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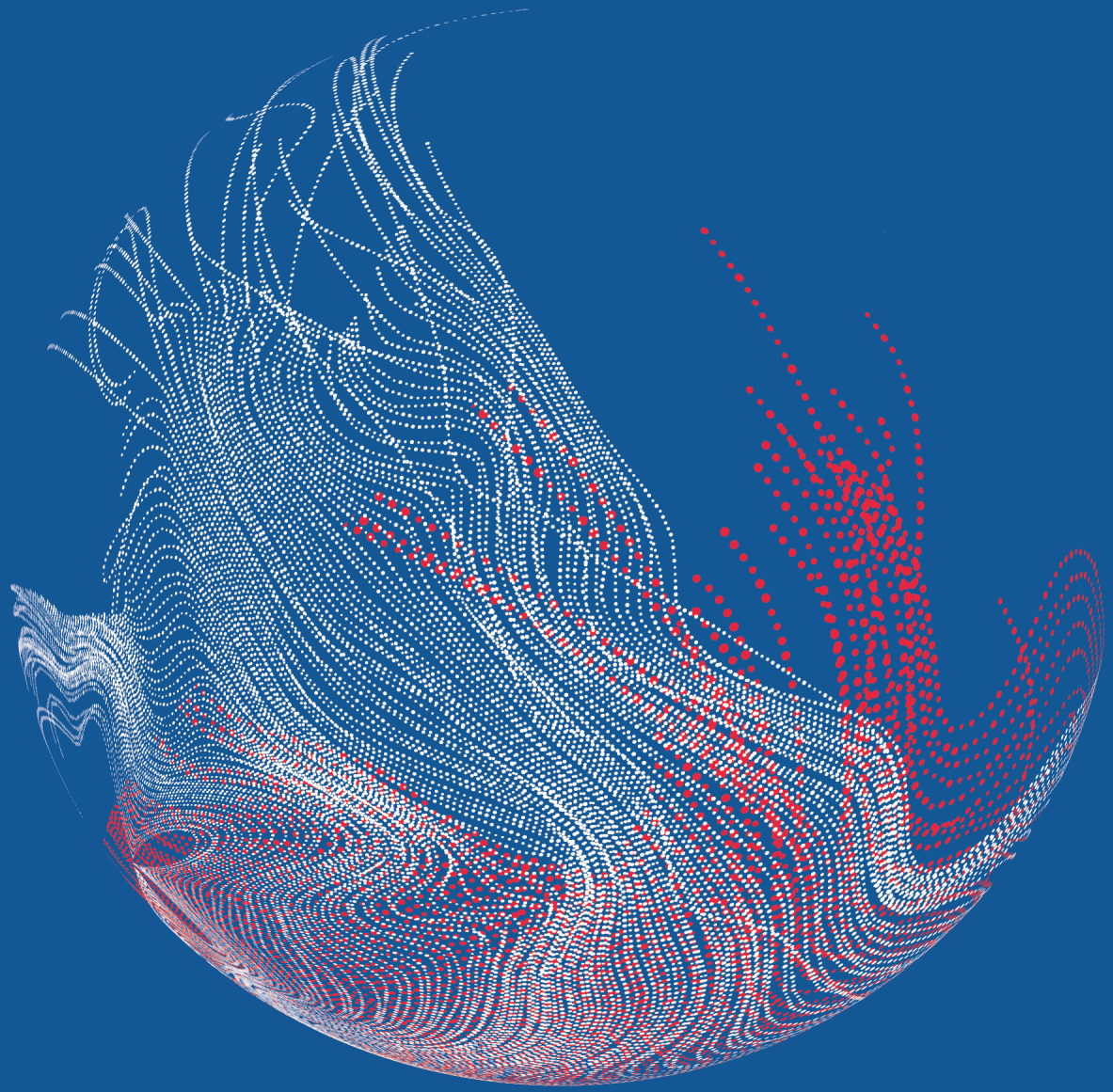
Business Case for Natural Refrigerants



June 12-13, 2023
Washington D.C.

