

# WPI

## Reducing Carbon Footprint of Energy-Intensive Industrial Drying by Novel Drying Technologies

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14th Annual WPI Sustainability Project Competition (2022)

Aligns with **Goal 9 (Industry & Innovation)** of United Nations Sustainable Development Goals

“retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes”

# Energy-Intensive Industrial Drying

## Paper



## Food



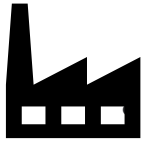
## Pharmaceutical



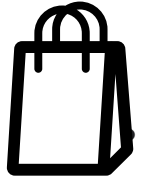
# Impact

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Are you aware how manufacturing a piece of paper impacts environment?



paper manufacturing → a quarter of the industrial energy used in the US



70% of the energy used in papermaking → drying paper.



Every day, around 2000 tonnes of CO<sub>2</sub> → dry paper.



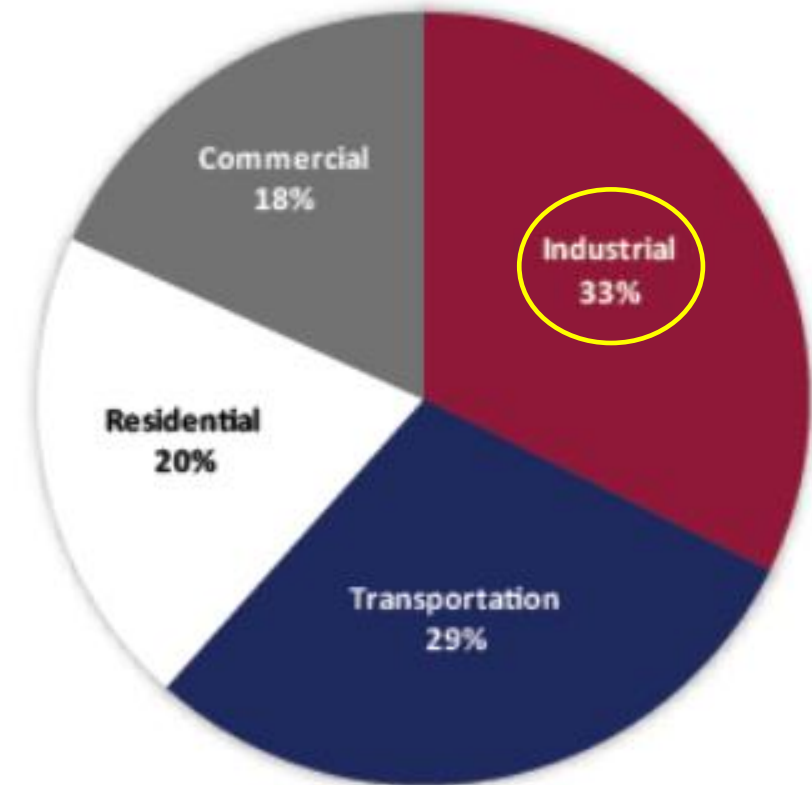
To capture the emission for one day, you must grow 100,000 trees for 10 years

# Impact

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- Industrial drying → 12% of the total energy used in manufacturing [1]
- About 40 percent of this energy can be saved with new drying technologies [2]

US ENERGY CONSUMPTION



[1] US Department of Energy, "Barriers to Industrial Energy Efficiency", Report to Congress, June 2015.

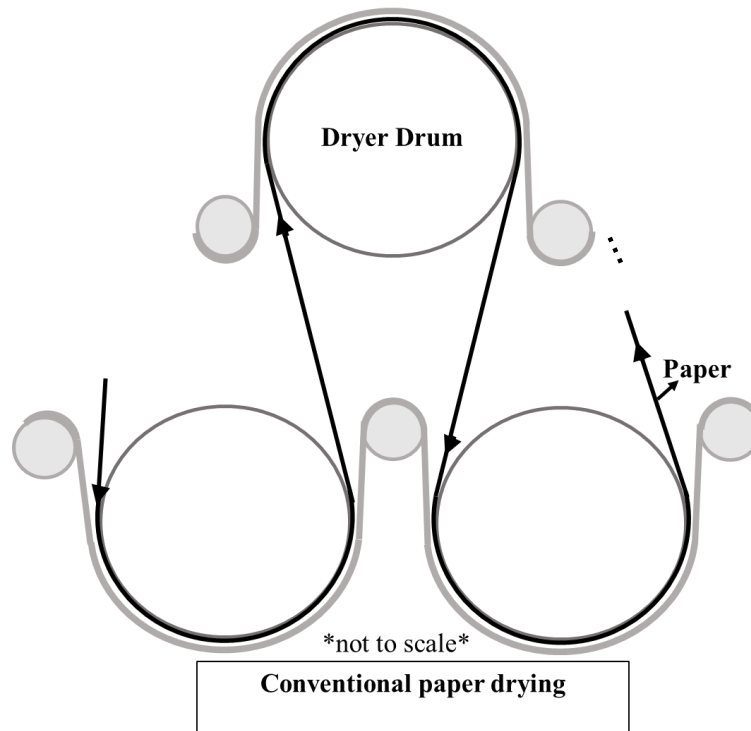
[2] US Department of Energy, *Quadrennial Technology Review*, September 2015, Table 6.2, p. 189.

