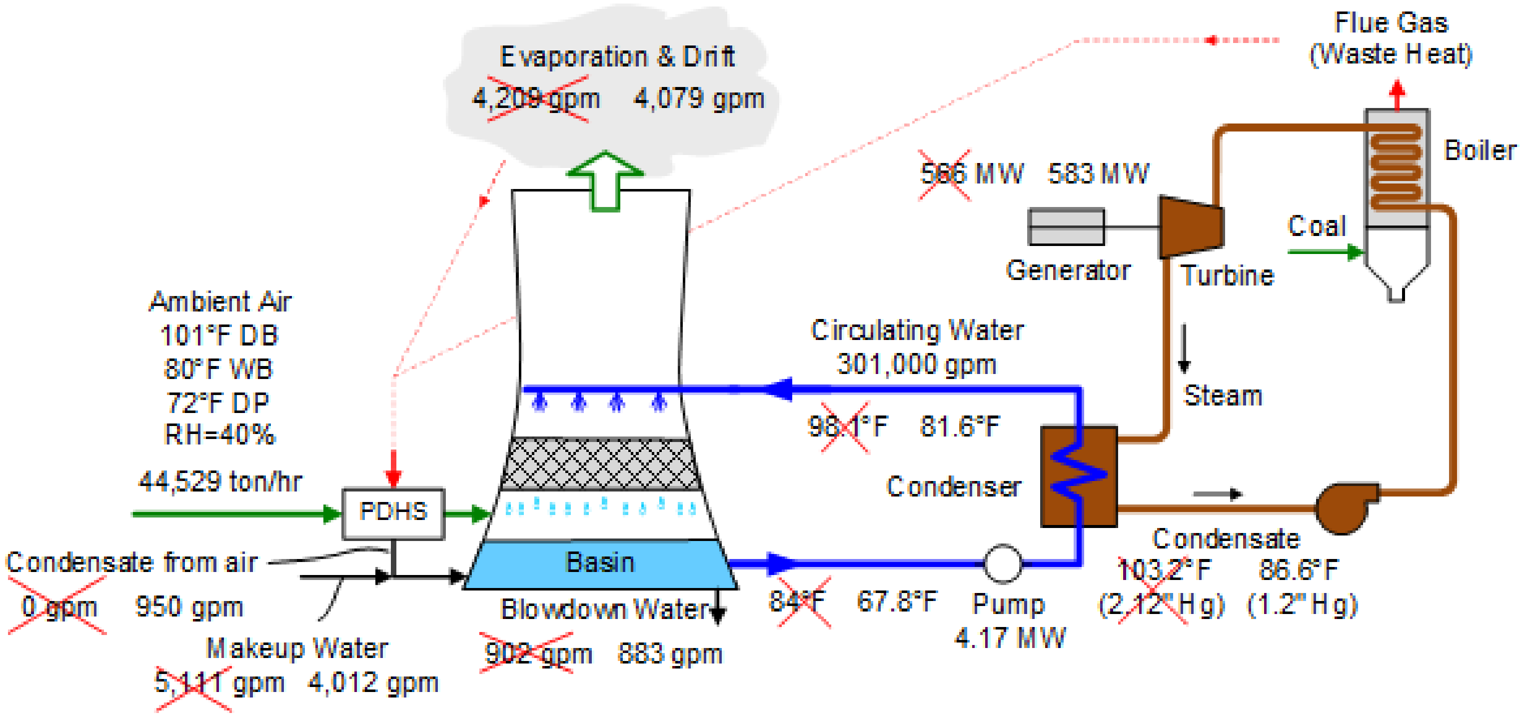
- The SDPCT technology will provide a solution to challenge facing the existing fleet of coal-fired power plants (CFPP) as well as enhance their operating performance and economics
- The Pressure Dehumidifying System (PDHS) will significantly lower (~20%) freshwater consumption without drastic increase in CapEx and OpEx
- Cooling the water below the ambient dew-point will lead to increased power plant net efficiency