ATMO AMERICA Summit

A Case Study for CO_2 Condensing Units in Various Climates

M&M Carnot & SubZero Constructors

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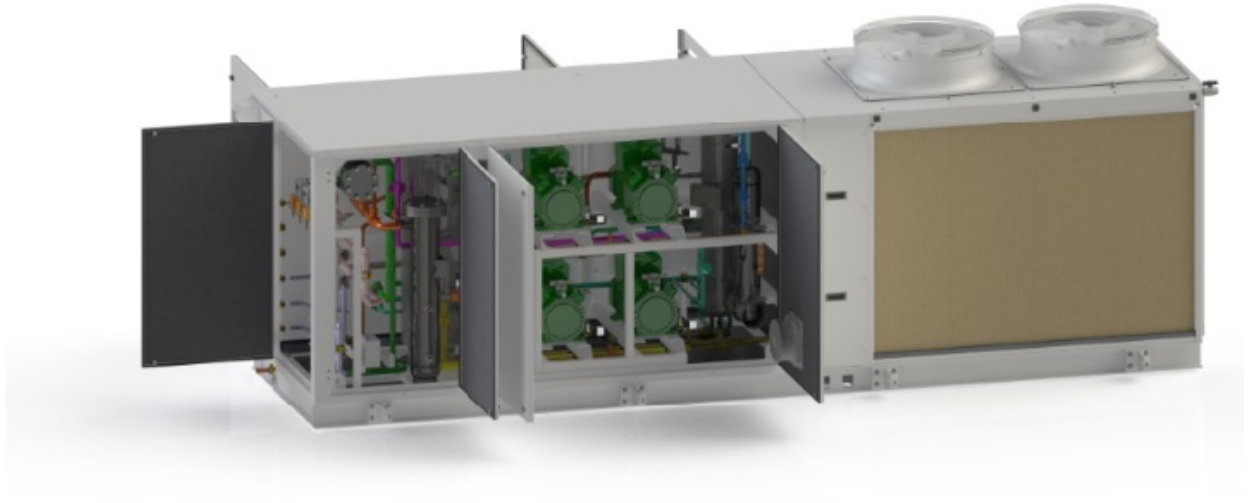
Introduction

- In North America, there is a growing need for natural refrigerant condensing units
- M&M Carnot and SubZero Constructors have collaborated on several TCCO2 freezer and cooler projects
- Key design features of TCCO2 condensing units
- Comparison of TCCO2 vs. R448A systems for three different locations (38F storage rooms)
  - Efficiency
  - Total installation costs
  - Operational costs
  - Life cycle costs
- Installation photos
- Barriers and challenges
- Opportunities and future plans

Aquilon DS



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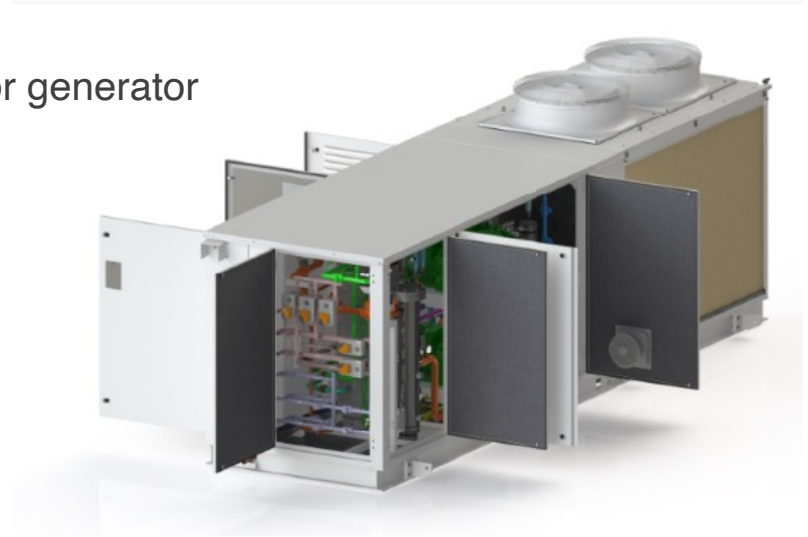
Key Design Features For:

- Reliability
  - High pressure design eliminates the need for back-up condensing unit or generator
  - High efficiency oil management system with coalescing oil separator
- Efficiency
  - Transcritical compressors with VFD drives on lead machines
  - Integrated adiabatic gas cooler with EC fans
  - Evaporator fan speed control as a standard
- Installation
  - Single point electric with power distribution to evaporators
  - All evaporator control valves integrated into condensing unit – field piping required only
  - Insulated vessels and cold piping



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Efficiency Analysis – San Diego, CA – 100TR

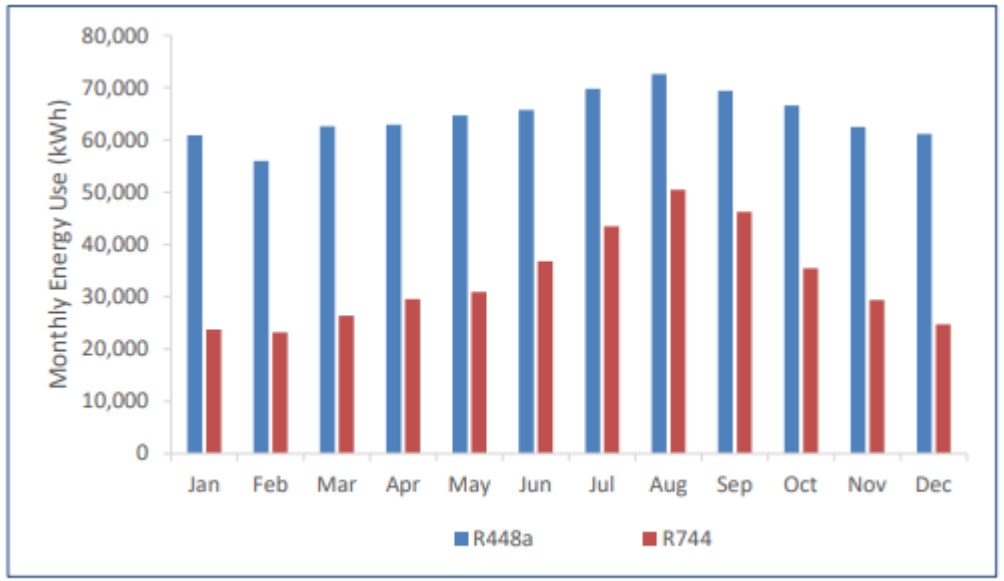

Figure 4: Monthly Energy Use Profile

Table 10: R448a Annual Energy Use by Component

R448a System	Annual Use	Unit
Compressors	398,556	kWh
Condenser Fans	61,295	kWh
Evaporator Fans	261,398	kWh
Electric Defrost	53,765	kWh
Total	**775,014**	**kWh**

Table 11: R744 Annual Energy Use by Component + Savings

R744 System	Annual Use	Unit
Compressors	307,254	kWh
Gas Cooler Fans	62,853	kWh
Evaporator Fans	30,189	kWh
Total	**400,296**	**kWh**
Energy Savings over R448a	**374,718**	**kWh**

Table 12: R744 Systems Annual Water Use

Component	Water Use	Unit
Adiabatic Gas Coolers	190,233	Gallons
Annual Water Use	**190,233**	**Gallons**

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Efficiency Analysis – Kissimmee, FL – 75TR

