U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

A Natural Gas–Driven Highly Efficient Thermo-Vacuum Clothes Dryer

Oak Ridge National Laboratory
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Project Summary

Timeline:

Start date: 10-01-2018

Planned end date: 09-30-2021

Key Milestones

1. Develop a performance model for a thermo-vacuum-based clothes drying technology
2. Demonstrate the proposed concept by designing, fabricating, and operating a bench-scale thermo-vacuum clothes dryer
3. Develop a commercialization path by engaging appropriate OEMs and end-use operators

Budget:

Total Project $ to Date:

- DOE: $600K
- Cost Share: $33K

Total Project $:

- DOE: $1,800K
- Cost Share: $100K

Key Partners (full spectrum of expertise):

Government/Academia | Small Business | NFP

OAK RIDGE National Laboratory

WILSON Engineering Technologies, Inc

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OEM | End-User

CONSOLIDATED LAUNDRY MACHINERY

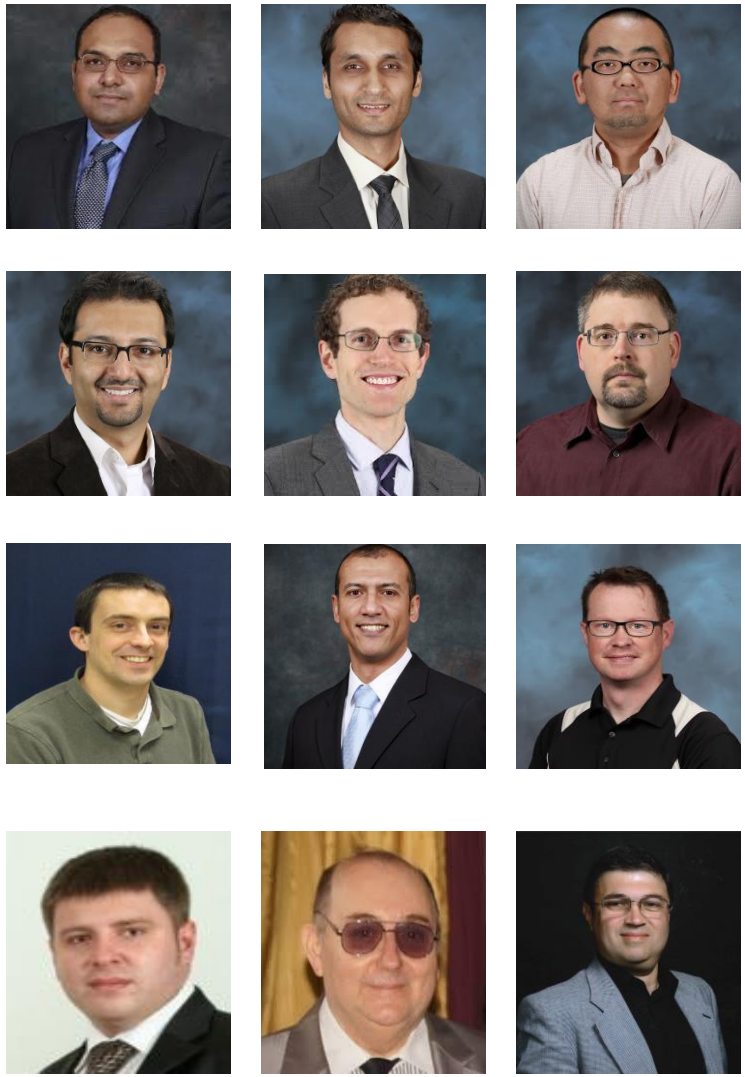
Mission Linen Supply
MISSION LINEN & UNIFORM SERVICE

Project Outcome:

- A revolutionary clothes drying technology leading to significant energy and water savings compared with the state-of-the-art drying concepts
- A relatively simple design with minimal moving parts and maintenance requirements
- The technology is to recover and re-use most of the water used on wet laundry
- A potential solution across industrial commercial and residential sectors