# Conventional Drying Methods

## Paper



Wet paper sheet



# Conventional Drying Methods

**Food**



**Conventional  
Nozzle**

**Hot Air Flow**

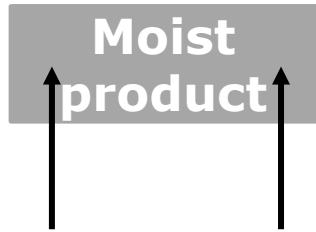


**Moist product**

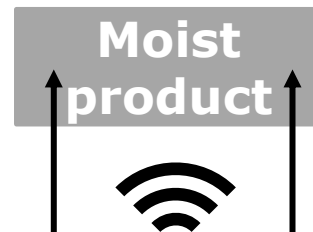


# Novel Drying Methods

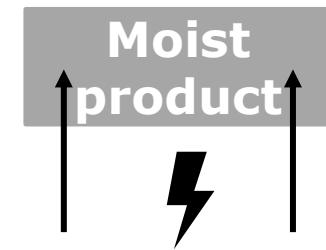
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**Slot Jet Reattachment  
(SJR) Nozzle**

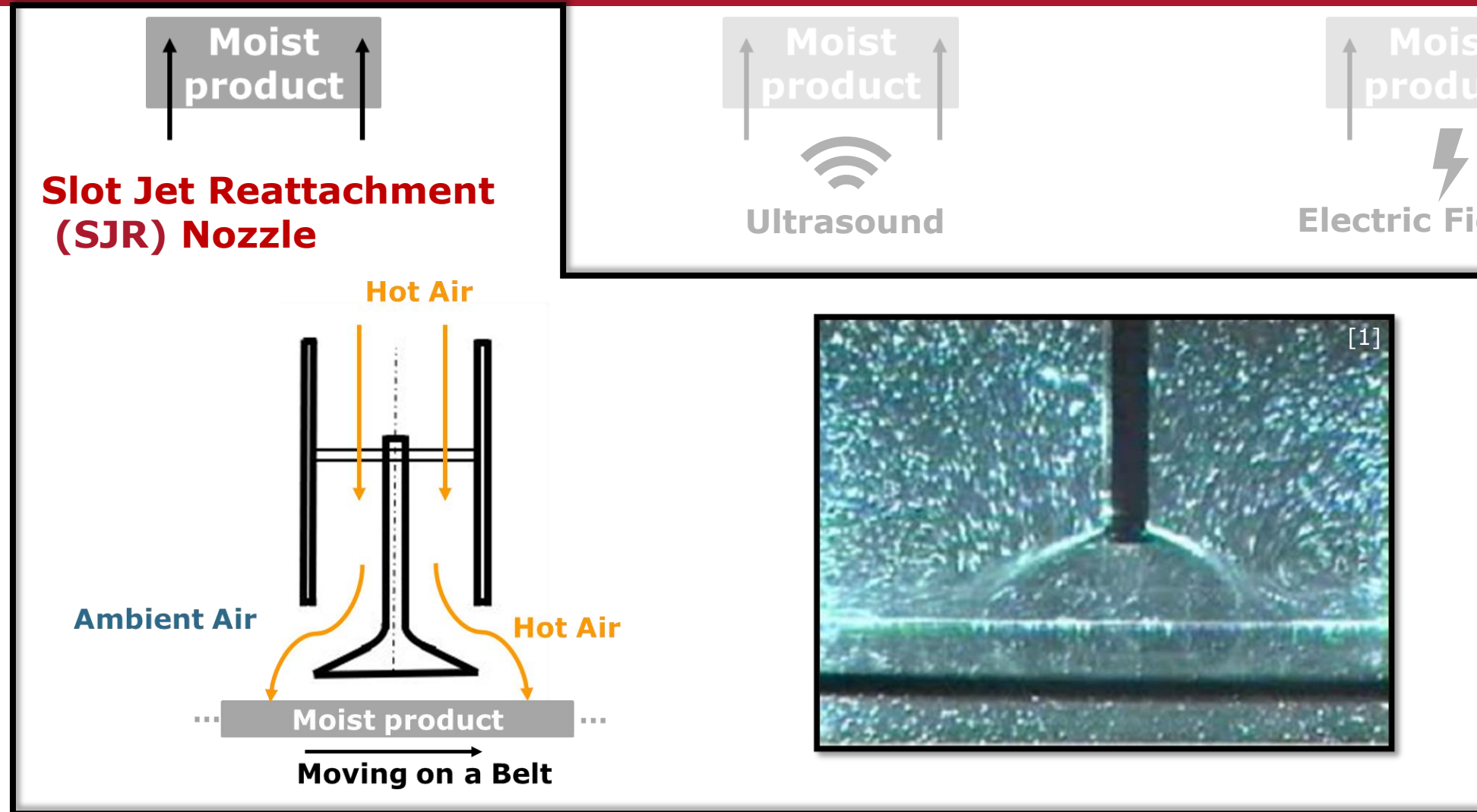


**Ultrasound**



**Electric Field  
(Dielectrophoresis )**

# Novel Drying Methods



[1] Narayanan, V., Seyed-Yagoobi, J., and Page, R. H., 1998, "Heat transfer characteristics of a slot jet reattachment nozzle," Journal of heat transfer, 120(2), pp. 348-356



# Novel Drying Methods



Slot Jet Reattachment  
(SJR) Nozzle



Ultrasound



Electric field



Video: Ultrasonic drying of a cloth with multiple piezoelectric transducers [4]

[4] U.S. Department of Energy. 2021. *Ultrasonic Clothes Dryer- No Heat Needed*. [online] Available at: <[https://www.youtube.com/watch?v=9oG9mIUHMG&feature=emb\\_logo&ab\\_channel=U.S.DepartmentofEnergy](https://www.youtube.com/watch?v=9oG9mIUHMG&feature=emb_logo&ab_channel=U.S.DepartmentofEnergy)> [Accessed 26 February 2021].

