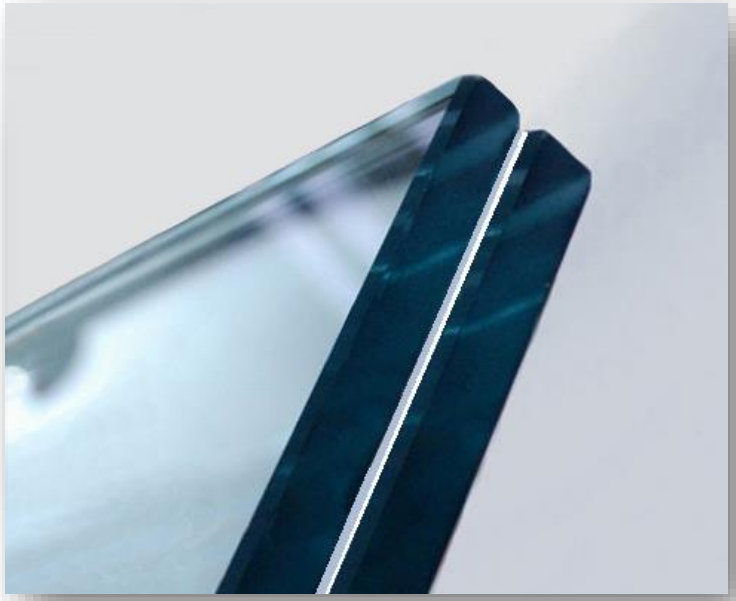
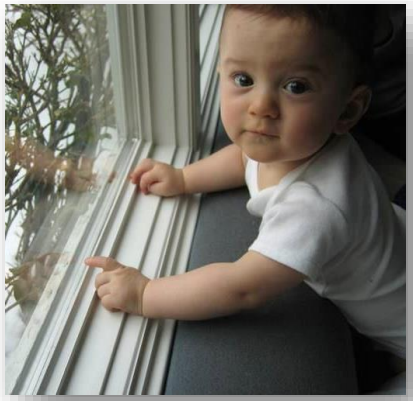
U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Vacuum Glass for R-10 Windows





Performing Organization: V-Glass LLC

PI Name and Title: Peter Petit, CTO

PI Tel and/or Email: 262.347.8404 | peter.petit@swingresearch.com

Project Summary

Timeline:

Start date: 8/27/2018

Planned end date: 8/26/2020

Key Milestones

1. Demo R-10 capable foil-sealed glazing | Aug 2019
2. Demo 50-yr life potential | Jul 2020
3. Identify roadmap to competitive mfg cost | Aug 2020

Budget:

Total Project $ to Date (3/31/19):

- DOE: $166,531
- Cost Share: $0

Total Project $:

- DOE: $1,007,593
- Cost Share: $0

Please note this data may be provided in later slides, take the time to make sure it matches.
This is a summary slide, please don't spend a large amount of time presenting this slide.

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Key Partners:

University of Sydney (Subawardee)
Edison Welding Institute (Subawardee)
Lawrence Berkeley National Lab
National Renewable Energy Lab
Anonymous Glass Industry Manufacturer

Project Outcome:

V-Glass continues to develop its oven-free manufacturing platform to achieve low-cost vacuum insulating glass (VIG).

After identifying our small welder as the barrier to improved vacuum life, a new, larger welder has been ordered that will increase weld speed by almost 3X, with more upside potential.

Failure to clearly demonstrate feasibility of using a flat bar welder for rapid foil-to-glass welding led to selecting a rotary seam welder similar to the current one, but larger, more robust, and faster.

Team

Peter Petit: Founder | CTO

- 40 years of innovation experience; including 25 years managing R&D and IP
- Driven new product investment process for world class firms
- Named inventor on 18 patents
- BS/MSME degrees from Marquette University.

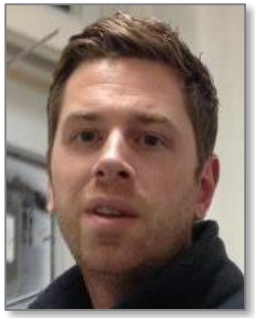
Michael Petit: CEO | CFO

- 30 year career in business, finance and technology
- Past EVP & President at PRA Group (NASDAQ:PRAA)
- BSME from the University of Illinois
- MBA from The University of Texas at Austin

Fred Krumberger: VP Business Development & Strategy

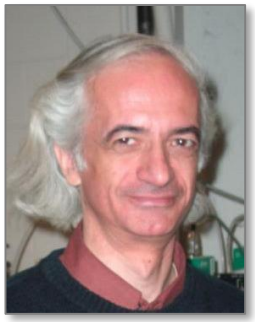
- 30-year executive leadership and international business development
- Past President, Netpeak Energy and Algoma Door
- BS Industrial Engineering from Northwestern University
- MBA from the University of Chicago

Team



Shields Bergstrom: Seal Weld Process Scientist

- Welding process development
- Weld parameter mapping
- BS Physics, Stanford University



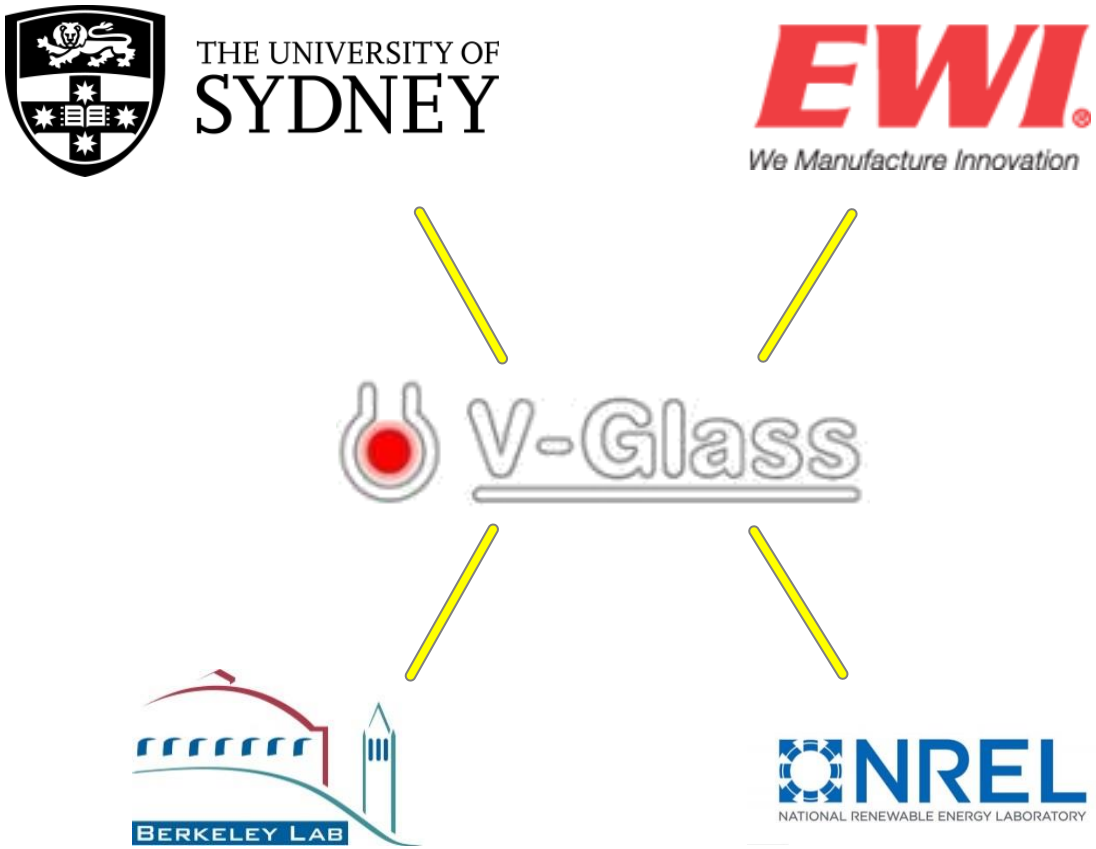
Dr. Sorin Manolache: Plasma Kinetics Scientist