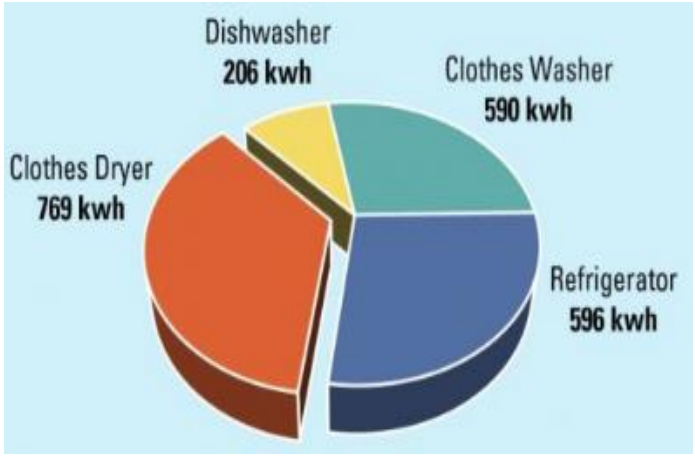
Project Team

- **Oak Ridge National Laboratory**
  - Kashif Nawaz (R&D staff)
  - Brian Fricke (R&D staff)
  - Viral Patel (R&D staff)
  - Matthew Sandlin (Postdoc associate)
  - Ayyoub Momen (R&D staff)
  - Kyle Gluesenkamp (R&D staff)
  - Mingkan Zhang (R&D staff)
  - Ahmad Abu-Heiba (R&D staff)
- **Gas Technology Institute**
  - Yaroslav Chudnovsky (Team lead)
  - Shawn Scott (R&D staff)
- **Wilson Engineering Technologies**
  - Olexiy Buyadgie (Team lead)
  - Dmytro Buyadgie (Director R&D)



Background

- Drying is energy intensive process, consuming on average 290,200 Btu of heat for each 1,000 lb of wet laundry
- Steam released into the atmosphere (0.30 lb per unit pound of wet laundry) intensifies the greenhouse effect and losses of scarce water resources
- The drying process at elevated temperatures (120°C–160°C) degrades fabric and increases energy loss to the environment



Energy consumption by appliances in residential buildings

0.42 Quads of primary energy annually

Background

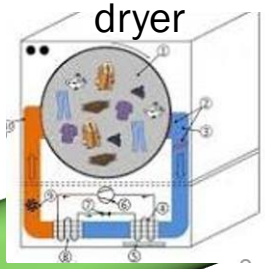
Sunlight for clothes drying

1938-First electric resistance dryer

1963-Auto termination sensors

2014-Energy Star clothes dryer

2016-Heat pump dryer

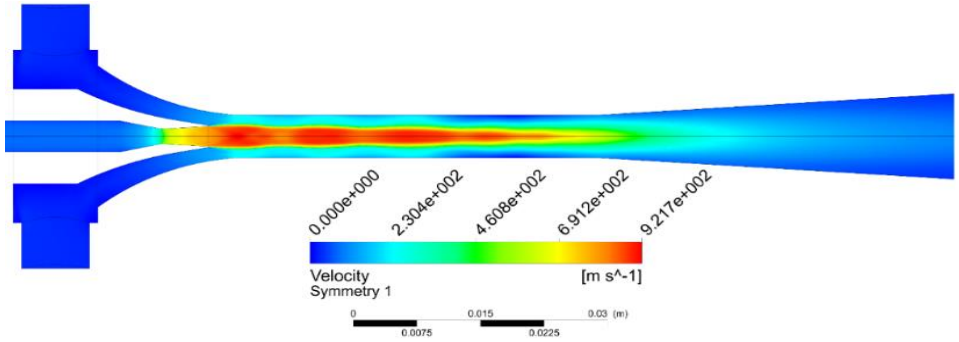


2030- ?