# Novel Drying Methods



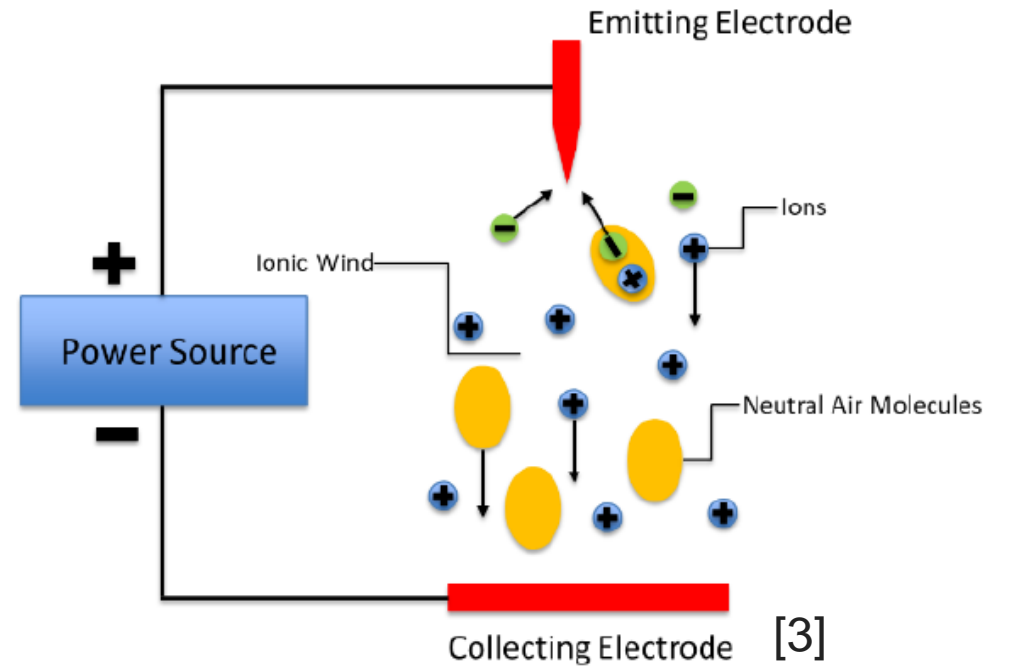
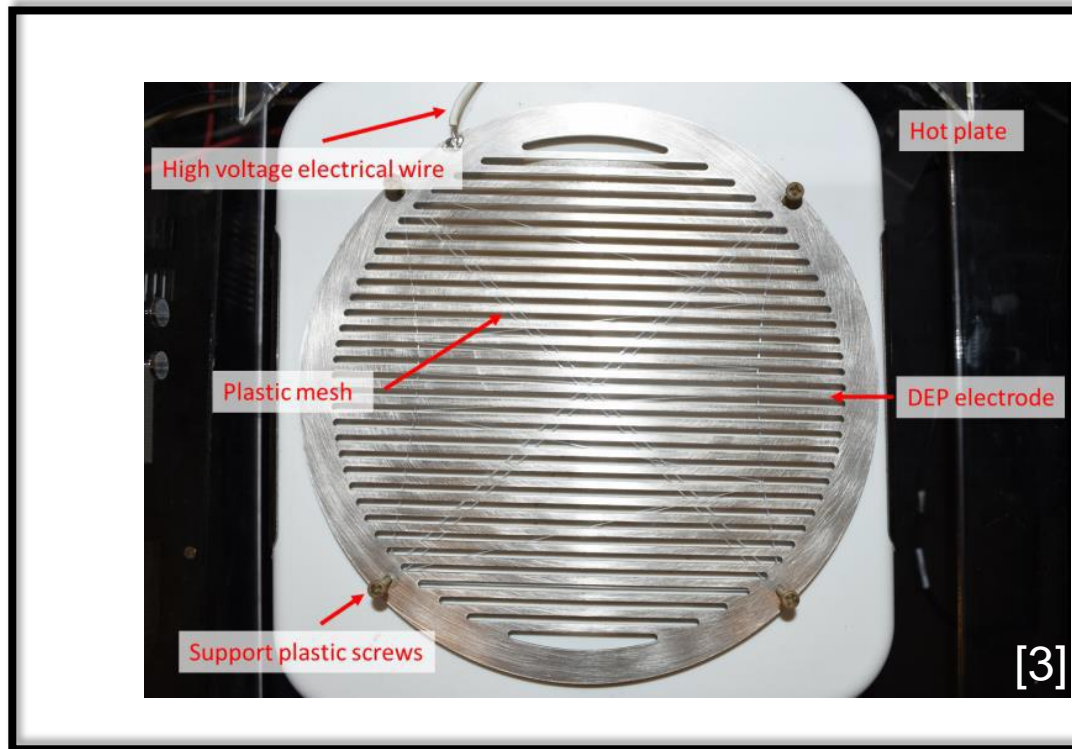
Slot Jet Reattachment Nozzle



