2024 PROJECT PEER REVIEW

U.S. DEPARTMENT OF ENERGY
BUILDING TECHNOLOGIES OFFICE

BTO Peer Review:

High-performance Lower-cost Plastic Heat Exchangers

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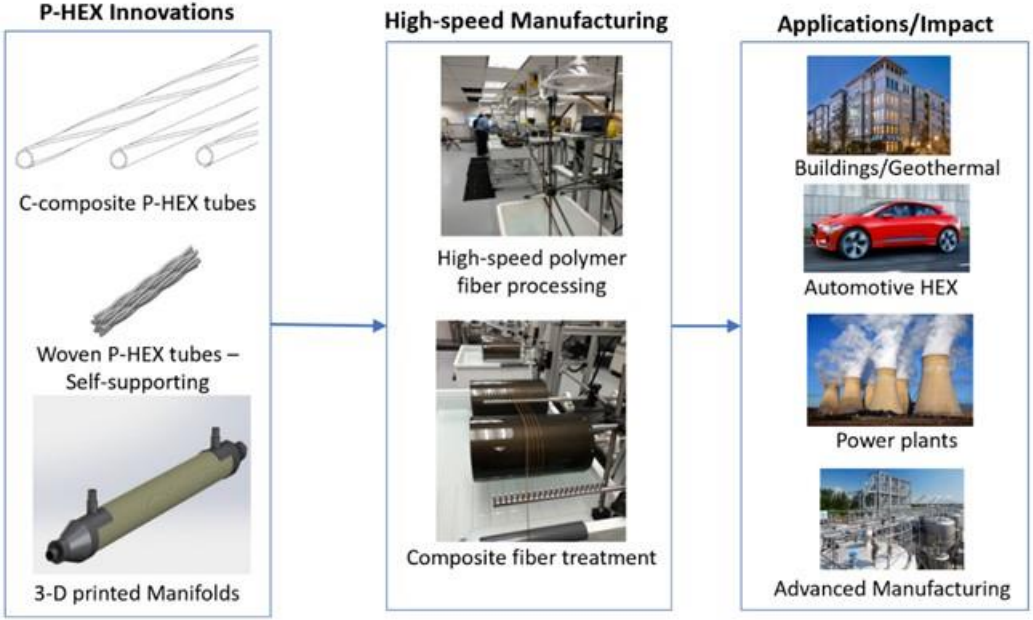

T2M Global, LLC
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Project Summary

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OBJECTIVE, OUTCOME, & IMPACT

- Scaleup the P-HEX technology by 10X.
- Validate high-speed manufacturing processes.
- Design market responsive P-HEX module for different market sectors.
- Increase P-HEX pressure capability to meet the need of these market sectors.
- Outcome and Impact: Validate feasibility of >70% recovery of waste heat → GHG reduction: up to 25%.

TEAM & PARTNERS

Trevi Systems: High-speed extrusion, P-HEX assembly and characterization.

OTS R&D: P-HEX heat transfer modeling to guide technology development and scale-up.

LARTA: Commercialization assistance.

STATS

Performance Period: 06/28/2021 – 08/21/2024

DOE Budget: $1,350k, Cost Share: $0

Milestone 1: 10 kW P-HEX prototype assembled ✓

Milestone 2: P-HEX Testing in real environment ✓

Milestone 3: Validate advanced P-HEX design ✓

Problem

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Issues:

- On average, more than half of a household's annual energy consumption is for heating and air conditioning.
- 25 quads of total low-level heat, ~$200 billion, are wasted annually in the U.S.
- Metallic heat exchangers are prohibitively expensive for low-level heat.
- Lack of heat recovery contributes to poor ventilation, increasing the risk of sick building syndrome and heightening vulnerability to airborne pathogens.

Opportunity:

- Advanced High-performance Plastic Heat Exchanger (P-HEX) technology can efficiently recover this wasted heat at low costs for reuse.

Alignment and Impact

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- **Increase Building Energy Efficiency:** P-HEX cuts building energy use by up to 25%.
- **Cost Benefits to Residential Consumers:** Recovered heat → $2 billion/yr savings.
- **Accelerate Building Decarbonization:** Potential to reduce GHG emissions by 25% using P-HEX.
- **Resiliency to Climate Change:** Improved reliability of heating and cooling systems at lower cost.
- **Accelerate Building Electrification:** Natural gas savings support intermittency of solar and wind.
- **Transform the Grid Edge at Buildings:** Energy savings contribute to grid resiliency.
- **Prioritize Equity, Affordability, and Resilience:** Attractive for deployment in disadvantaged communities. P-HEX energy savings are most impactful for low-income families.