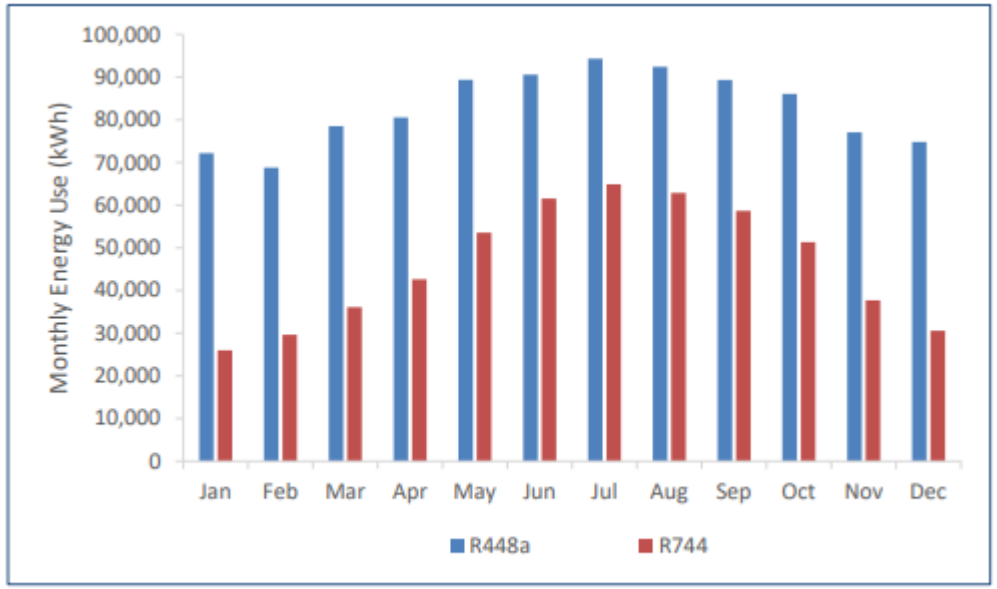

Figure 4: Monthly Energy Use Profile

Table 10: R448a Annual Energy Use by Component

R448a System	Annual Use	Unit
Compressors	492,285	kWh
Condenser Fans	81,443	kWh
Evaporator Fans	348,531	kWh
Electric Defrost	71,701	kWh
Total	**993,960**	**kWh**

Table 11: R744 Annual Energy Use by Component + Savings

R744 System	Annual Use		Unit
	4-Fan	3-Fan	
Compressors	451,625	478,369	kWh
Gas Cooler Fans	62,513	46,885	kWh
Evaporator Fans	41,364	41,364	kWh
Total	**555,503**	**566,618**	**kWh**
Energy Savings	**438,458**	**427,342**	**kWh**

Table 12: R744 Systems Annual Water Use

Component	Water Use		Unit
	4-Fan	3-Fan	
Adiabatic Gas Coolers	256,176	192,132	Gallons
Annual Water Use	**256,176**	**192,132**	**Gallons**

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Efficiency Analysis – Indianapolis, IN – 125TR

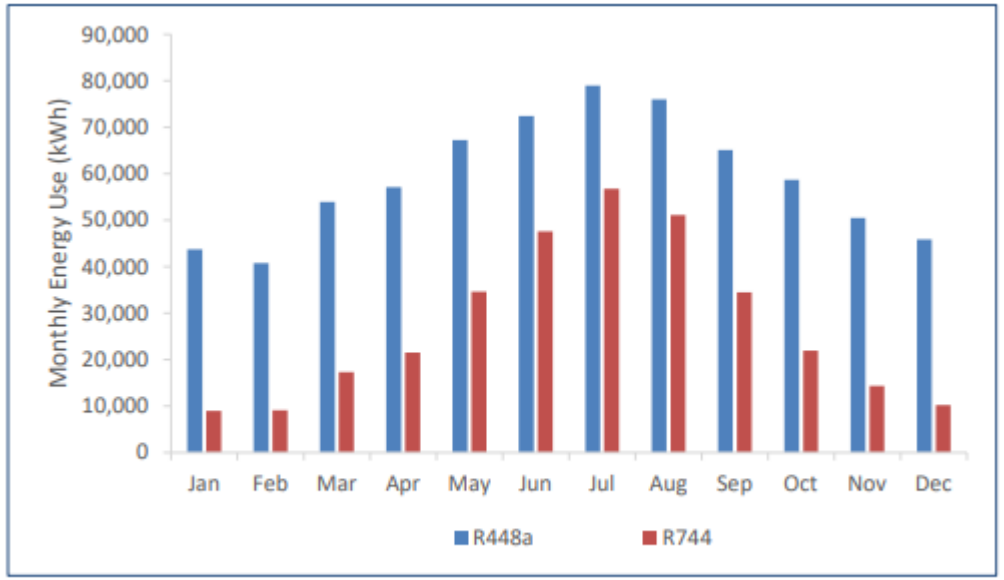

Figure 4: Monthly Energy Use Profile

Table 10: R448a Annual Energy Use by Component

R448a System	Annual Use	Unit
Compressors	348,092	kWh
Condenser Fans	47,355	kWh
Evaporator Fans	261,398	kWh
Electric Defrost	53,765	kWh
Total	**710,609**	**kWh**