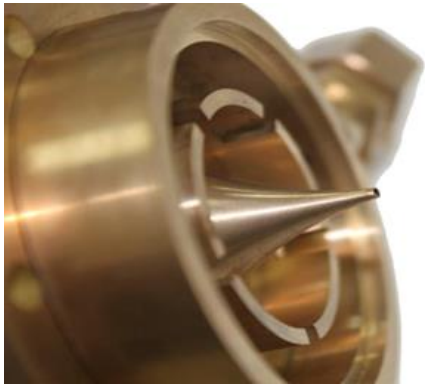
An energy-efficient cost-effective process will transform the market
Exceptional history in next-generation clothes dryers development

Solution Approach

- The innovative **thermo-vacuum drying** method
- 10 times faster moisture removal than any conventional methods
- Natural-gas driven approach
- Minimal electrical power requirements (drum rotation and controls)
- Waste heat and water recovery for re-use



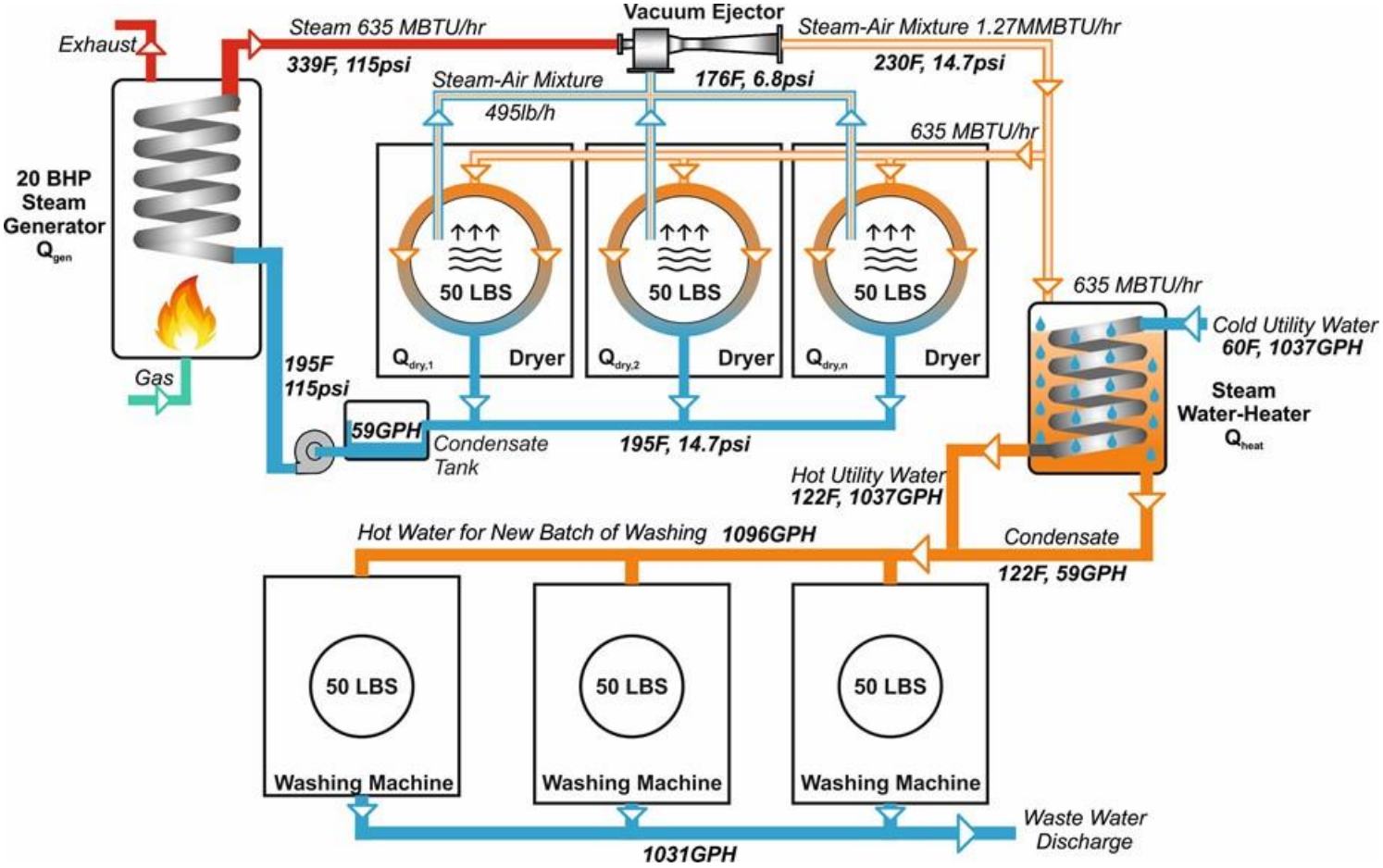
Velocity profile of vacuum ejector



Ejector Nozzle

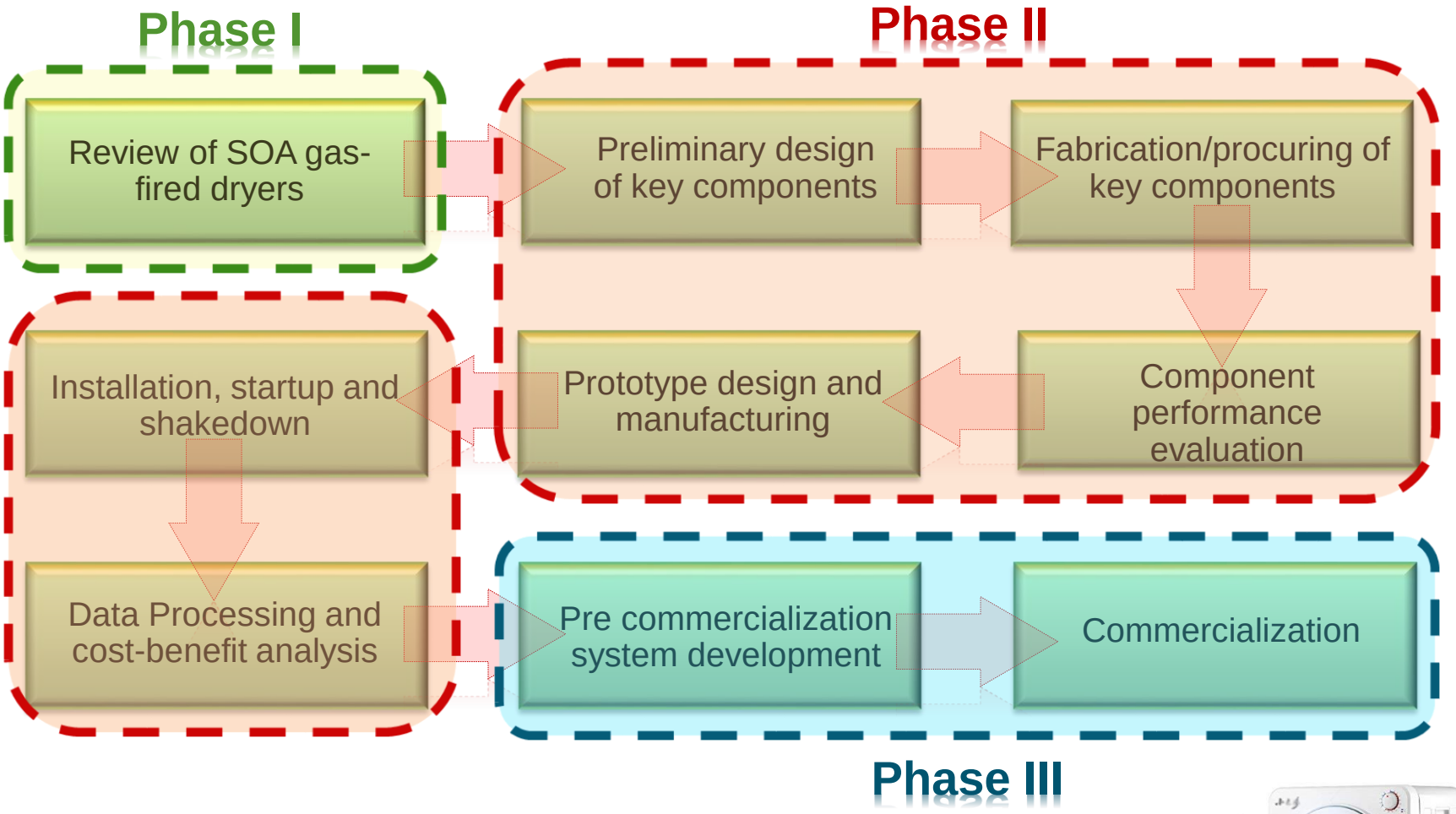
The steam ejector is the core of the technology that generates dynamic vacuum to intensify the drying process