Ultrasound



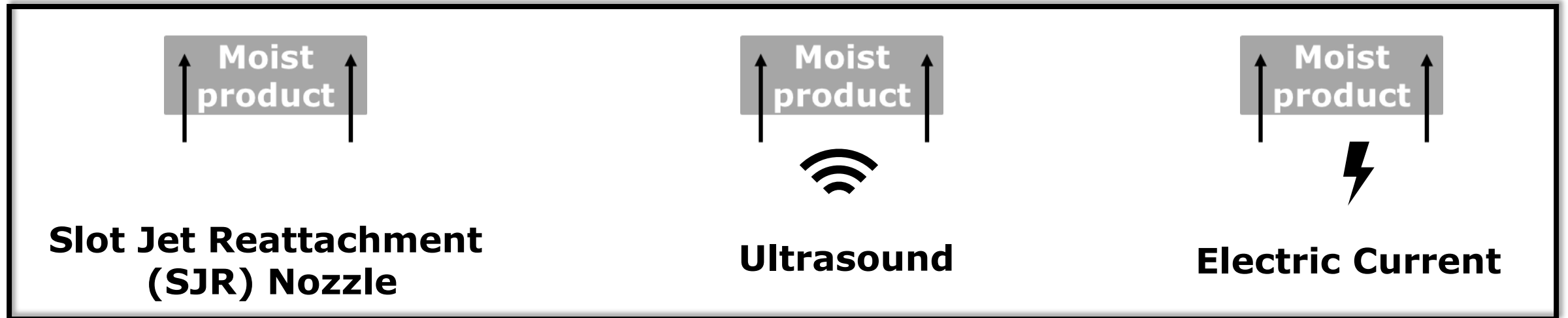
Electric Field



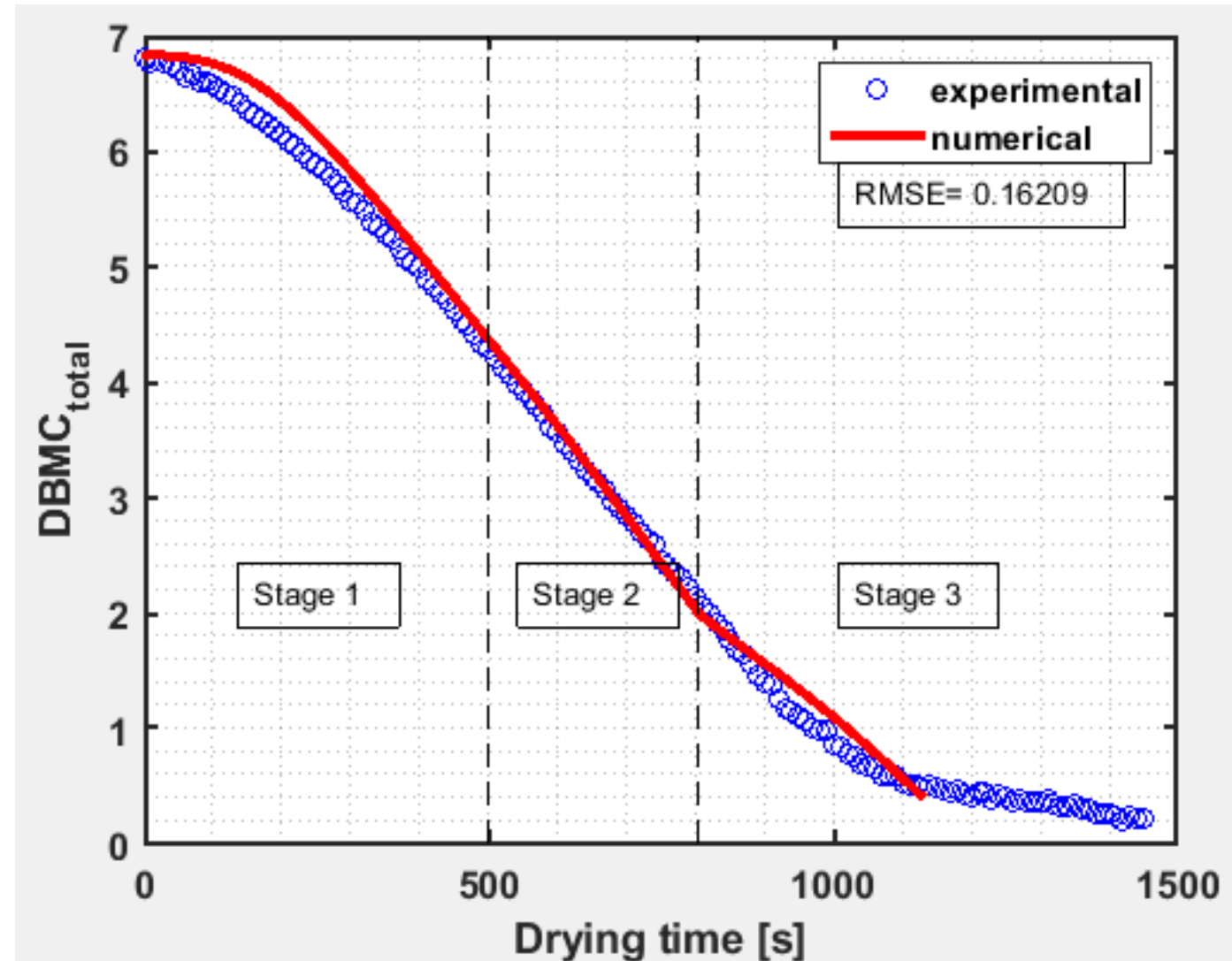
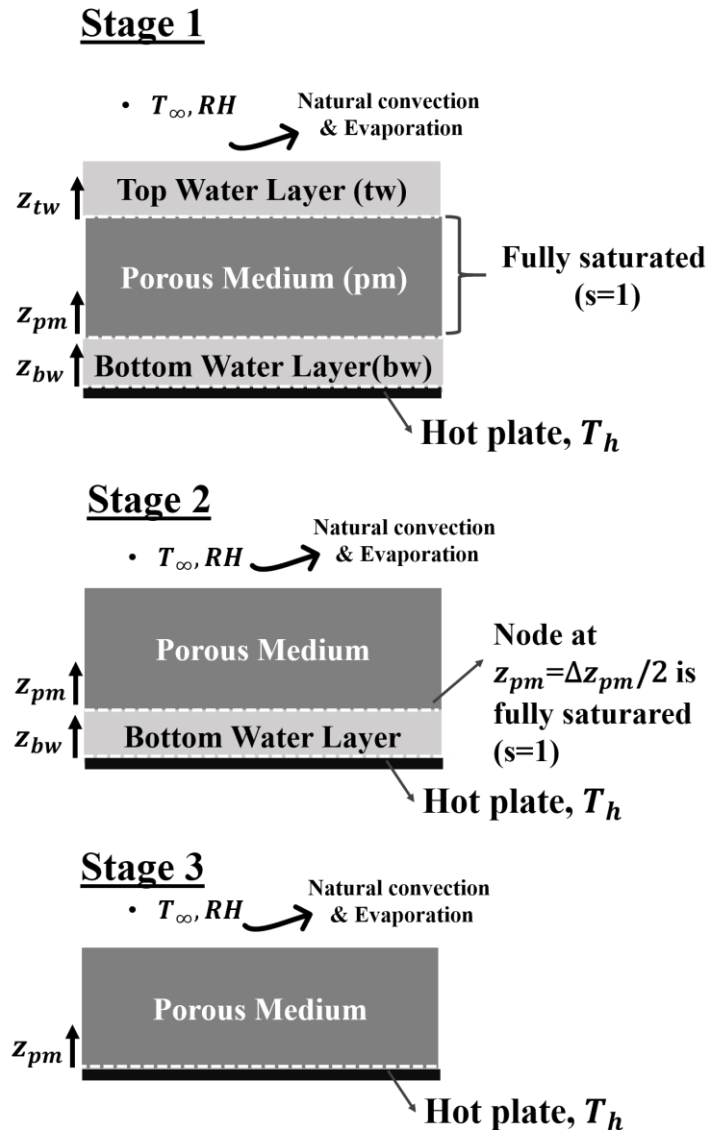
# What is my task?