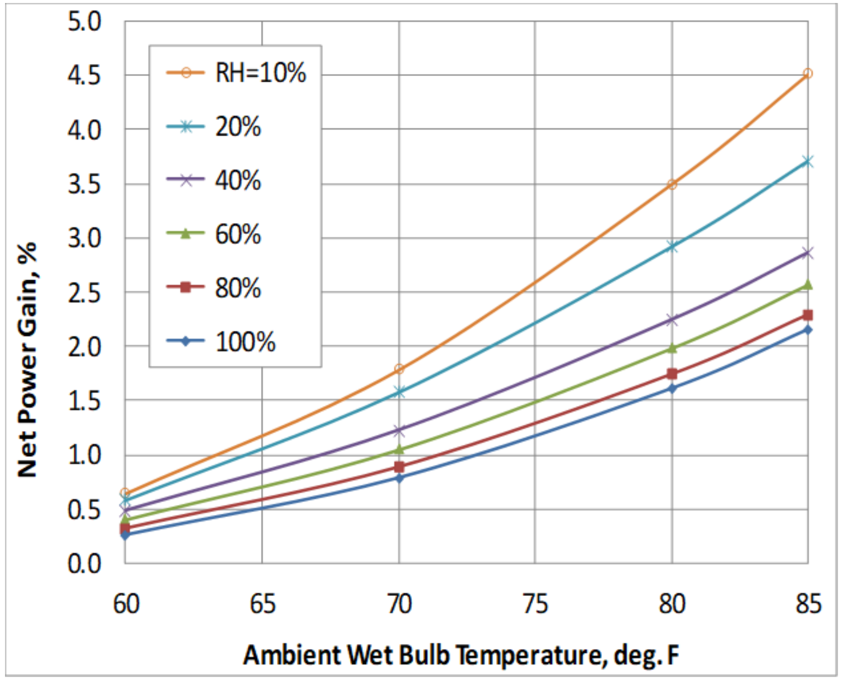
Original SDPCT Concept
[retrofit option]



Motivation and Technology Layout

To perform a preliminary technical feasibility analysis of the PDHS and SDPCT concept to improve the CFPP fleet performance efficiency and operating flexibility





Predicted net power gain for a 550 MWe SDPCT-enhanced coal-fired power plant

Project Objectives

Objectives

- Initial objective: preliminary process design, modeling, performance characterization
- Subsequent objective: pre-package a pressure dehumidification system (PDHS), perform the laboratory evaluation and develop the plan for SDPCT prototype testing
- Final objective: conduct SDPCT prototype testing, complete performance data processing, and a techno-economic analysis (TEA) including integration and scale-up

Technology benchmarking

- State-of-the-art cooling towers of maximum efficiency with approach temperatures of 5°F to 7°F above the wet bulb. The SDPCT technology under development to achieve sub-dew point temperature

Industry/input or validation

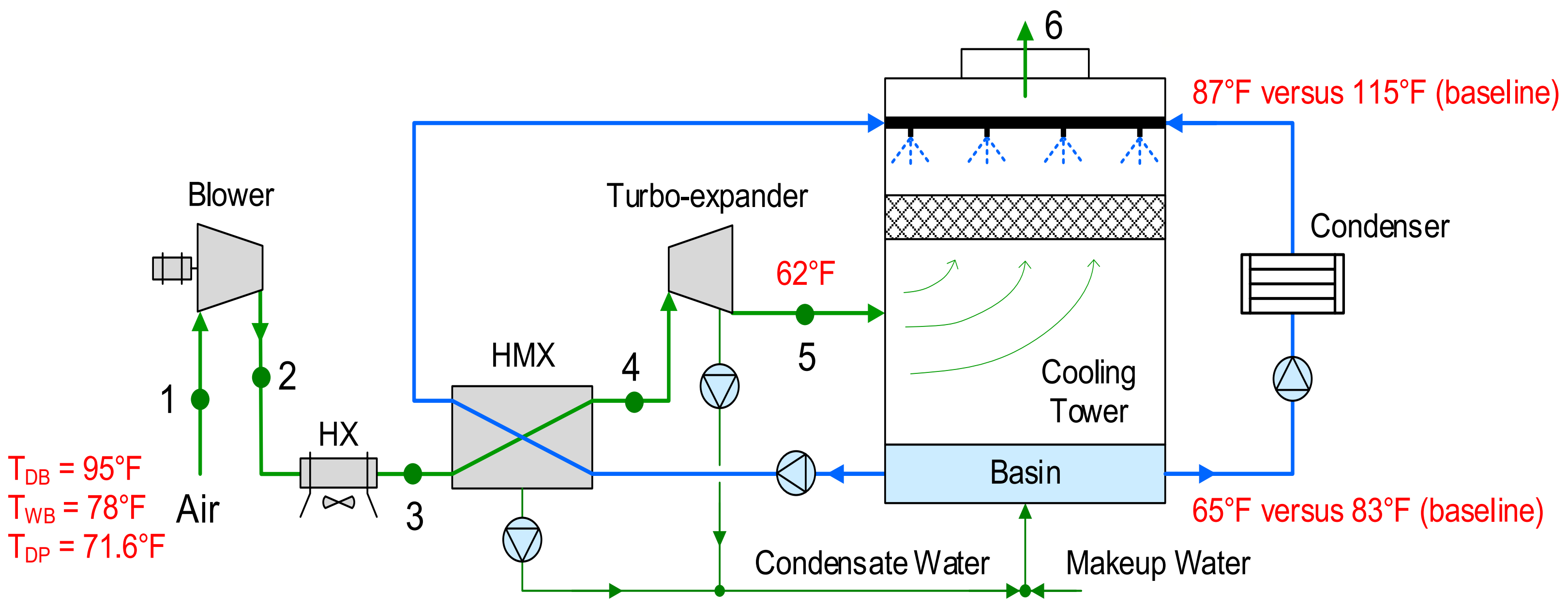
- Baltimore Aircoil Company (BAC) participates in design review, conducts SDPCT prototype construction and testing. Worley/Advisian conducts SDPCT performance modelling and cost-estimating