Solution Approach



- The process heat (635 MBtu/hr) is fully recovered and utilized
- 60-100 GPH of hot water is harvested and re-used for washing
- Drying rate is 150 lb per load with drying time of 8 min

Solution Approach



Phase II of the project will focus on two major sectors:

1. Commercial and industrial dryer
2. Residential dryer (multifamily and single family machines)

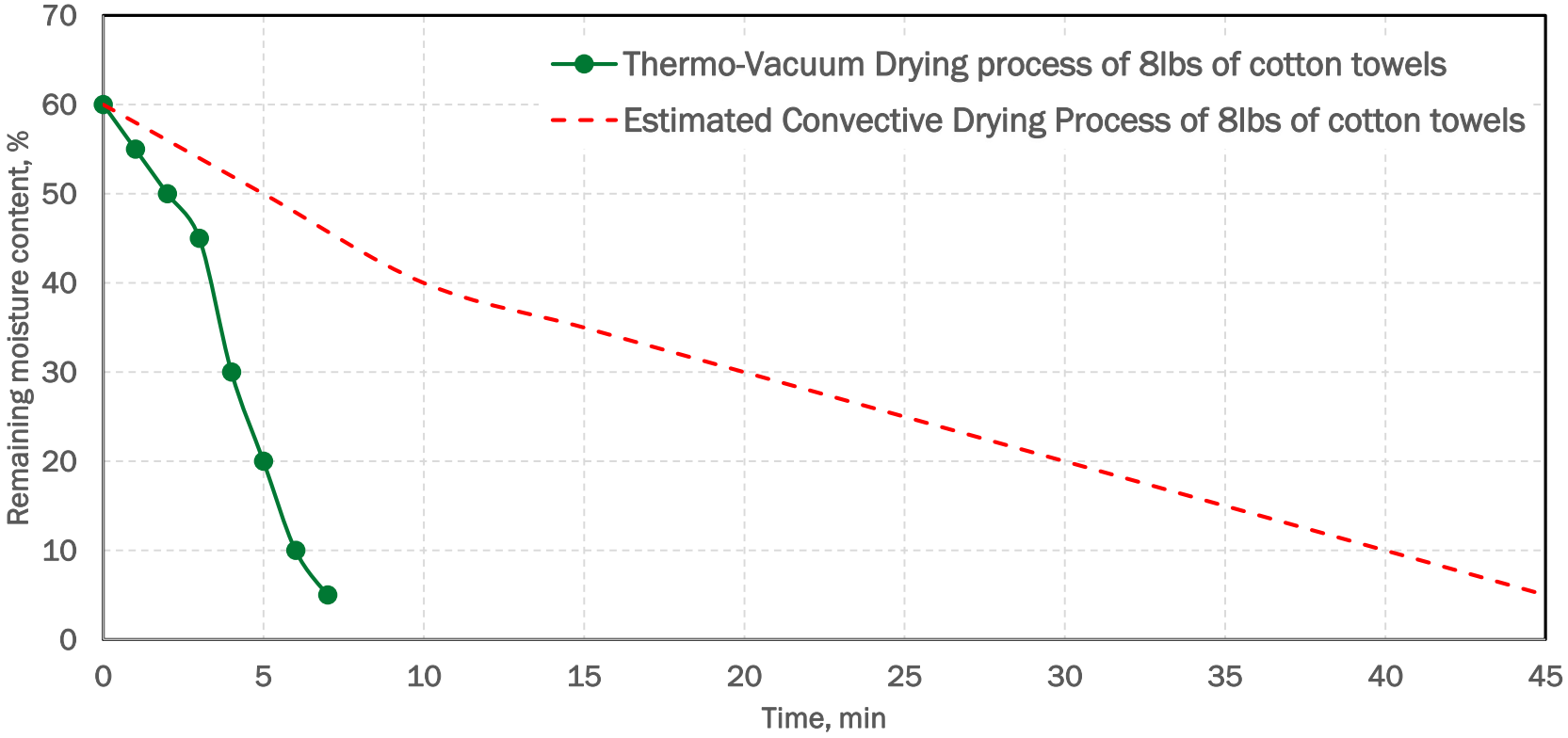
Project Impact

An improved clothes drying technology:

- Aligned with BTO goal to develop energy-efficient technology to effect 45% energy savings by 2030 compared with 2010 technologies