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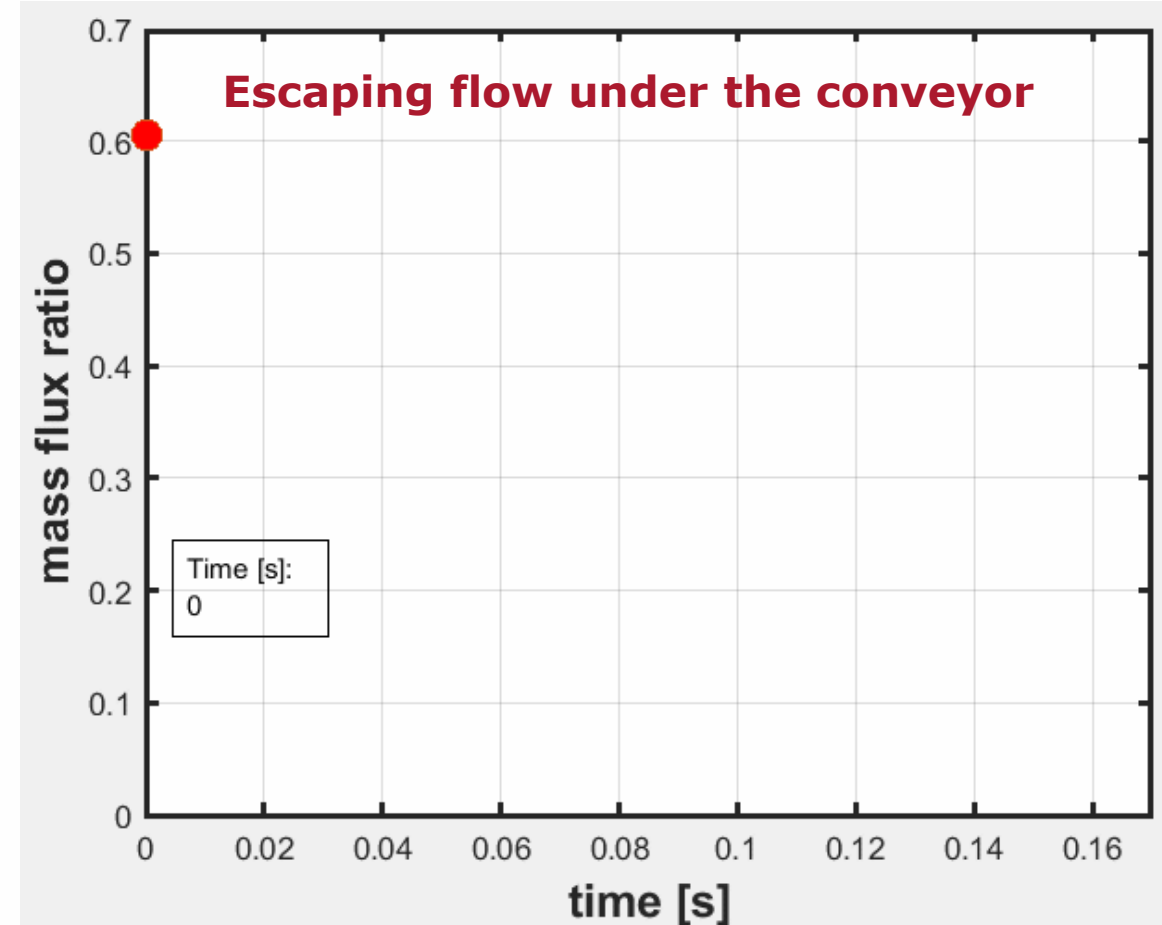
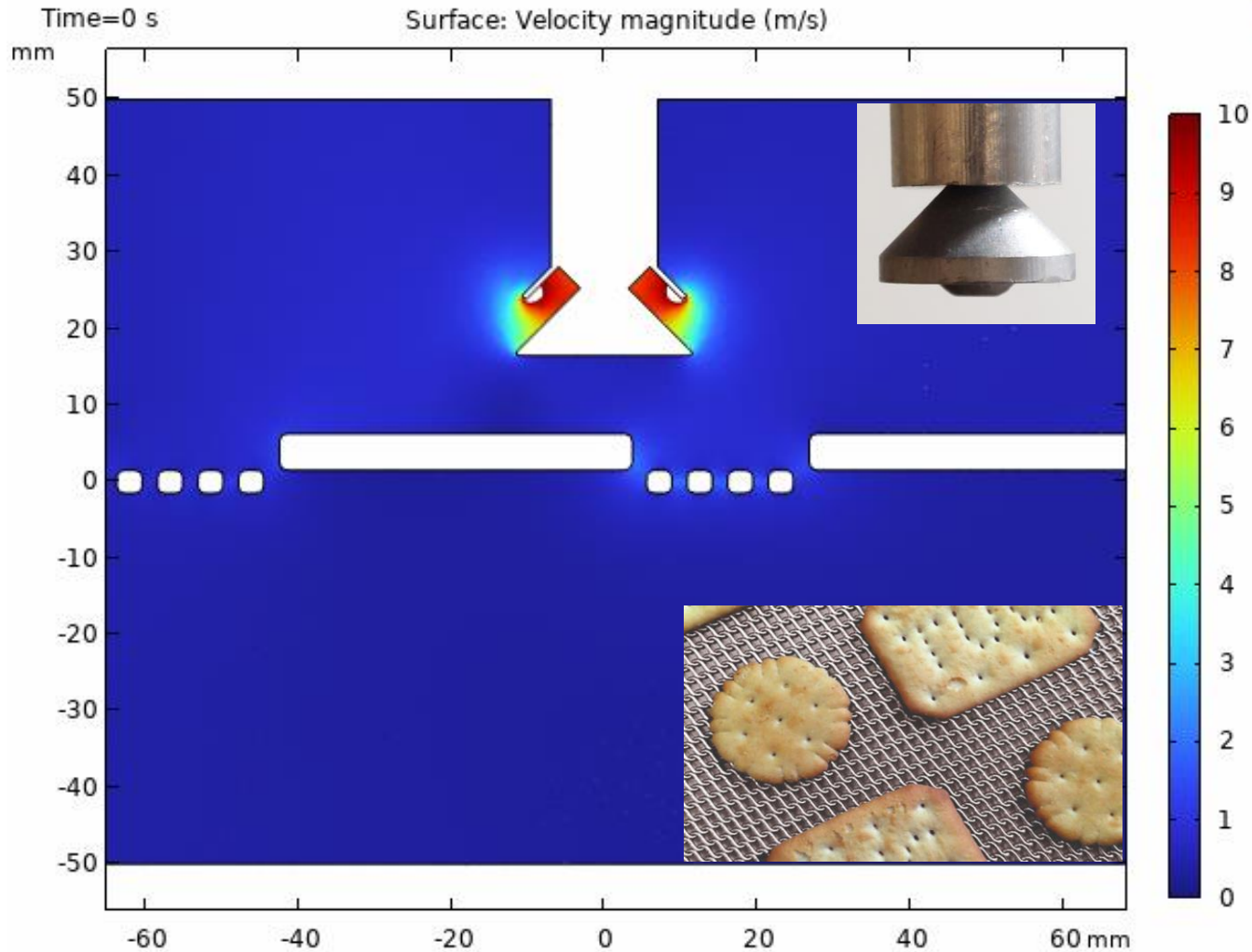
- Modeling and **heat transfer & fluid dynamics** analyses of moist products
- **Combining drying methods** to reduce energy use → system level analysis