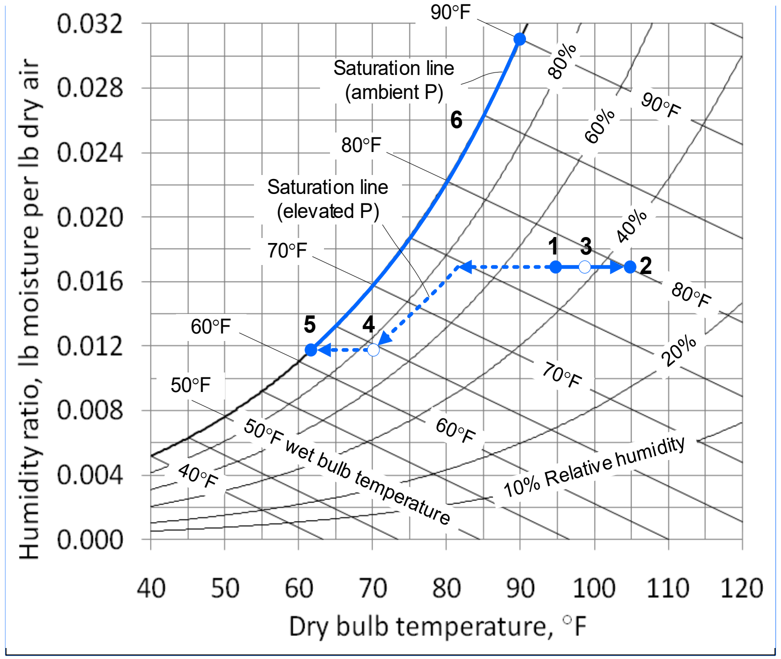
Project Updates and Accomplishments

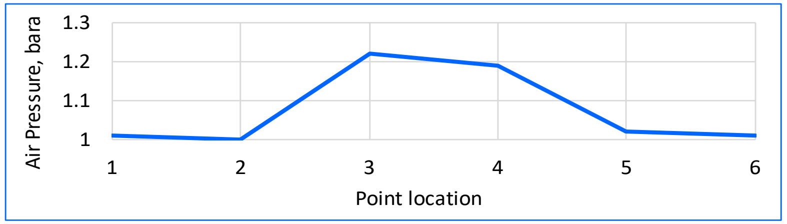
- The proposed concept of efficient dehumidification technique based on near-atmospheric pressure regulation has been refined and optimized to achieve improved performance benefits
- Initial, boundary, and operational conditions for the PDHS were specified, simulations have been conducted to characterize the overall PDHS performance
- Sub-dew point temperature of air entering the cooling tower was achieved at the nominal operating parameters
- Preliminary techno-economic assessment (TEA) of the SDPCT along with benefits comparison against state-of-the-art cooling tower has been performed
- Pilot-scale evaluation and cooling tower retrofit have been discussed with participating cooling tower manufacturer (BAC)

Refined Concept

U.S. Patent Pending







SDPCT for 650 MW CFPP with PDHS under nominal design conditions:

HX – air cooled heat exchanger, HMX – heat and mass exchanger, T_{DB} – dry bulb temperature, T_{WB} – wet bulb temperature, T_{DP} – dew point temperature, RH – relative humidity