Project Deliverables

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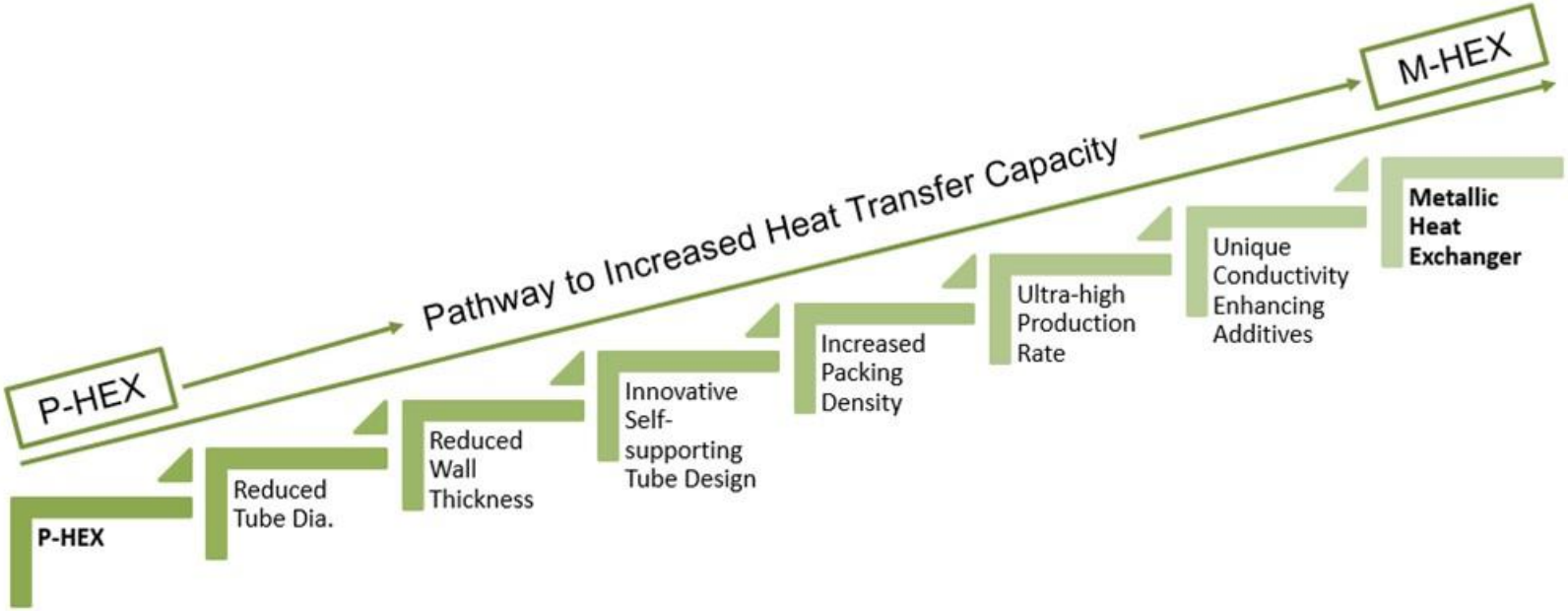
- 10X Scaleup; 1-kW → 10 kW-Class P-HEX, >70% heat recovery, 10 psi pressure capability.
- Scaleup high-speed manufacturing process; laboratory → bench scale.