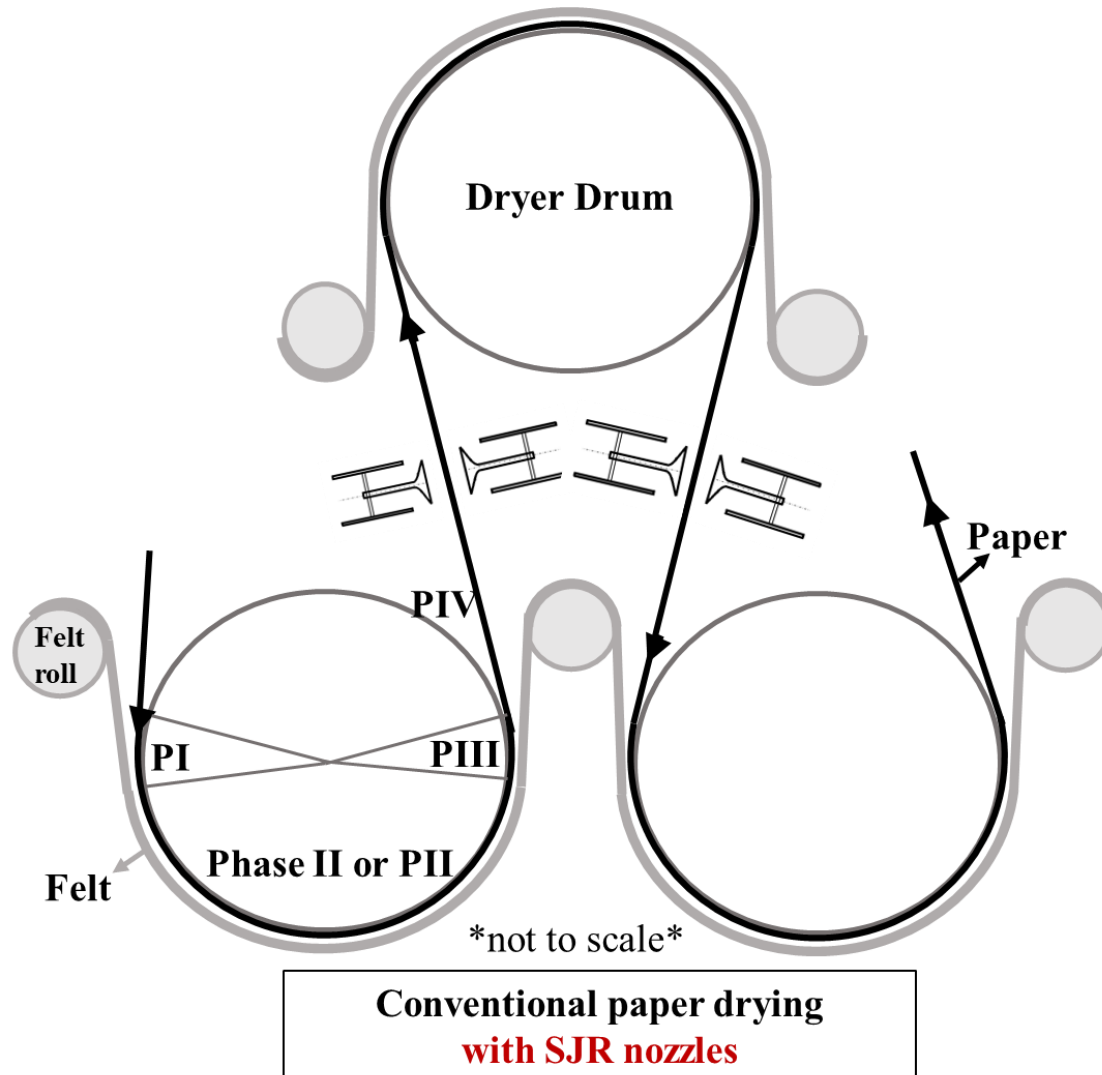
# Modeling of Drying for Porous Medium with Excess Water