Performance Comparison

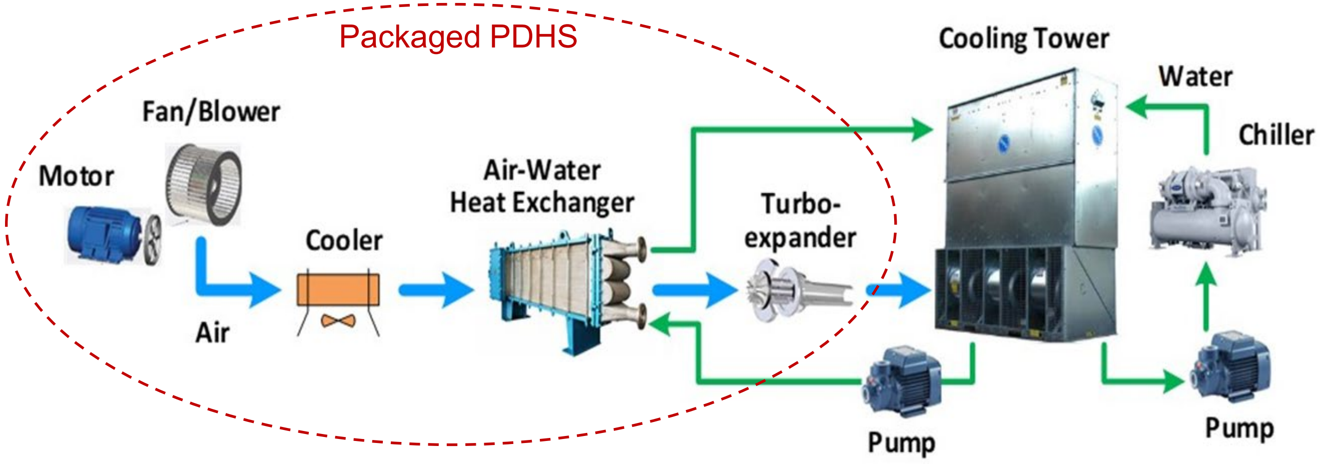
- Three different cases of the SDPCT were estimated for the referenced 650MW CFPP
- 1.6% net plant efficiency gain
- 24% makeup water reduction leads to reduced water cost from 3.95 $/MWh (baseline) to 2.95 $/MWh (retrofit)
- Higher performance is expected for other baseline configurations (i.e. B11A)

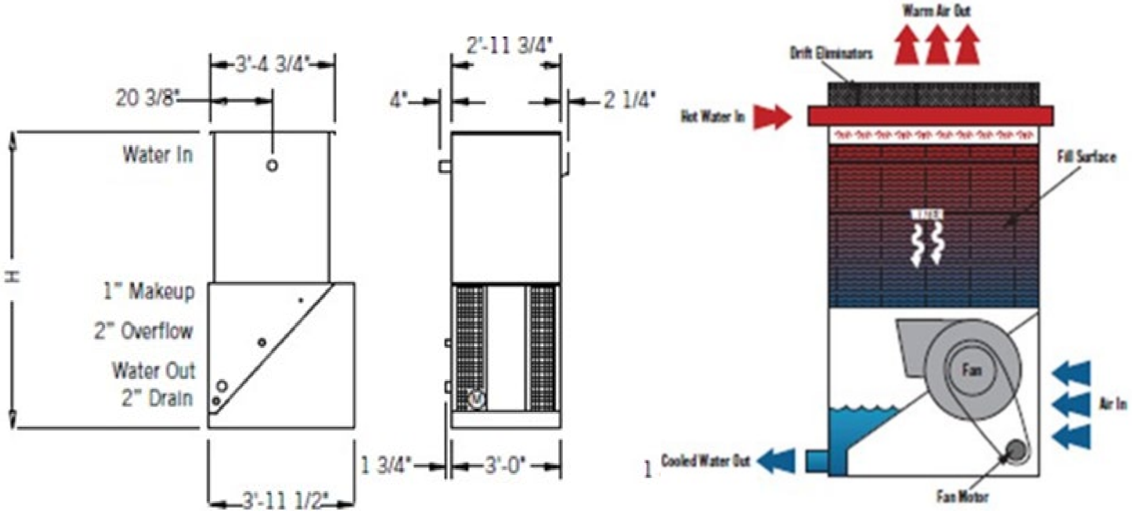
Basis: 650 MW Supercritical Coal-Fired Power Plant based on DOE Baseline Case B12A Configuration — Rev A. Dec 18, 2020