- Vacuum stability and VIG life
- Degassing process development
- PhD Chemical Engineerin Gh. Asachi Polytechnical Institute, Iasi, Romania

Dr. Cenk Kocer: USyd Subawardee PI

- VIG Group Leader
- Member, ISO VIG Standards Development Task Force
- PhD Physics, University of Sydney

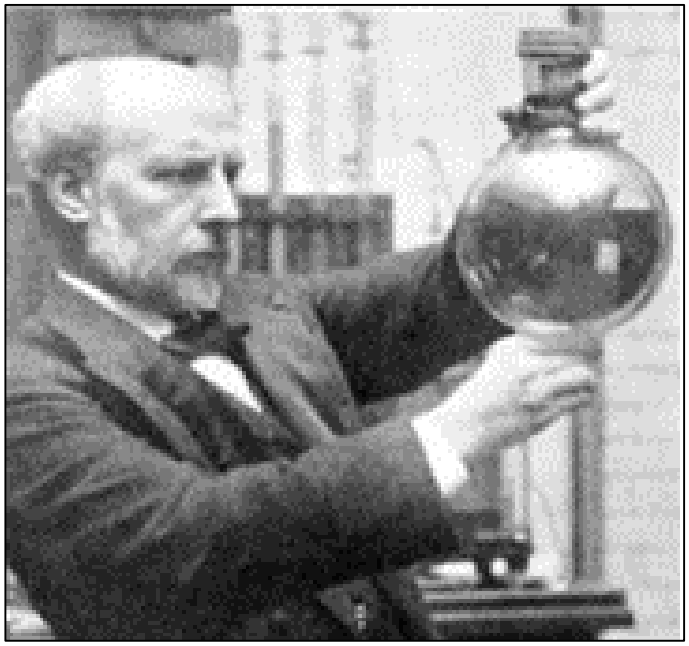
Team



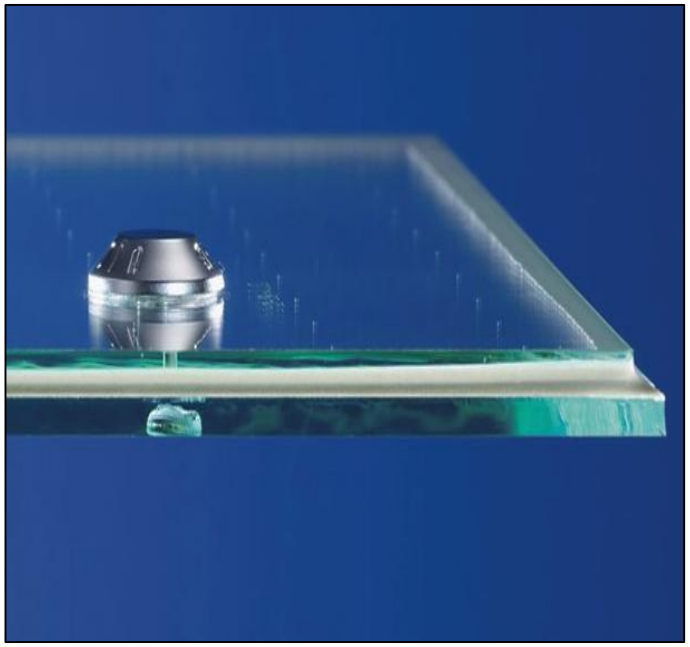
V-Glass currently collaborates with these world-class institutions.