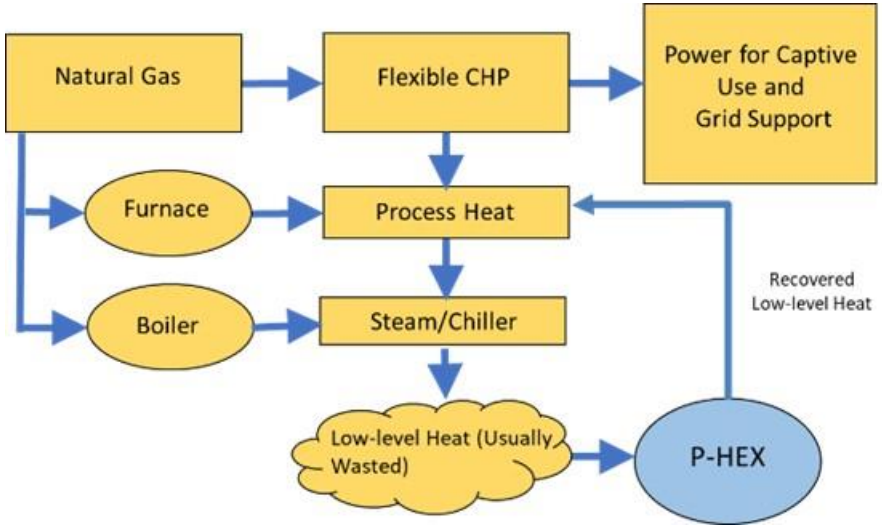
- Commercialization Plan - Create Pathway for technology scaleup to attract investment.
- DEI Plan – Outreach to disadvantaged communities.
- Final Project Report - Project accomplishments and recommendations.

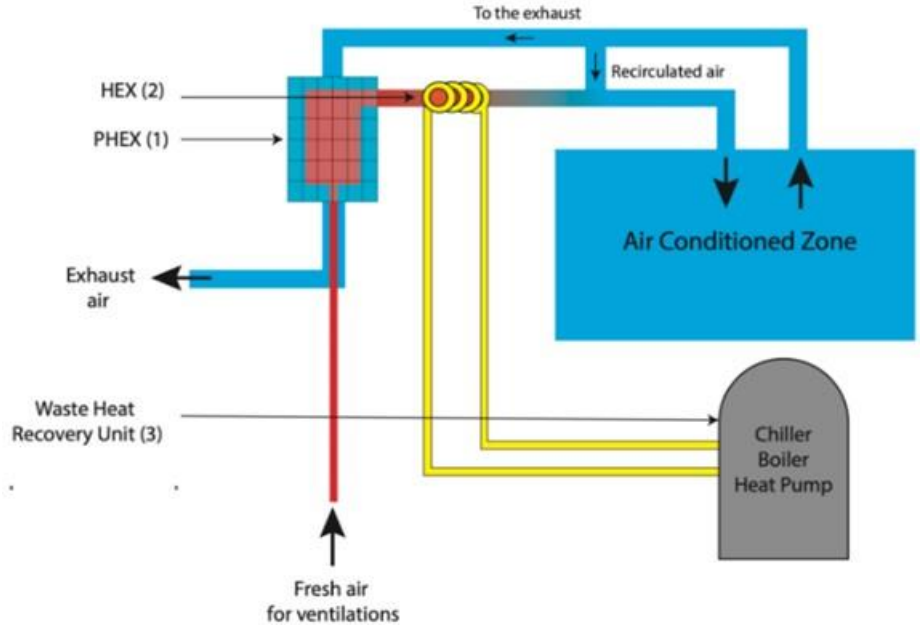
Approach to Low Temperature Heat Exchange



- Reduce Material Costs: Cheaper material; Increased packing density → less material use.
- Increase Heat Recovery: High performance additives boost heat transfer.
- Improve Production Efficiency: Ultra-high production rates enable faster manufacturing.

Relevant Sectors: Commercial and Residential





Near-term Targets are Building Heating/Cooling Systems:
Cross-cutting integration with HVAC, boilers, and furnaces.