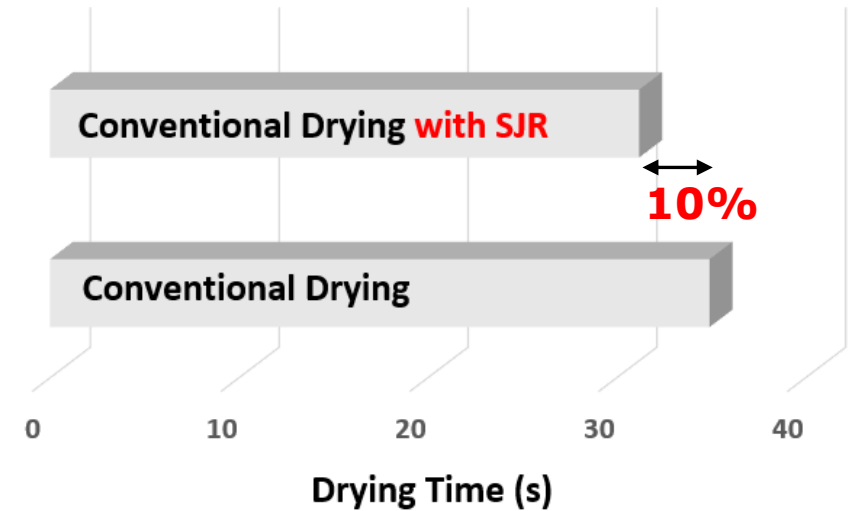
# Food Drying with Slot Jet Reattachment Nozzle