Team: University of Sydney Pioneered VIG

1892 ⟷ Almost one century ⟷ 1988

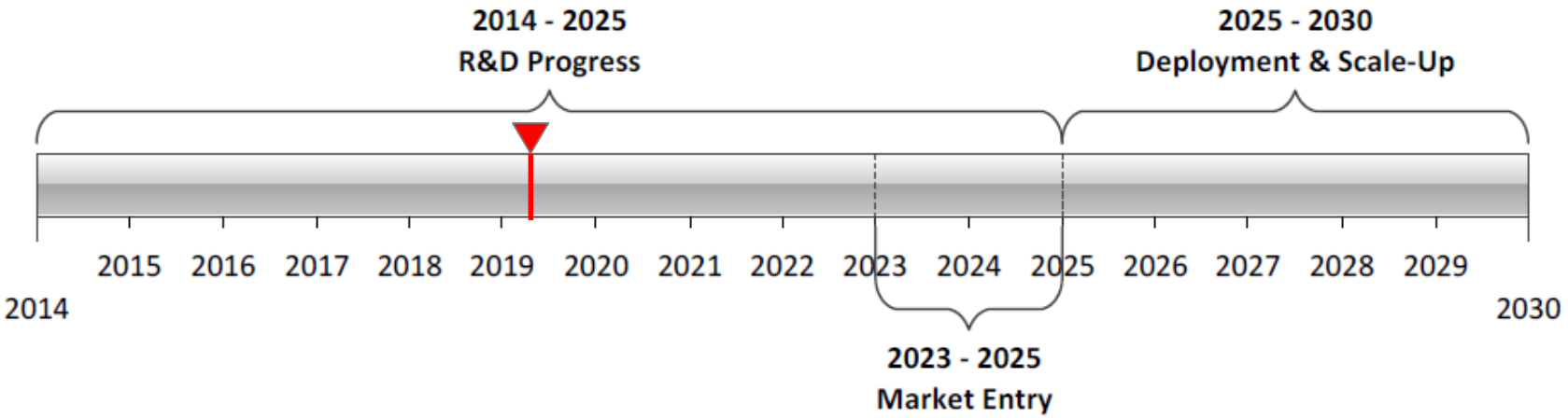


Round Vacuum Flask
James Dewar



Flat Vacuum Glass
Richard Collins & Jack Tang
University of Sydney

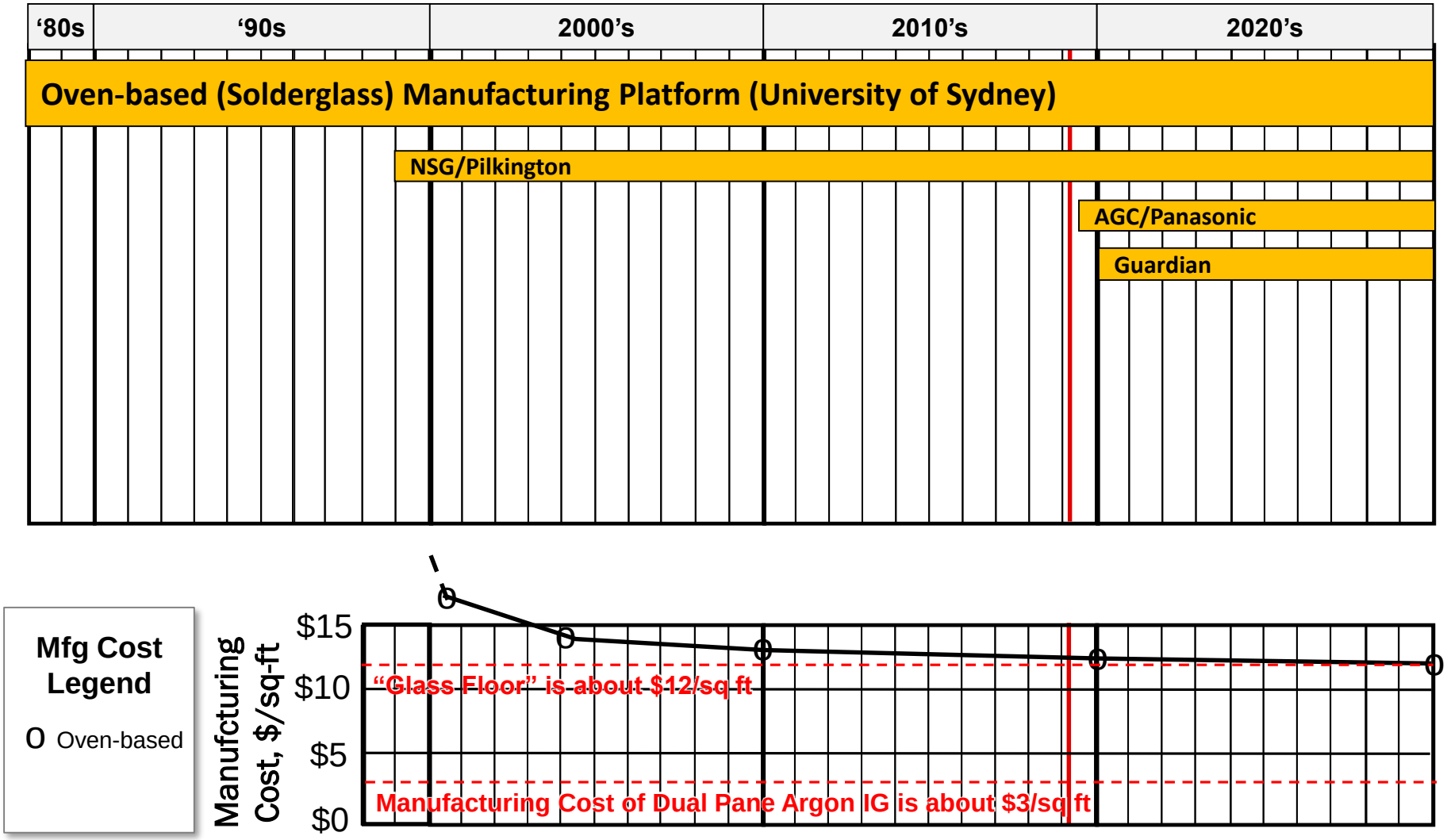
Challenge: Barriers to Program Goal



Excerpted from "Windows and Building Envelope Research and Development: Roadmap for Emerging Technologies," U.S. DOE, February 2014, page 4.

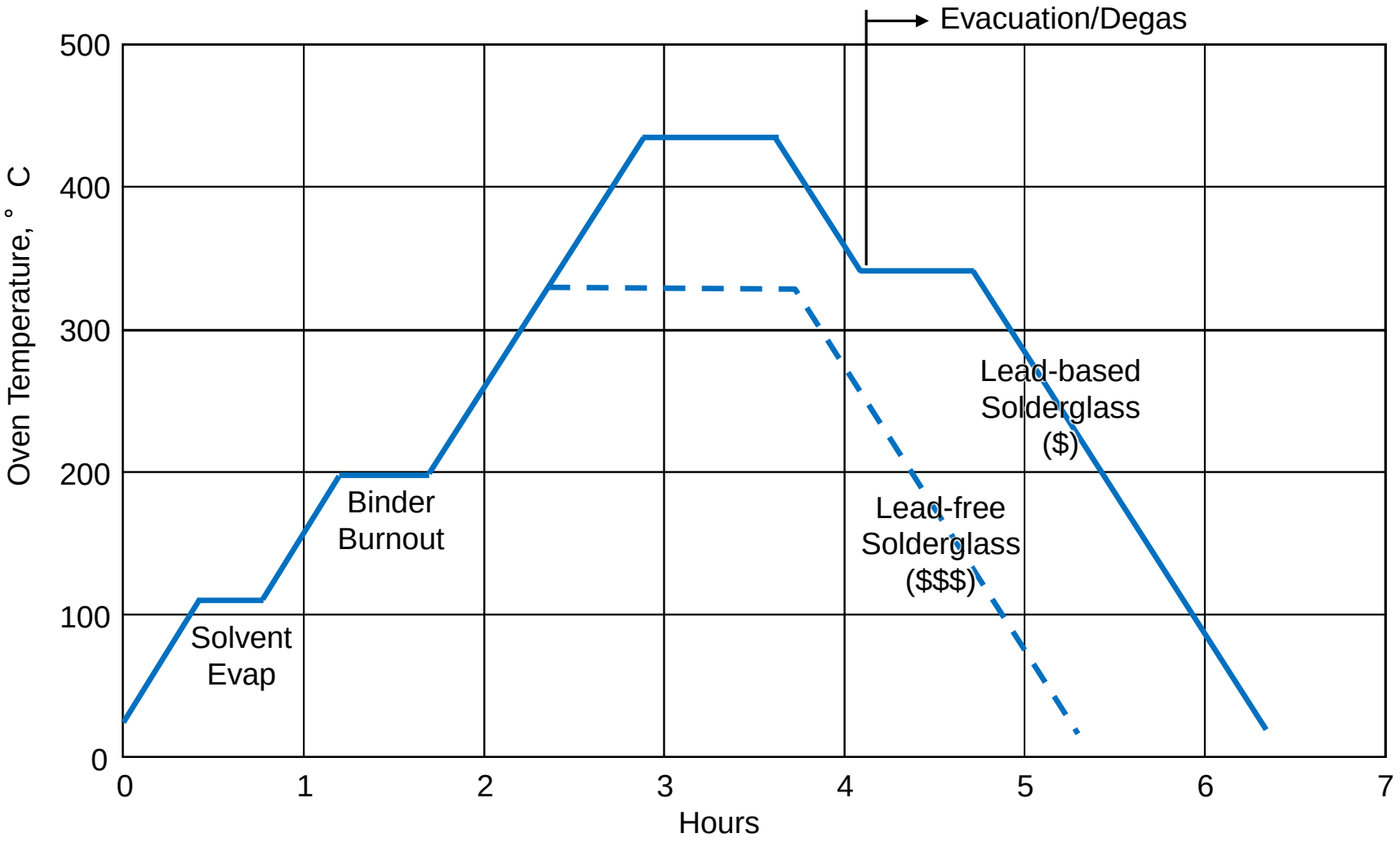
- Program Goal: Market Entry by 2023-2025
- Barriers:
  - a) VIG manufacturing cost is at least 4X higher than dual pane IG.
  - b) energy is cheap, hurting incentive to invest more in windows.
- Evidence: After two decades of commercial sales, penetration of VIG into the global IG market is only 10%.
- Root Cause: Current VIG manufacturing processes are oven-based, inherently slow, and a barrier to further cost reduction.