Increasing Packing Density for P-HEX

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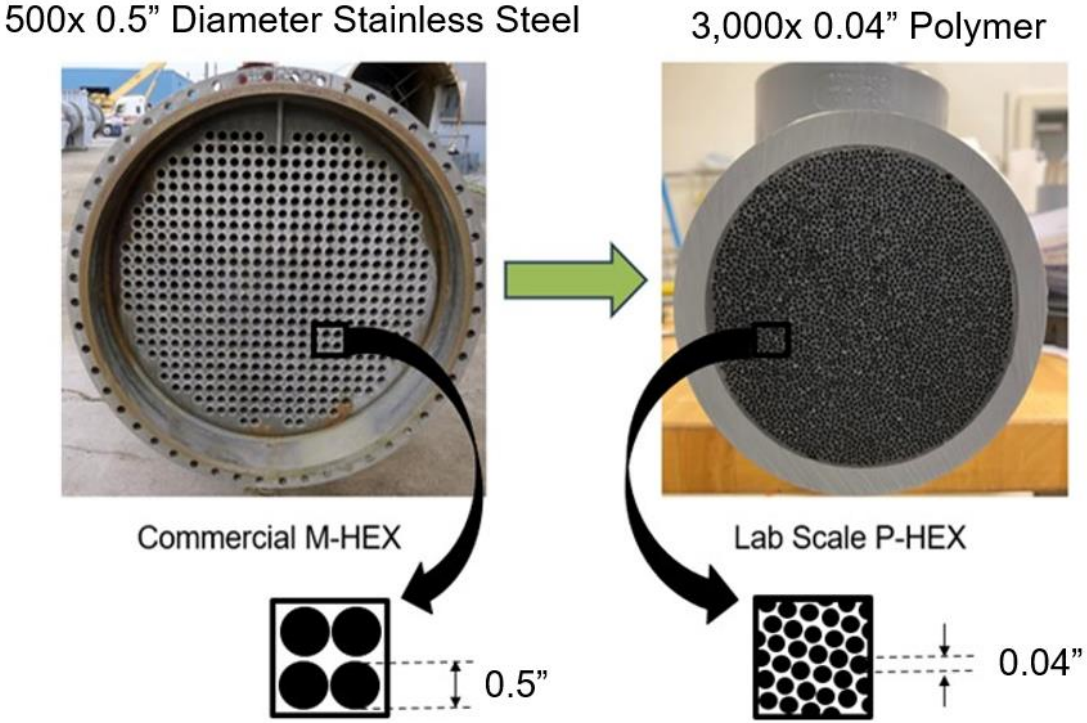

Novel Process: Tube Diameter Reduced by >10X:
Light-weight P-HEX weighs 90% less than M-HEX.

Technical Challenges

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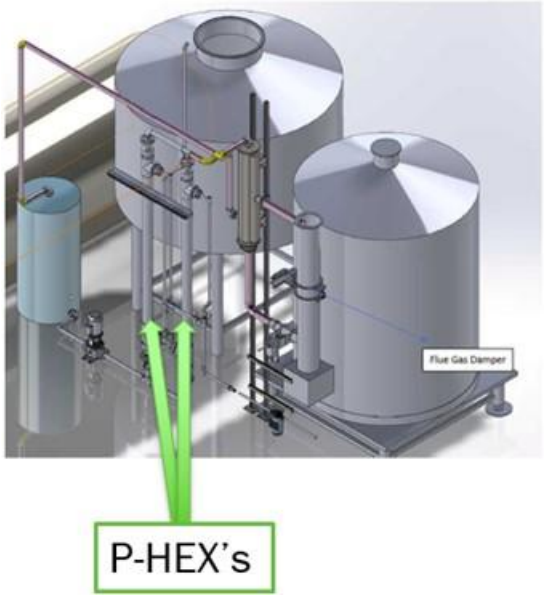
- **Low Manufacturing Yield**: Formulation for high-speed extrusion and tube assembly.
  - ➢Mitigation: Selection of conductivity enhancers and sealants.
- **Poor Thermal Performance:** Undesirable bypass of process fluids.
  - ➢Mitigation: Self-aligning tube geometry for enhanced heat transfer, rapid assembly.
- **Pressure Capability:** Thicker walls increase heat transfer resistance.
  - ➢Mitigation: Composite formulations for enhanced heat transfer.
- **Host Site Requirements:** Constrained access, variable heat duty.
  - ➢Mitigation: Modular design for rapid deployment, efficient control system.

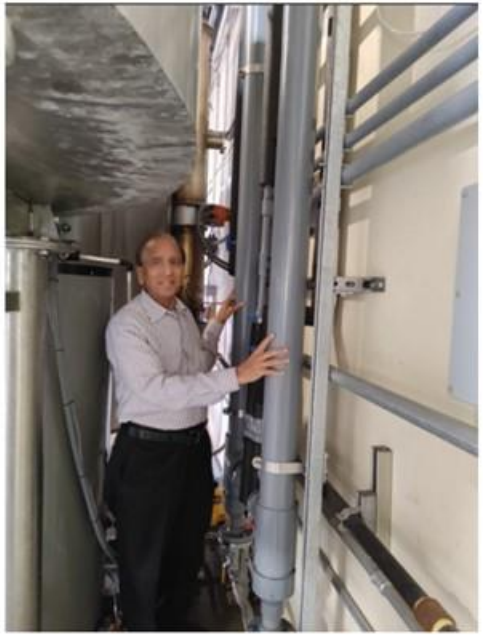
Stakeholder Engagement for Market Transformation

- **Technology Advisory Committee (TAC):** Representatives from different market sectors, utility companies, research institutions, sponsors, and investors.
- **TABA:** Engaged with highly skilled experts from LARTA Institute for near-term markets, financing, and IP.
- **DEI Communities:** Engaged multiple stakeholders in California for outreach of P-HEX benefits.