Case Description	Baseline	PDHS Retrofit w/o Condenser Upgrade	PDHS Retrofit w/Condenser Upgrade	PDHS Retrofit w/ Condenser Upgrade & Exhaust Recovery	Remarks
1. Ambient Conditions					
Dry Bulb Temperature, °C (°F)	35 (95)				Summer Ambient
Wet Bulb Temperature, °C (°F)	25.5 (77.9)				
2. Cooling System Operating Parameters					
Condenser Circulating Water Flow, kg/s (lb/s)	14,467 (31,894)	14,467 (31,894)	14,467 (31,894)	14,467 (31,894)	
Total Cooling System Aux Power Consumption, MW	**8.1**	**32.2**	**32.2**	**20.6**	Power consumed and generated
3. Plant Performance					
Steam Turbine Output, MW	668.6	689.4	691.3	691.3	
Plant Net Output, MW	633.6	630.2	632.1	643.7	
Plant Net Output Difference, MW	Base	(3.4)	(1.5)	10.1	
Plant Net HHV Efficiency, %	39.20%	38.99%	39.10%	39.82%	
Plant Net HHV Efficiency Difference, %	Base	-0.21%	-0.09%	0.63%	
4. PDHS System Capital Cost, Million USD					
Total PDHS System and Associated Retrofit CAPEX	NA	64.7	72.2	64.5	
Total CAPEX for PDSH retrofit, $/kW	Base	-	-	6,356	Incremental net output to Baseline
5. Water consumption					
Makeup water consumption, kg/s (lb/s)	368.3 (812.8)	279.9 (617.3)	279.9 (617.3)	279.9 (617.3)	
Makeup water consumption reduction, %	-	24%	24%	24%	
Water cost, $/1,000 gal	7.13	7.13	7.13	7.13	Ind. water treatment and sewerage
Water cost, $/MWh	3.95	3.02	3.01	2.95	

Challenges and Plans

- Existing CFPP cooling tower may require minor modifications for adopting PDHS
- Further enhancement and optimization of the PDHS is required to minimize system power consumption and increase the CFPP net power output
- The full-size VT0-12-E cooling tower from BAC will be retrofitted
- Nominal (design) conditions: 53 kW cooling capacity, 36 GPM water flowrate, 5000 CFM air flowrate, 95°F ambient temperature, 47% RH
- PDHS components are either off-shelf or custom modifications to be packaged prior to scale-up and system integration





Testing Facilities

- The SDPCT prototype testing and demonstration have been preliminary discussed
- GTI will package and evaluate PHDS at the Industrial Testing Facility prior to sending to BAC for integration and performance evaluation
- BAC is committed to provide adequate research and development facility, resources and measurement capability for the performance data collection
- The research and development facility at BAC is well known across the industry for its ability to support the demonstration testing and to serve as an independent testing lab for new developments

GTI Industrial Testing Facility at Des Plaines, IL

BAC R&D Testing Facility at Jessup, MD

Upcoming Steps

- SDPCT-prototype system performance will be experimentally tested and process-modeled for a wide range of process temperatures and flow rates
- Data will be collected using BAC data acquisition system followed by project team review, analysis, and modeling verifications
- Technical support will be provided by all team members throughout the execution of the approved test plan
- The goal of the performance testing is to demonstrate the SDPCT to achieve the cooled water temperature at least 1°F below ambient dew point under various ambient conditions while providing water consumption reduction benefits
- Project team will work on the TEA with the primary objective to perform cost-benefit analysis of SDPCT. The economic model and sensitivity analysis will identify focus areas for further actions
- The TEA will consider baseline coal-fired power plant (B11A and/or B12A) located at three typical US locations and 3 ambient conditions at each location

Preparing Project for Next Phase

Market Benefits/Assessment

- Advanced SDPCT technology for "all weather" conditions
- Reduced make-up water consumption (~20%)
- Increased CFPP efficiency potential

Technology-to-Market Path

- The PDHS can be added as a simple retrofit to existing cooling towers for CFPP improved performance and water savings
- Further development of the SDPCT technology and its experimental evaluation are required to validate the technology benefits
- Identified industry collaborators: Baltimore Aircoil Company, Worley
- Technical Advisory Group (energy companies, power plants, etc.) pending

Concluding Remarks

Applicability to Fossil Energy (FE) and alignment to strategic goals

- The following key FE challenges are addressed by the SDPCT technology:
  - Enhanced performance and economics of existing and new CFPP
  - Decreased CFPP water consumption
- The new cooling technology consistent with the Water Security Grand Challenge, U.S. DOE led framework to advance transformational technology and innovation to meet the global need for safe, secure, and affordable water

TRL

- The current TRL 4 was attained by integration of key PDHS components that are commercially available with validated performance
- The next TRL 5 will be attained after PDHS is packaged and evaluated at GTI Industrial Testing Facility to establish the PDHS components are working together
- The project will attain TRL 6 at the end of integrating PDHS with cooling tower test platform at BAC R&D facility followed by the performance data collection and TEA of the SDPCT-enhanced prototype including scale-up recommendations

Acknowledgment

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Disclaimer

Questions, Comments, Concerns