Challenge: Manufacturing Cost



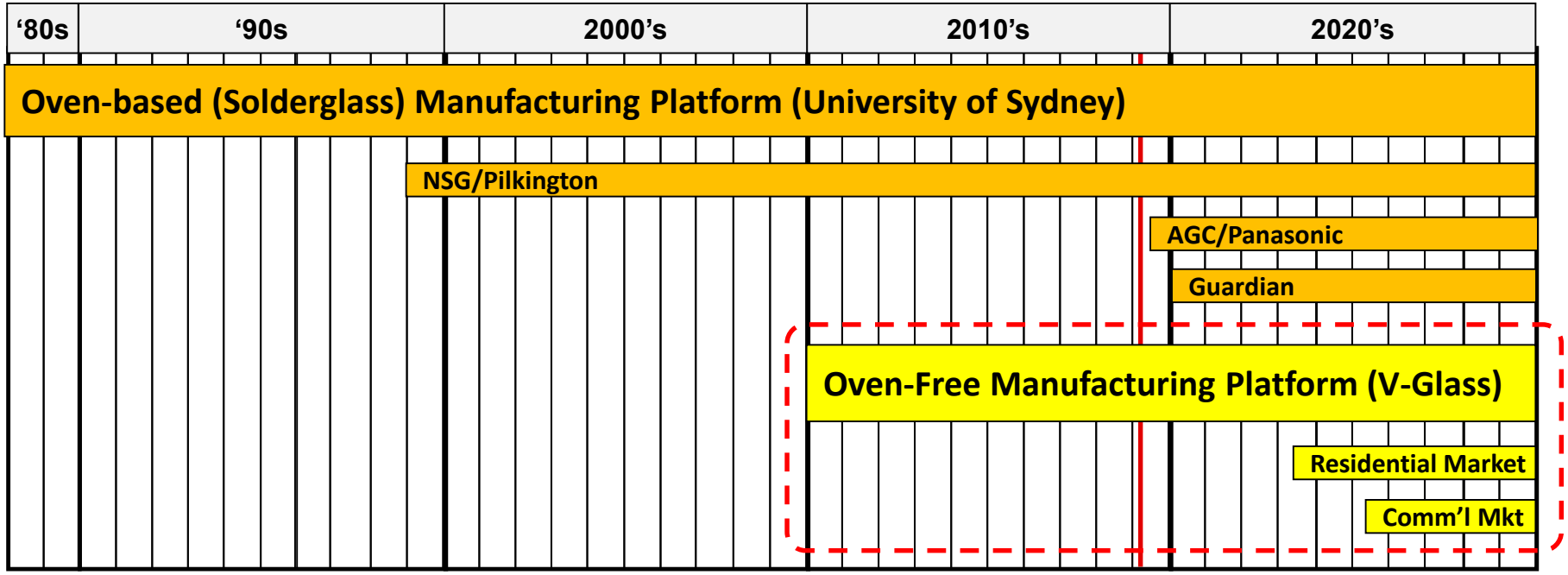
Oven-based VIG platforms cannot break through the "glass floor" at about $12/sq ft.

Challenge: Manufacturing Cost



In contrast, dual pane IG production rate is 1 unit every 30 seconds

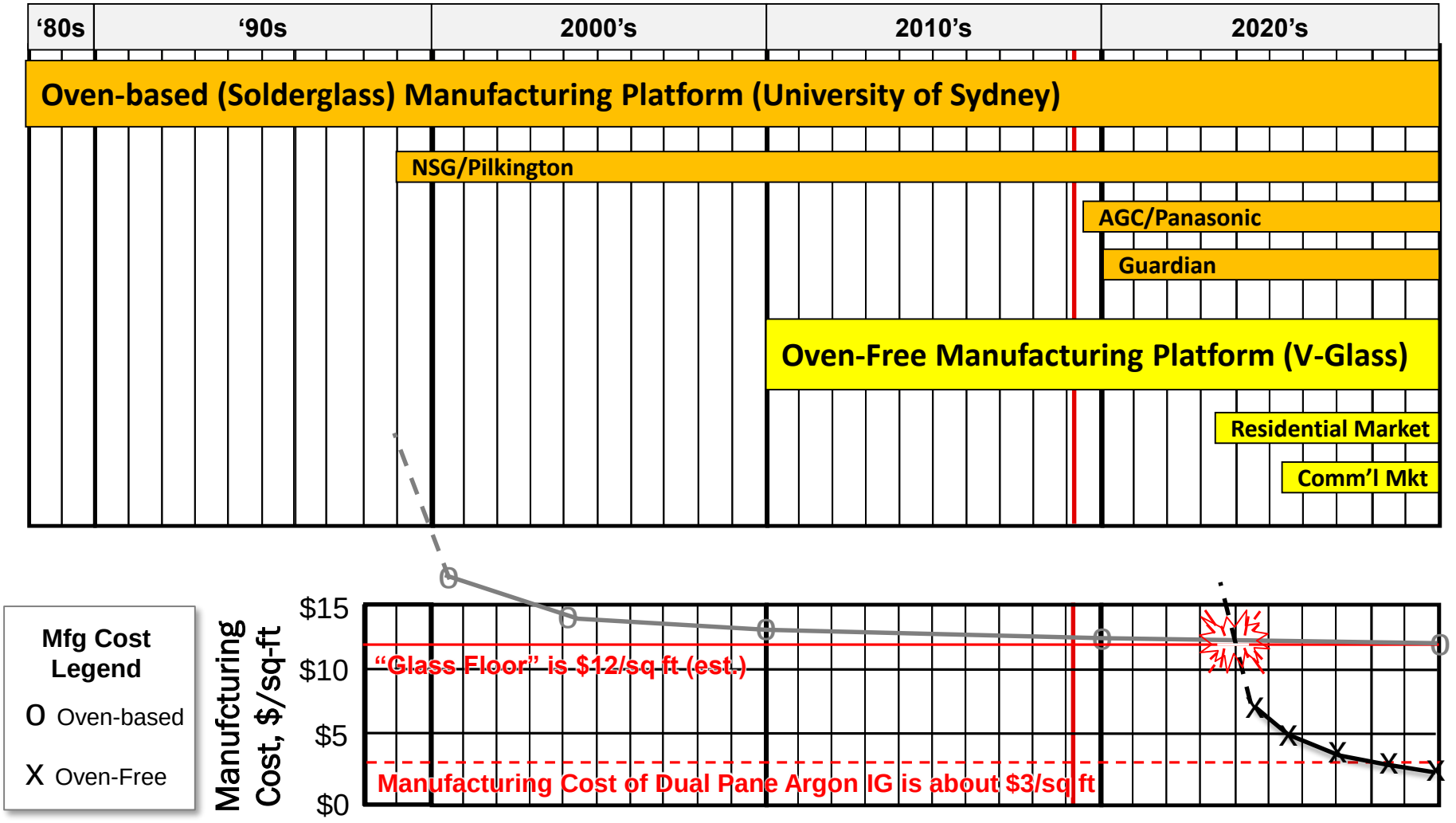
Challenge: Manufacturing Cost



As an an alternative to the oven-based manufacturing platforms, V-Glass is developing a new oven-free platform to eliminate:

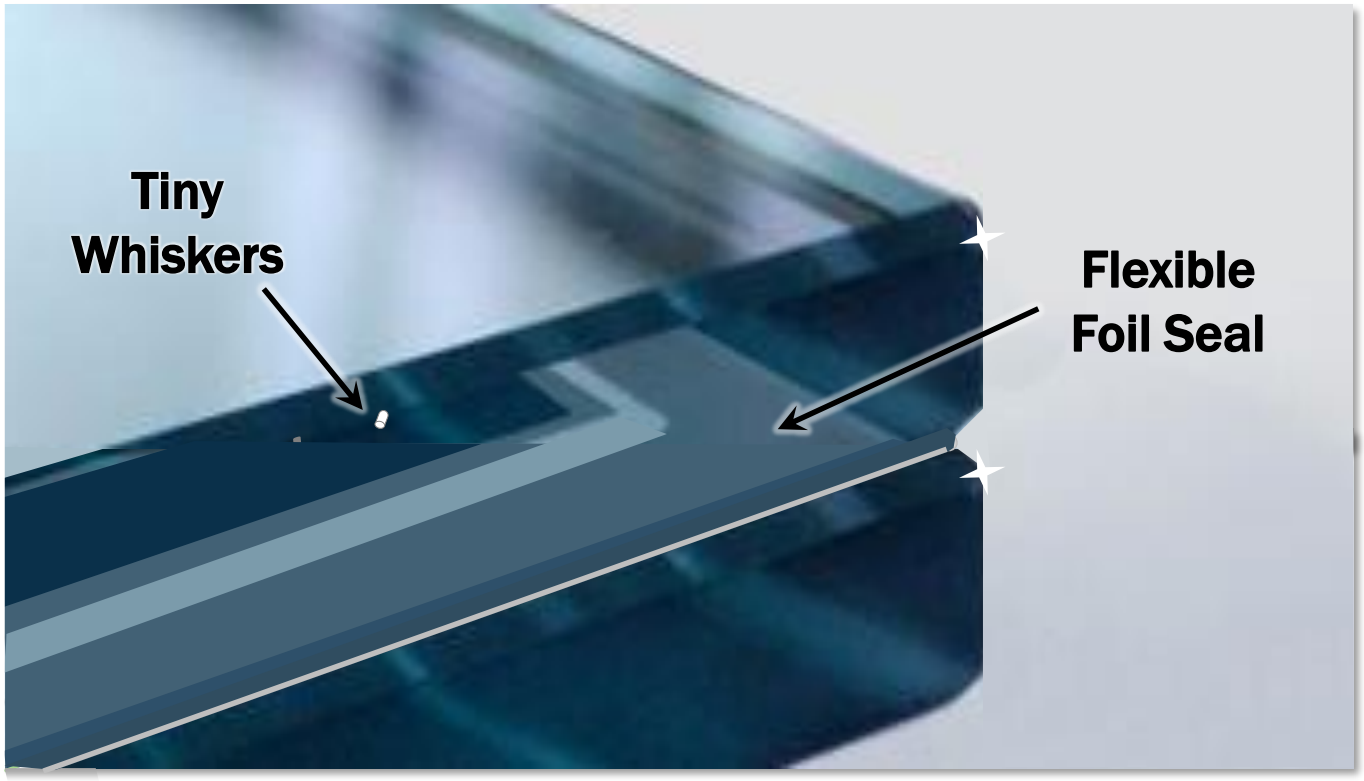
- process bottlenecks (barriers to high throughput),
- high energy demand and increased capital outlay for ovens.

Challenge: Manufacturing Cost



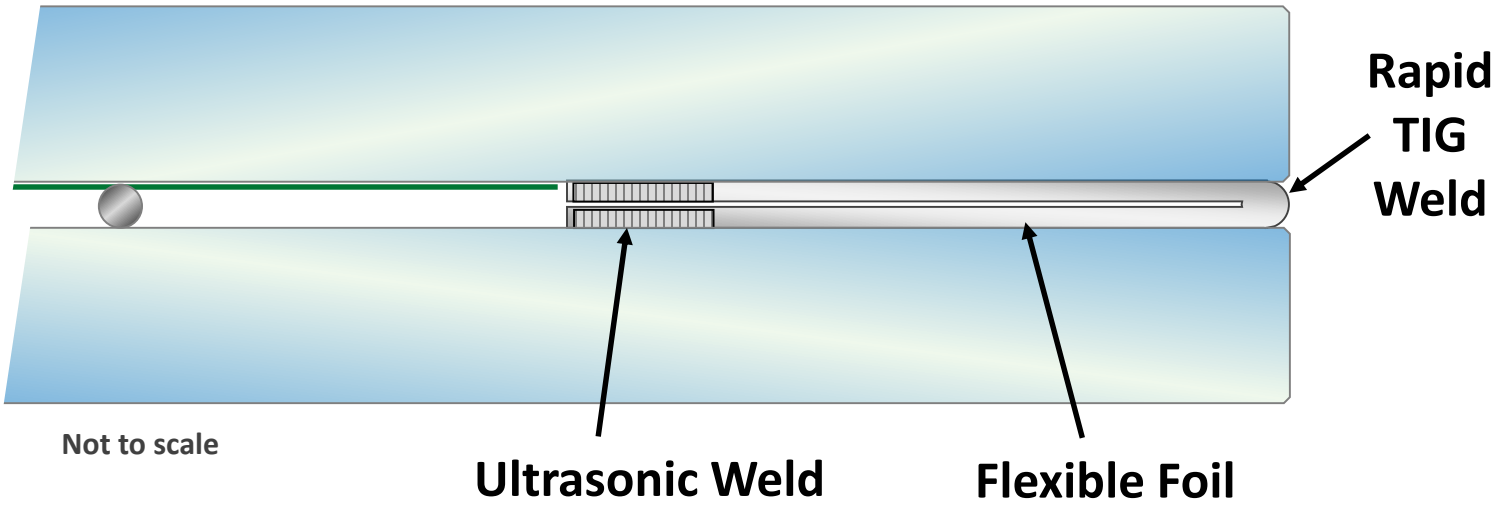
V-Glass intends to break the "glass floor" by developing an oven-free platform.

Approach: VIG Construction



The final foil-to-foil seal will be made using a non-ultrasonic weld.
Welding will still be done at room temperature without preheating.
Low current draw will not damage glass.

Approach: Cold-Weld Foil Seal

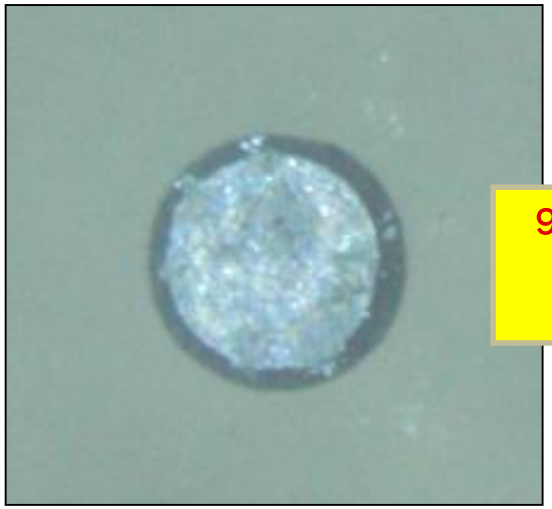


V-Glass is the only company in the world pursuing a “mismatched” seal (analogous to a 1917 Houskeeper seal, a design for joining two materials of different Coefficient of Thermal Expansion, or CTE).

Our mismatched seal was validated by cyclic thermal testing at NREL (2018 under NSF funding), exceeding 50 years equivalent life without delamination or fatigue.