- Simplified design, improved reliability and durability
- 3-5 times longer life of laundry
- 1.5 times higher combined energy factor (CEF)
- Easy industrial and commercial retrofits
- At least 0.2 Quad/year energy savings
- Opportunities to create 1,000+ new jobs
- Implications for additional processes for power generation, waste heat recovery, energy and water harvesting

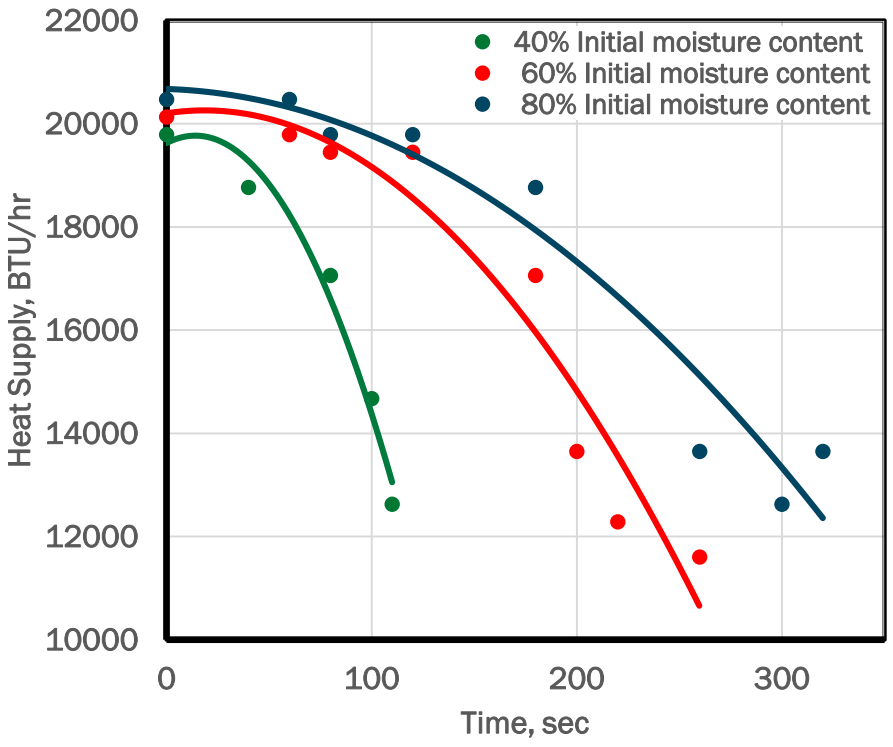
How would you feel if your laundry completely dried in 5-10 minutes without exposing to high temperature?