# Paper Machine with Addition of SJR Nozzles



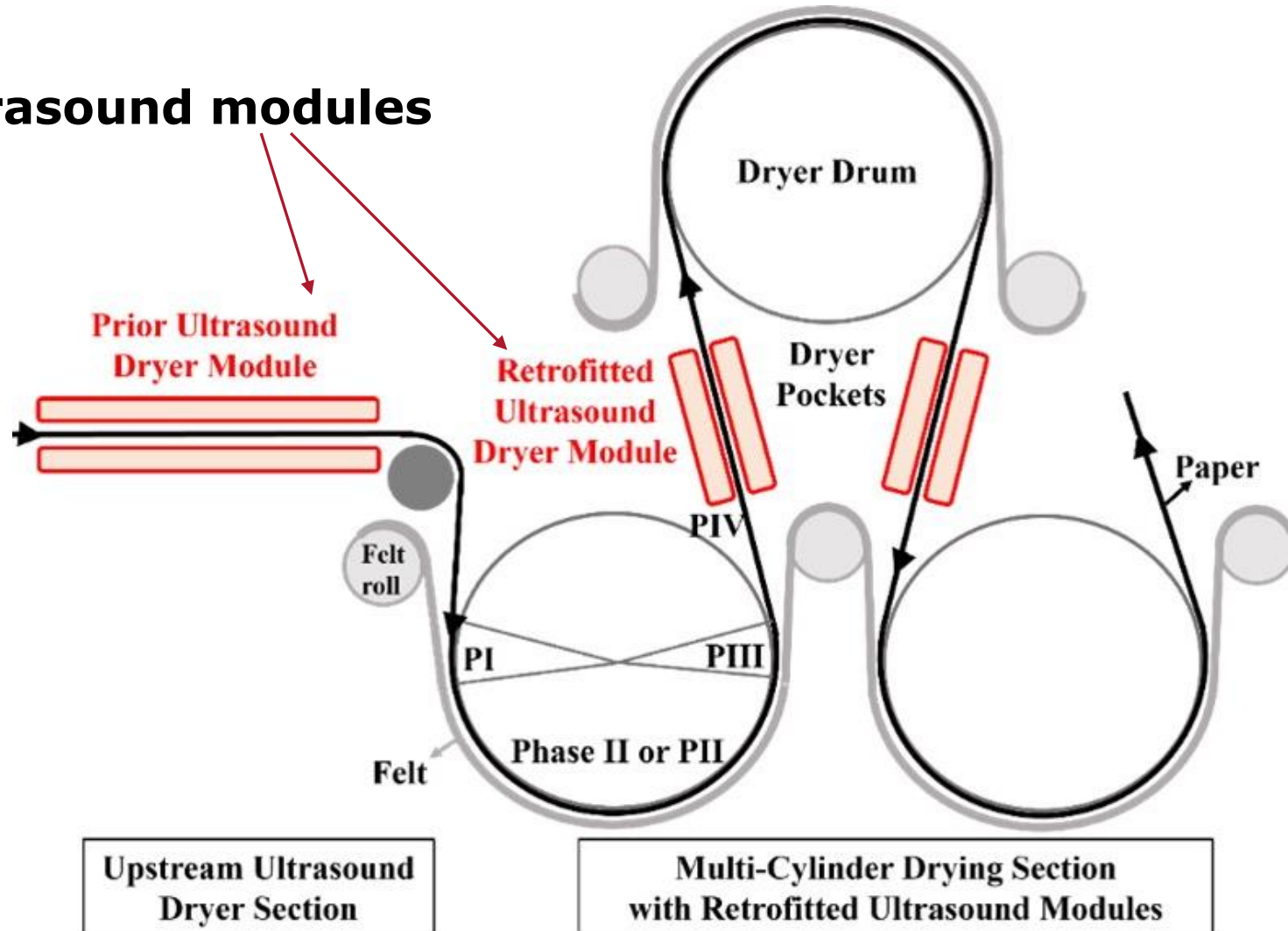
## Drying Time with and without SJR



- 9% net energy savings
- reduces the emissions by 200 tonnes per day.

# Paper Machine with Addition of Ultrasonic Drying

## Ultrasonic modules

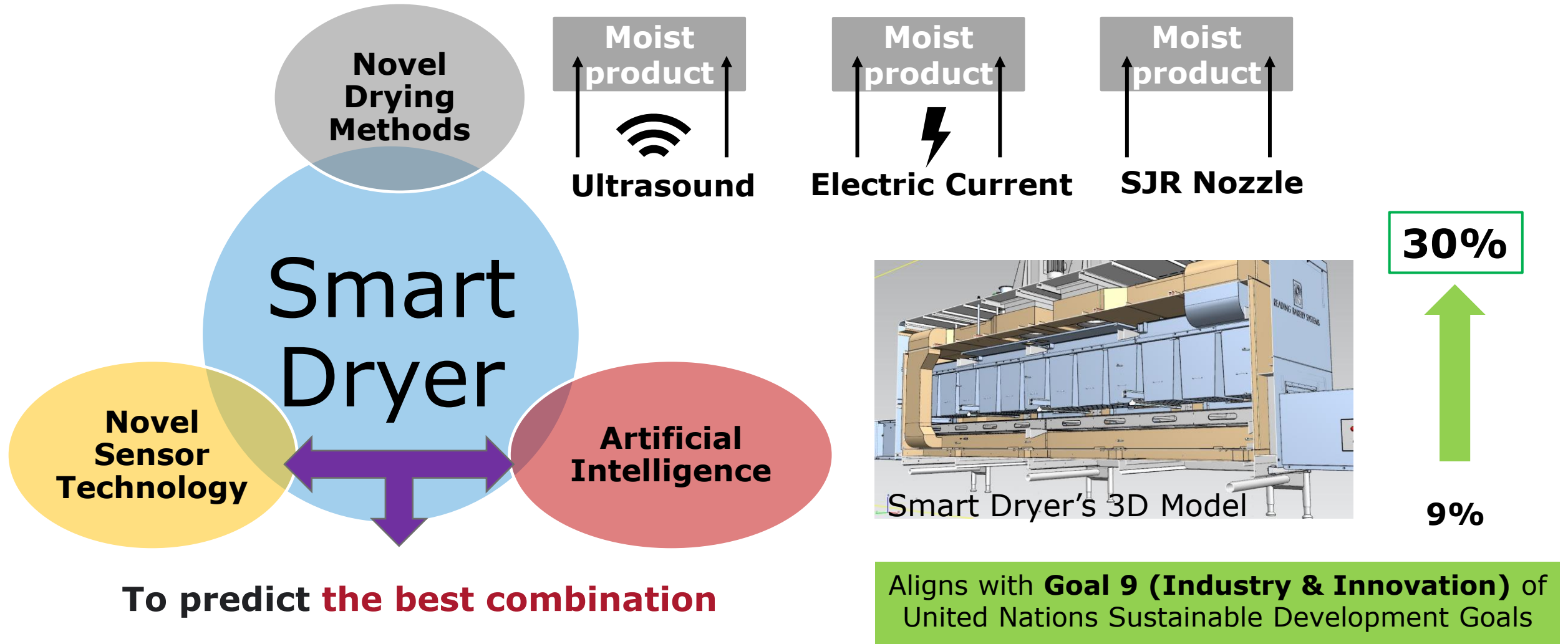


ultrasound dryer modules



15% enhancement

# Can all this be further improved?



To predict **the best combination**

Aligns with **Goal 9 (Industry & Innovation)** of United Nations Sustainable Development Goals



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**Thanks 😊**