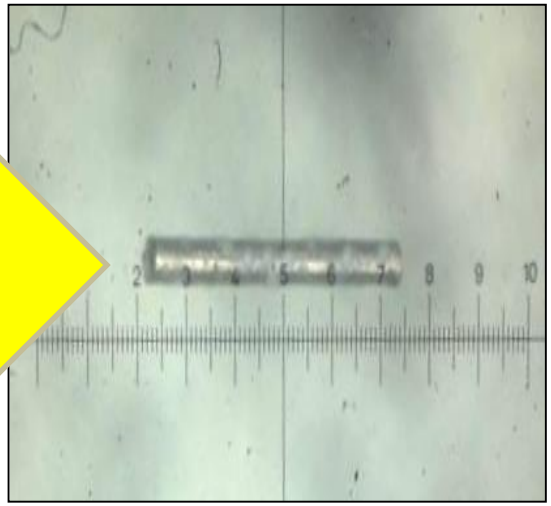
Approach: Whisker Spacerette

Sliding Pillar

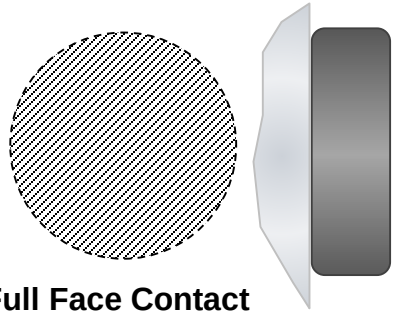


96% Less Contact Area

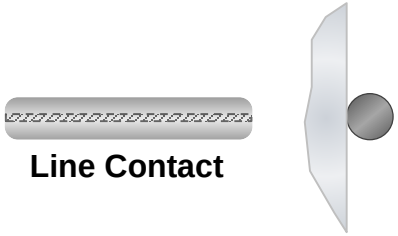
Whisker Spacerette



Less:
- Heat Loss
- Friction
- Visible



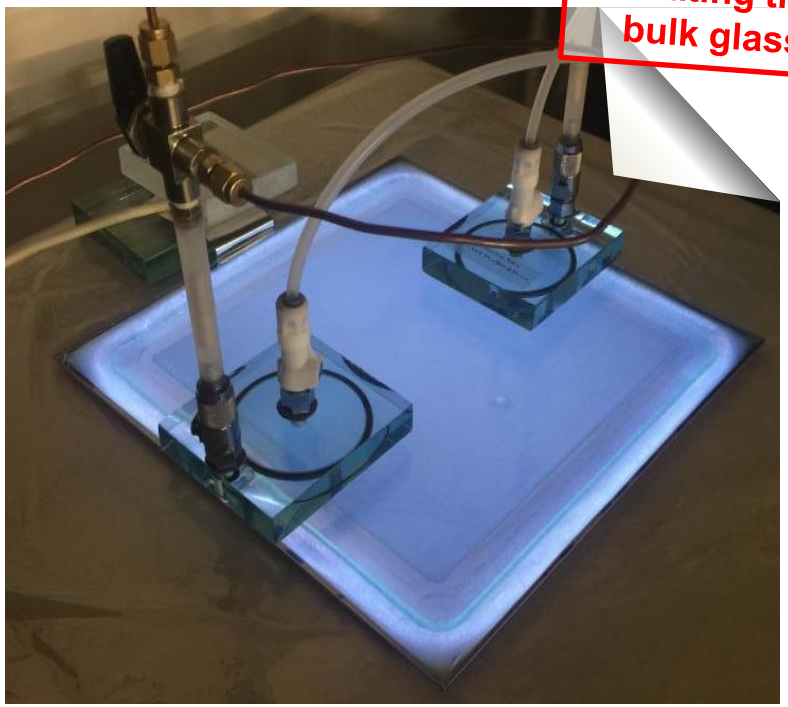
Full Face Contact

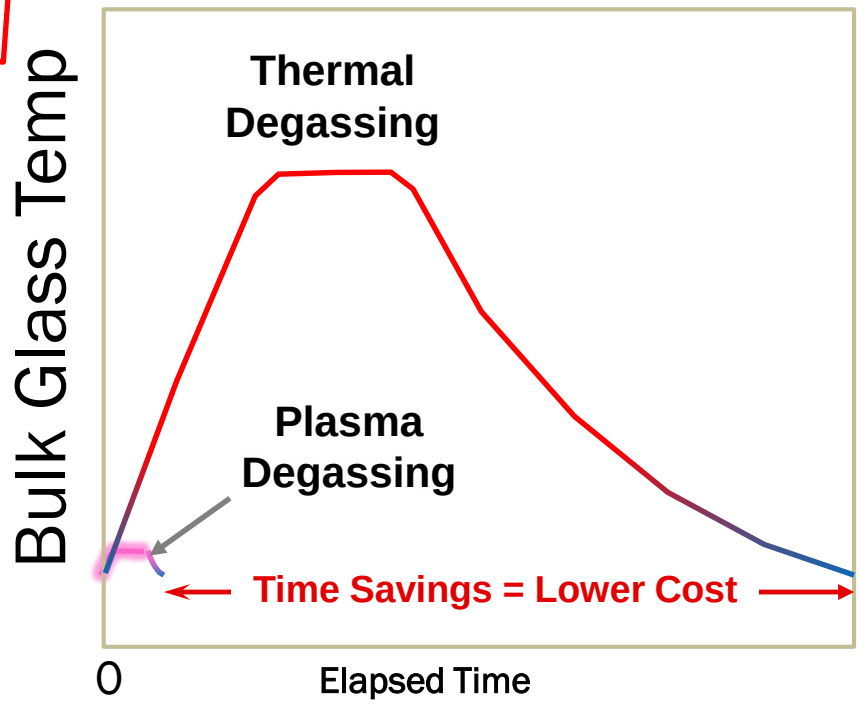


Line Contact

The whisker spacerette enables VIGs to attain R-10 performance using annealed glass (75% of residential market). Otherwise, to achieve R-10 using pillars, panes would need to be tempered (a costly, oven-based process).

Approach: In-situ Plasma Degassing





Research on atmospheric pressure plasma degassing was funded by NSF.