Multiprong Approach for Stakeholder Input:
Technical guidance, commercialization experts, and DEI community.

P-HEX Application: Validation in a Real Environment





High Thermal Performance P-HEX Developed and Validated:
Performance on par with M-HEX proven in liquid-to-liquid applications.

Evaluation of Heat Exchange

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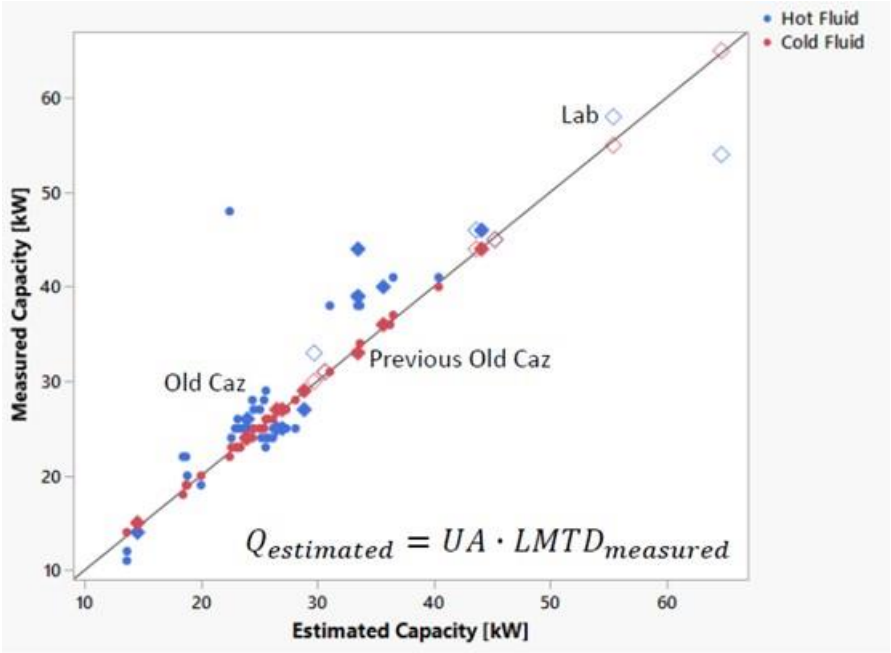
Hot Bore Side				Cold Shell Side					
Flow (GPM)	Temp In (°C)	Temp Out (°C)	Pressure Drop (PSI)	Flow (GPM)	Temp In (°C)	Temp Out (°C)	Pressure Drop (PSI)	Heat Exchanged (kW)	Effective ness (%)
5	90.4	74.5	17	1	15.2	86.4	3	18.6	94.3
5	83.5	54.8	14	2	15.2	74.2	5	30.9	86.4
5	71.6	44.1	20	3	14.8	60.5	6	35.8	80.3
2.9	70.8	55.1	12	1	15.2	66.8	1	13.5	81.7
2.9	78.9	39.5	15	2	15.2	68.1	4	27.7	82.9

Highly Promising Heat Recovery Performance:
>80% heat transfer efficiency and up to 35 kW heat exchange.

Evaluation of P-HEX Durability

Stable P-HEX Operation During Five Month Test Period:
Exceeded project performance targets with four flow regimes.

Modeling of P-HEX Thermal Performance



Excellent Match Between Estimated and Measured Capacity:
The modeling tool will guide P-HEX technology scaleup.