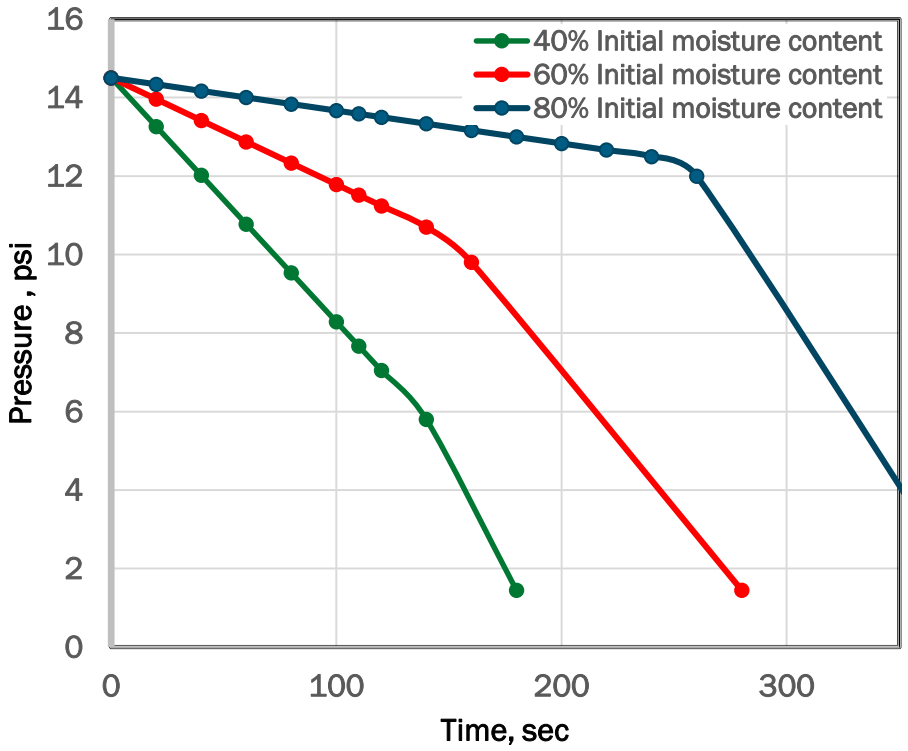
Proof of Concept



- Conventional drying (air convection) method requires higher drying time and energy input to heat the clothes, heat the air and power the air blower
- The drying rate depends on the moisture content in the clothes

Proof of Concept





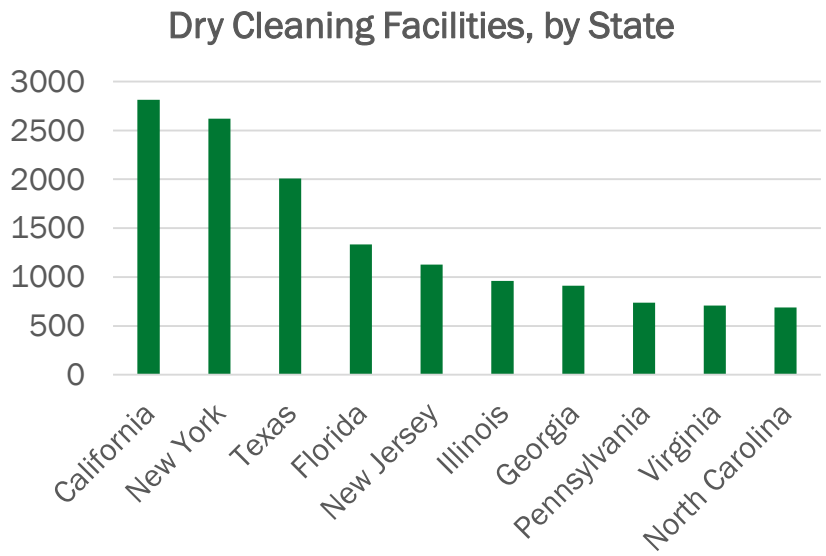
- Supplied heat is fully utilized for maintaining dynamic vacuum conditions inside the drum and clothes heating
- Heat consumption decreases as moisture content in the clothes decreases