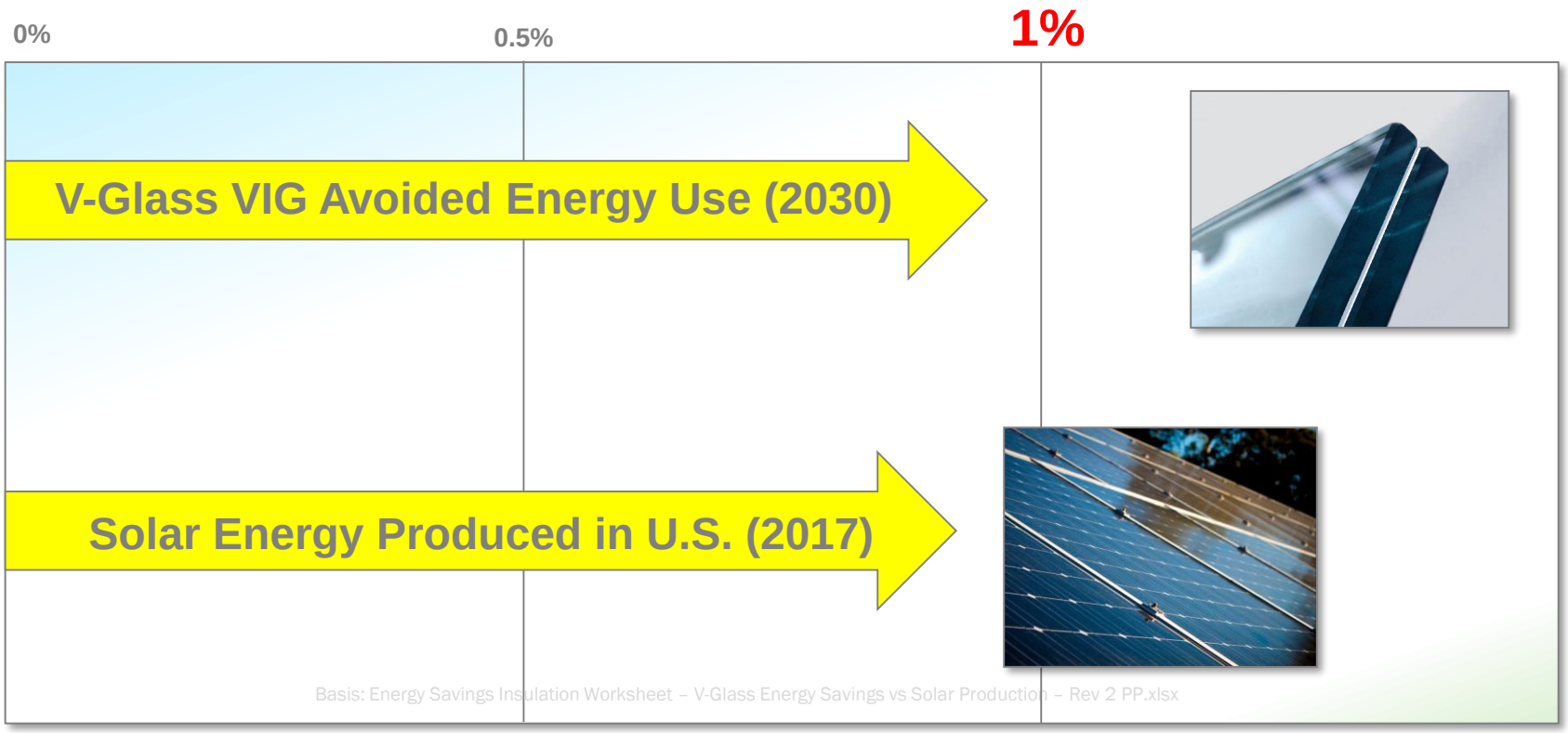
Impact: Windows Roadmap (most recent draft)

	Building Sector	Performance		Installed Price Premium		Primary Energy Savings (quads)	
						2030	2050
Highly Insulating Windows	Residential	13	R-value	2.9	$/ft² window area	1.28	1.07
	Commercial	10	R-value	8.5	$/ft² window area	0.93	0.72
Dynamic Windows	Residential	0.05/0.65	SHGC (active/inactive)	2.9	$/ft² window area	1.35	1.5
	Commercial	0.05/0.65	SHGC (active/inactive)	15	$/ft² window area	1.56	1.64
Daylighting	Commercial	40%	Lighting energy savings	13	$/ft² window area	0.26	0.17

V-Glass is targeting R-10 window and an installed price premium of $0 (assuming new construction).

Impact: Avoided Energy Use

% of Total 2030 U. S. Energy Use*

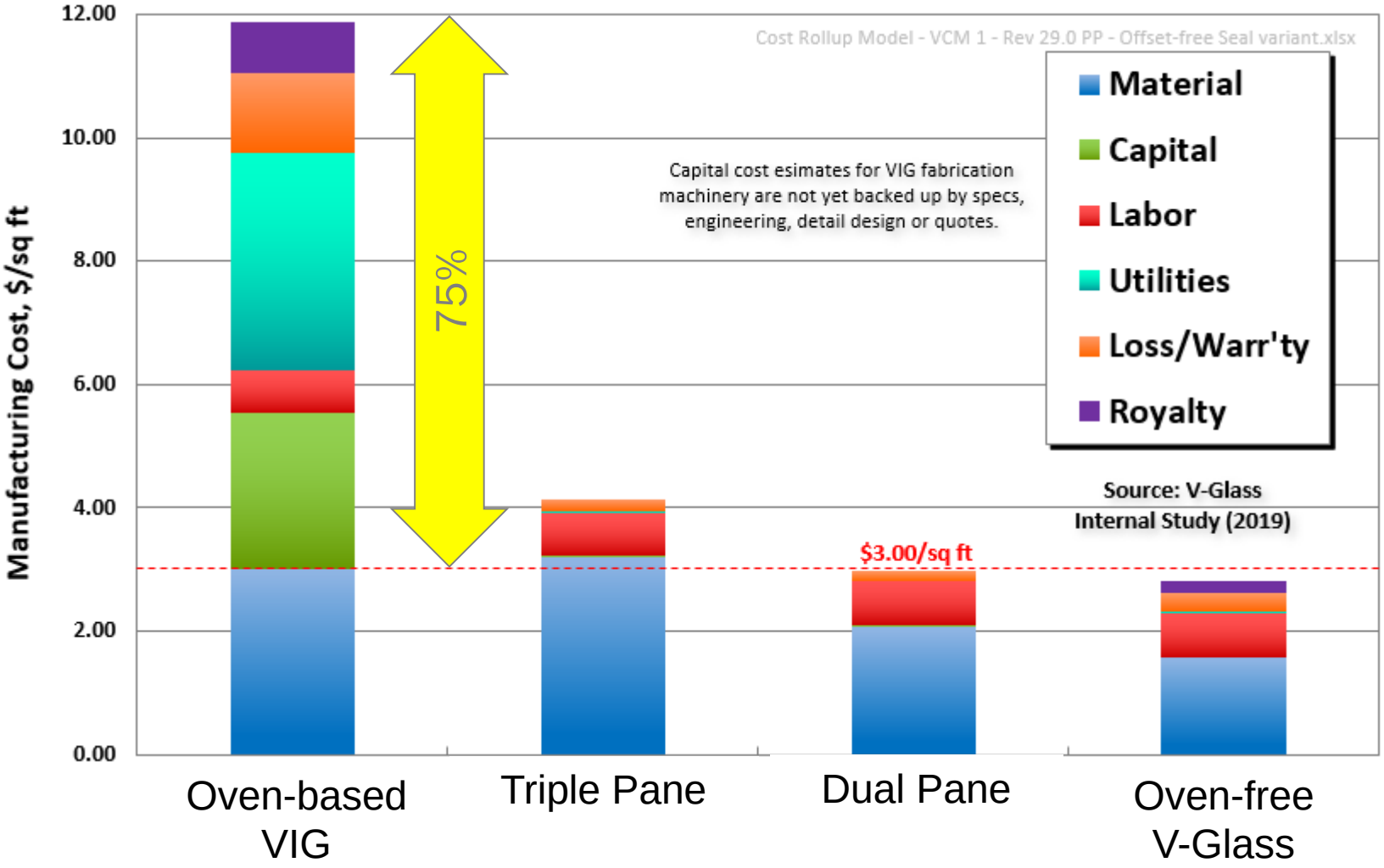


*Total taken as 100 Q

Projected 2030 primary energy savings is more than all the solar energy generated in the U.S. in 2017.