Lessons Learned

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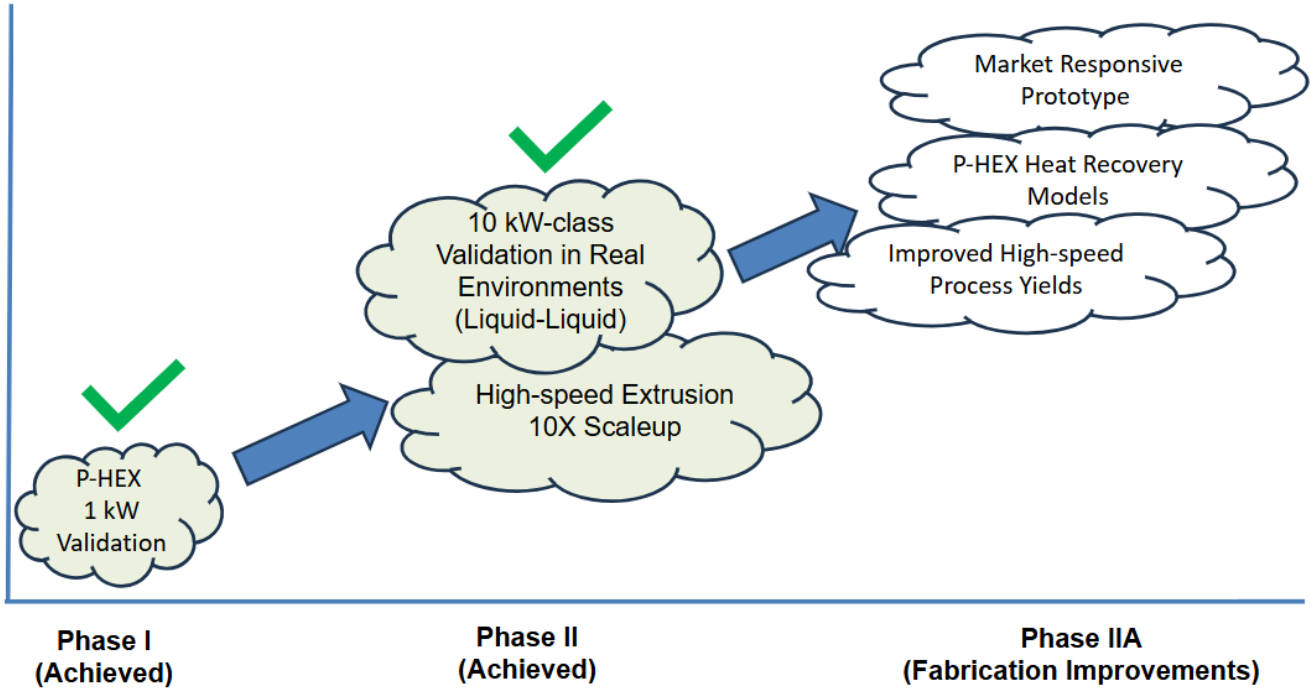
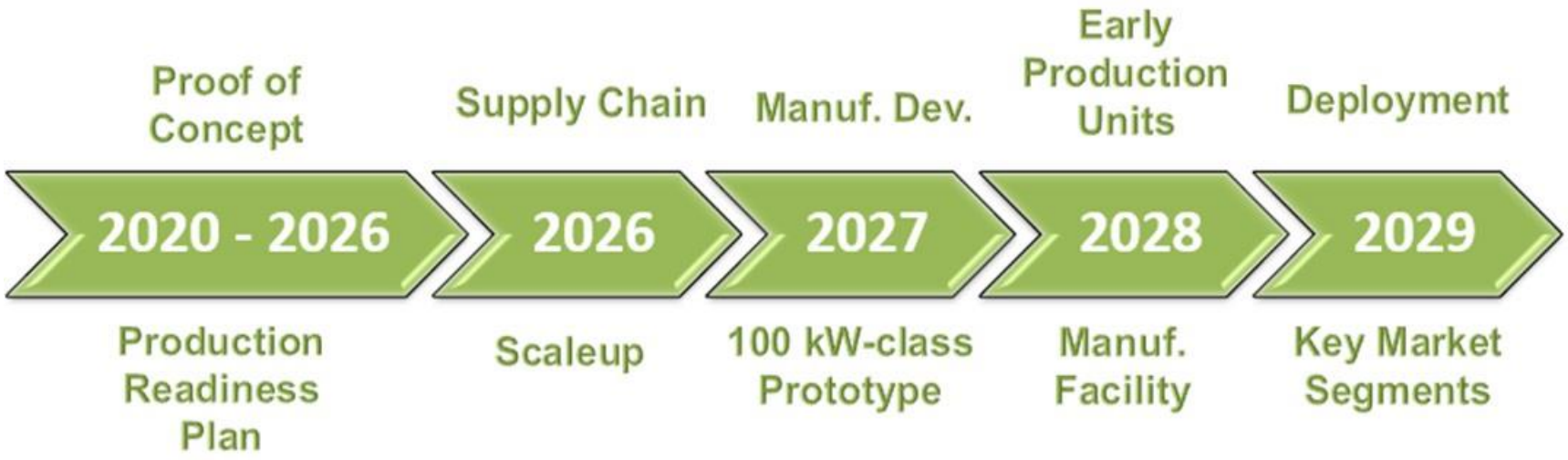
- **Yield in High-Speed Manufacturing:** Variability in composite formulations has a strong impact on the quality of P-HEX products and manufacturing efficiency.
  - ➢Improved sensors with real-time adjustments to increase manufacturing yield.
- **Heat Supply and Demand Mismatch:** Waste heat availability doesn't always align with demand.
  - ➢Demand-side management for thermal load ramping or thermal storage.
- **Handling High Temperature Waste Heat:** Some waste heat sources may be outside of the P-HEX operating window.
  - ➢Guard M-HEX to pre-condition waste heat for safer operation of P-HEX.