Table 11: R744 Annual Energy Use by Component + Savings

R744 System	Annual Use	Unit
Compressors	259,846	kWh
Gas Cooler Fans	42,010	kWh
Evaporator Fans	26,333	kWh
Total	**328,188**	**kWh**
Energy Savings over R448a	**382,421**	**kWh**

Table 12: R744 Systems Annual Water Use

Component	Water Use	Unit
Adiabatic Gas Coolers	162,761	Gallons
Annual Water Use	**162,761**	**Gallons**

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Cost Analysis

Location	System Type	Installation Cost	Annual Operating Cost	Life Cycle Cost - 20 Years	Payback Period Using R744 (years)
San Diego, CA	R448a - 100TR	$957,500	$104,704	$3,751,588	3.8
	R744 - 100TR	$1,154,800	$55,744	$2,919,687	
Kissimmee, FL	R448a - 75TR	$699,500	$110,429	$3,608,079	2.5
	R744 - 75TR	$824,900	$62,254	$2,719,987	
Indianapolis, IN	R448a - 125TR	$1,325,750	$71,629	$3,458,338	6.4
	R744 - 125TR	$1,586,800	$33,466	$2,906,124	
Average % Difference Using R744		19%	-48%	-21%	

Location	Energy	Water
	$/kWh	$/kgal
San Diego, CA	0.1351	8.749
Kissimmee, FL	0.1111	2.1
Indianapolis, IN	0.1008	2.3645

	Average Annual Maintenance Cost
R448a (5 units)	$35,000
R744 (2 units)	$32,500

- 4.2 year average payback period for using R744
- Efficiency gains are even greater in Freezers

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Installation Photos

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Barriers and Challenges For:

- End Users
  - Initial cost of TCCO2 vs. basic synthetic condensing units
  - Local maintenance expertise for TCCO2 systems
  - Lower efficiency in high wet-bulb climates
- Installation/Manufacturing
  - Fewer and heavier rooftop condensing units present challenges for the structural engineer
  - Increasing costs for manufacturing/installing condensing units for all applications
- Commissioning/Service
  - Commercial controls platform with limited capability and user interface
  - Extended commissioning time with a newer product line

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Opportunities for:

- End Users
  - Contractor/manufacturer collaboration to provide lowest first cost TCCO2 system
  - Grow the nationwide network of TCCO2 trained service technicians
  - Implement climate specific design features to maximize efficiency
- Installation/Manufacturing
  - Consider alternative equipment layout vs. traditional rooftop placement
  - Increase standard size range of condensing units to accommodate a wider range of applications
- Commissioning/Service
  - Standardize with industrial controls platform and larger HMI touchscreen for operating/troubleshooting
  - Continuous improvement in engineering/manufacturing to reduce commissioning time

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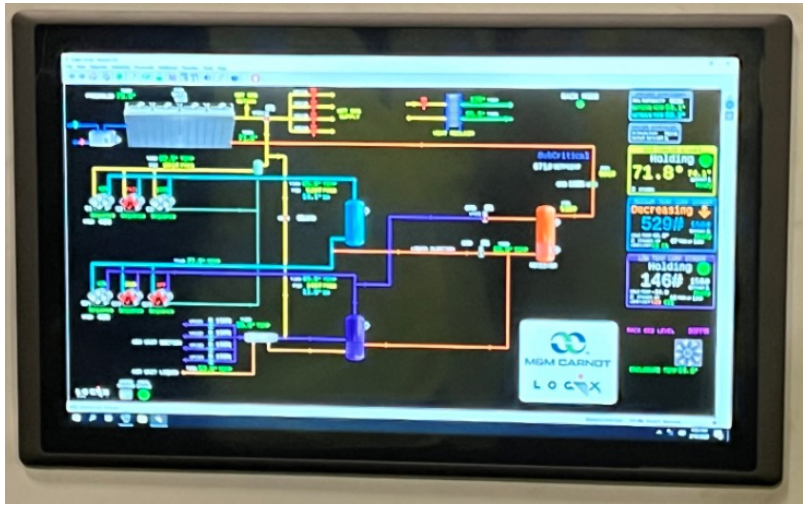
Future Plans:

- Increase standard size range of TCCO2 condensing unit
- Testing TCCO2 condensing units as air source heat pumps
- Standardize with Logix Controls touchscreen with system flow diagram
- Provide Logix supervisory system to network multiple condensing units



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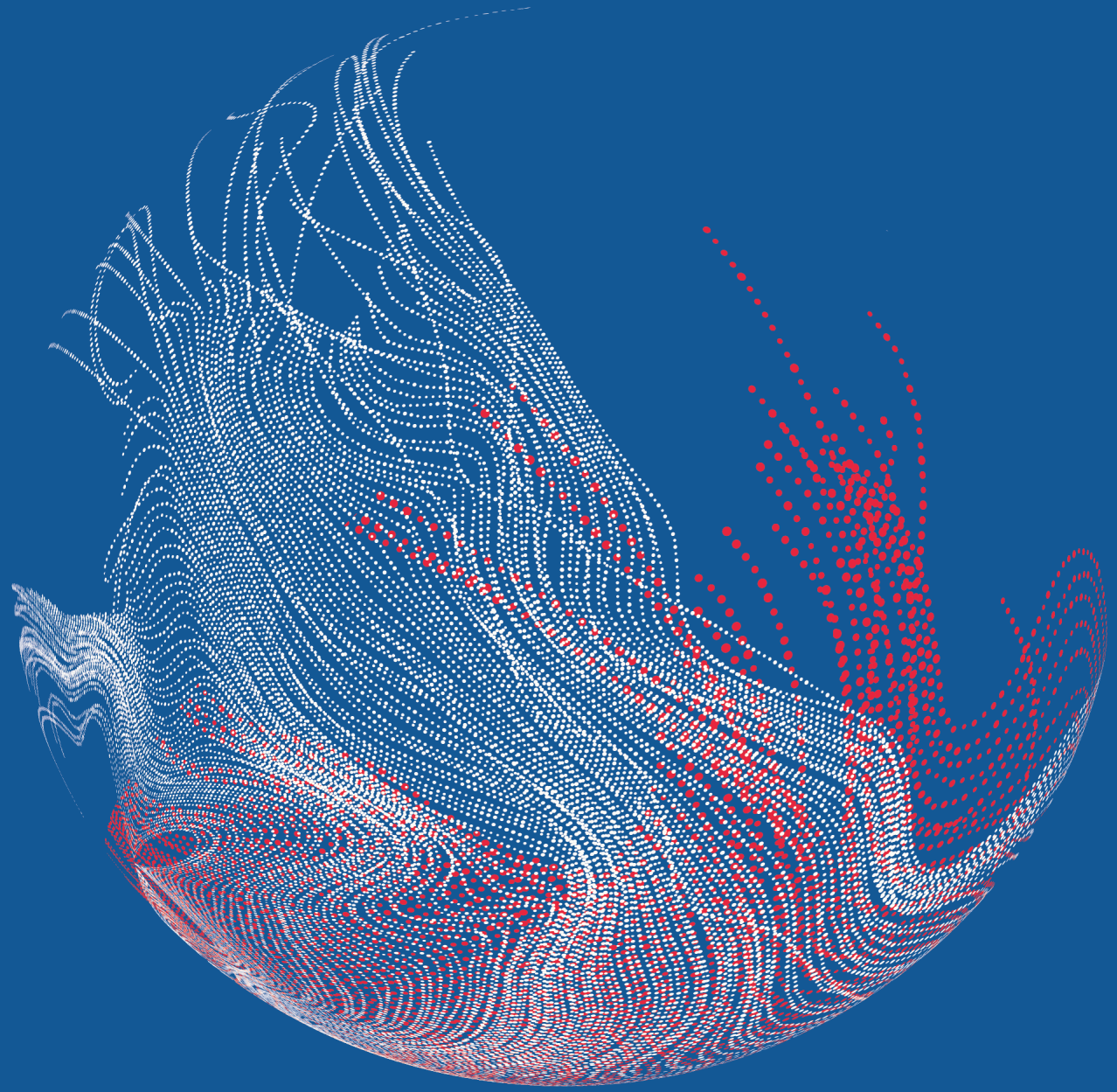

Thank you for listening!