Overview of Market Study

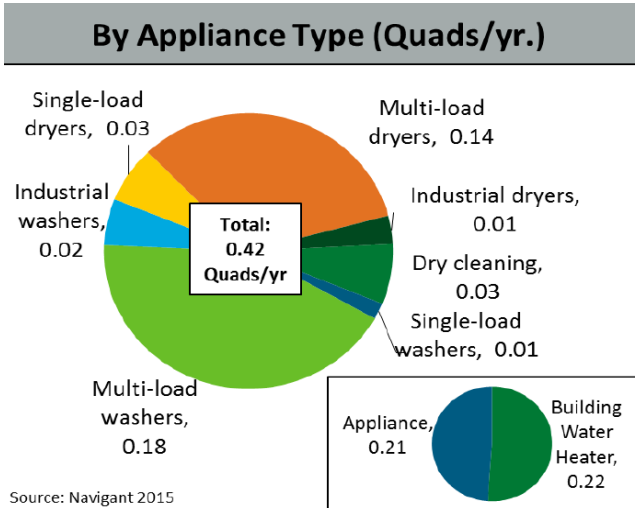
- Commercial and industrial laundries include a variety of facilities and services
- Each site may have from one up to dozens of dryer units
- Wide spectrum of the drying items of different moisture content

Facility Type	Typical Dryer Capacity, lb	Estimated No of Facilities	Source
Multifamily housing	18-50	300,000 - 600,000	DOE/Navigant Consulting (2009)
Coin-operated	30-120	29,500	Coin Laundry Association (2019)
On-premise laundries*	50-170	60,000	DOE/Navigant Consulting (2009)
Dry cleaners	50-170	22,558	US Economic Census (2012)
Industrial operations	200+	2,364	US Economic Census (2012)
*includes hospitality, health care, correctional facilities, live-in institutions, etc.			

Overview of Market Study



Natural gas is estimated to account for 88% of energy consumption, largely to supply hot water for washing and hot air for drying. The remaining 12% of energy use is electric



Overview of Market Study

- Expected service life will depend on the particular application but is estimated to be between 7–14 years, with a wide range expected.
- Energy breakdown of a typical dryer cycle is roughly 90% for air heating and 10% for motor operation

- **Manufacturers within the US market include**
  - Alliance Laundry Holdings (18–200 lb)
  - American Dryer Corporation (30–400 lb)
  - Braun (300–800 lb)
  - Consolidated Laundry Machinery (165–1,200 lb)
  - Continental Girbau Inc. (20–200 lb)
  - Dexter (20–120 lb)
  - Electrolux (small MF)
  - GE (small MF)
  - Pellerin Milnor (30–750 lb)
  - Wascomat (20–135 lb)
  - Whirlpool (small MF)

Stakeholder Engagement

- **Development of the technology**
  - Participation of commercial laundries
  - Industrial visits and collaboration meetings
  - Analysis of industrial energy data
- **Collaboration with end-users**
  - Site visits and preliminary data analysis
- **Collaboration with OEM**
  - Strong interest in efficiency improvement
- **Meetings with experts at technical platform**
  - ASHRAE (TC 1.3)
  - ASME (IMECE, SHTC)

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CLM CONSOLIDATED LAUNDRY MACHINERY

Remaining Project Work

- Market assessment of clothes drying industry
- Preliminary design of components
- Fabrication and purchase of components
- Component level performance evaluation
- Prototype design and manufacturing
- Installation, startup and shakedown
- Performance data collection
- Cost benefit analysis
- Final reporting

Thank You!

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REFERENCE SLIDES

Project Budget

Project Budget: $1.8M, $100K cost share
Variances: None
Cost to Date: $50K
Additional Funding: None

Budget History					
FY 2018 (past)		FY 2019 (current)		FY 2020 (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
		$600K	$33K	$600K	$33K

Project Plan and Schedule