Future Development Efforts



Planned Improvements Based on Lessons Learned:
Improve manufacturing yield from 30% → >60%.

P-HEX Commercialization Pathway



Highly Skilled TABA Consultants Guiding Commercialization:
Develop market responsive prototype at lower cost.

Thank you

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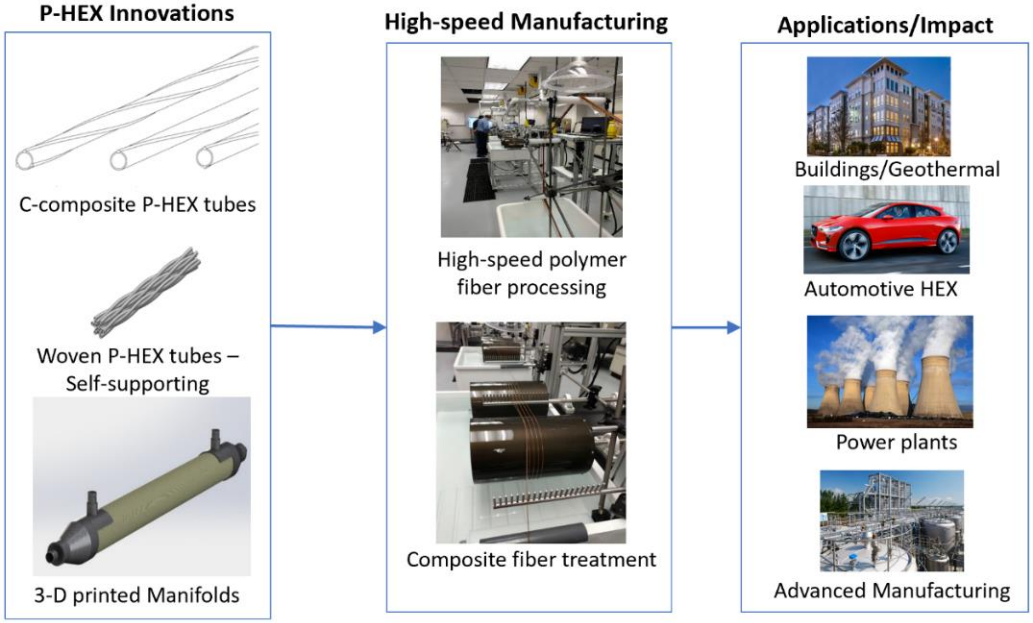

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Reference Slides

Project Execution

	FY2022				FY2023				FY2024			
Planned budget												
Spent budget												
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Past Work												
Milestone A: A homogenous composite formulation ready for extrusion												
Milestone B: High performance tubes for P-HEX with enhanced heat transfer capability (target 500% increase)												
Milestone C: Test report on baseline P-HEX in real environment testing												
Go/No Go Milestone: Validate low-cost 10-kW class baseline P-HEX design with >60% heat recovery effectiveness												
Milestone D: Description of improved fabrication process for Baseline and Advanced P-HEX												
Milestone E: Test report on P-HEX performance degradation Test report on P-HEX performance degradation												
Milestone F: Summary report on design improvements using developed models												
Milestone G: MW-class module design description for multiple market sectors												
Current/Future Work												
Milestone H: Final technical report as per DOE requirements												

Team

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