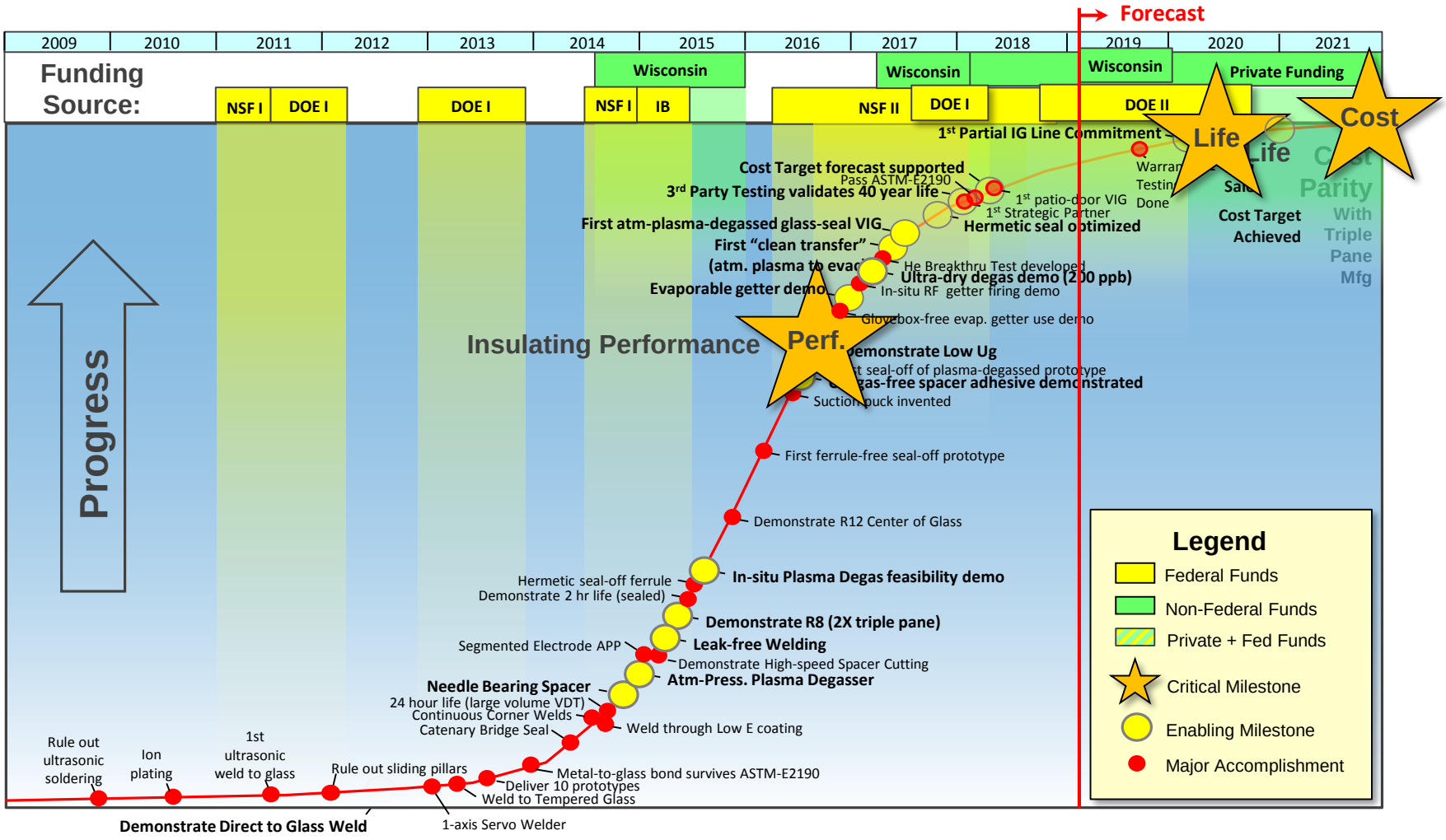
From "Windows and Building Envelope Research and Development: Roadmap for Emerging Technologies," U.S. DOE, February 2014, page 16 and 19.

Impact: Economic Analysis



V-Glass™ VIG manufacturing cost could be 75% less than oven-based VIGs.

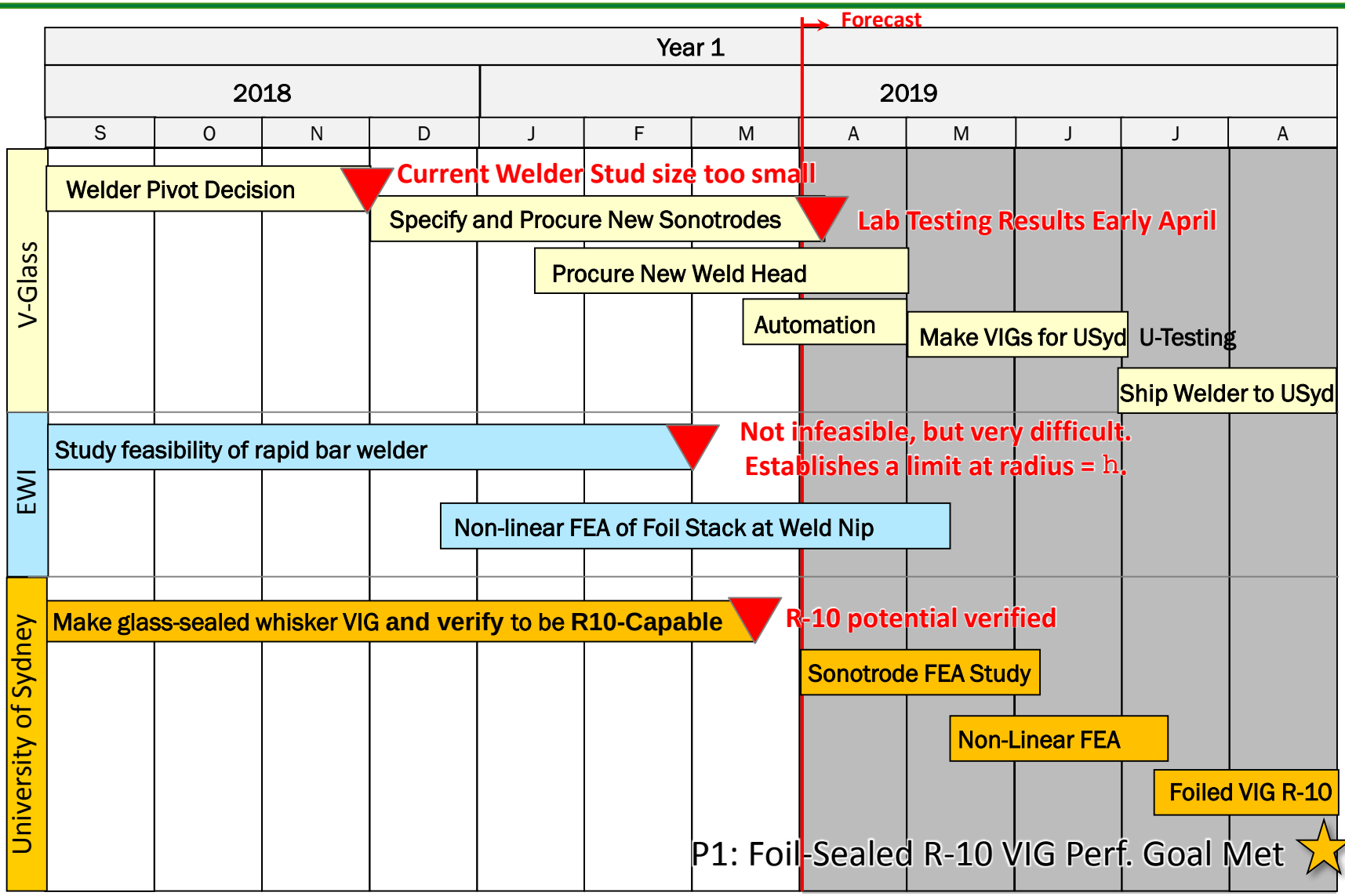
Progress: Historic Overview



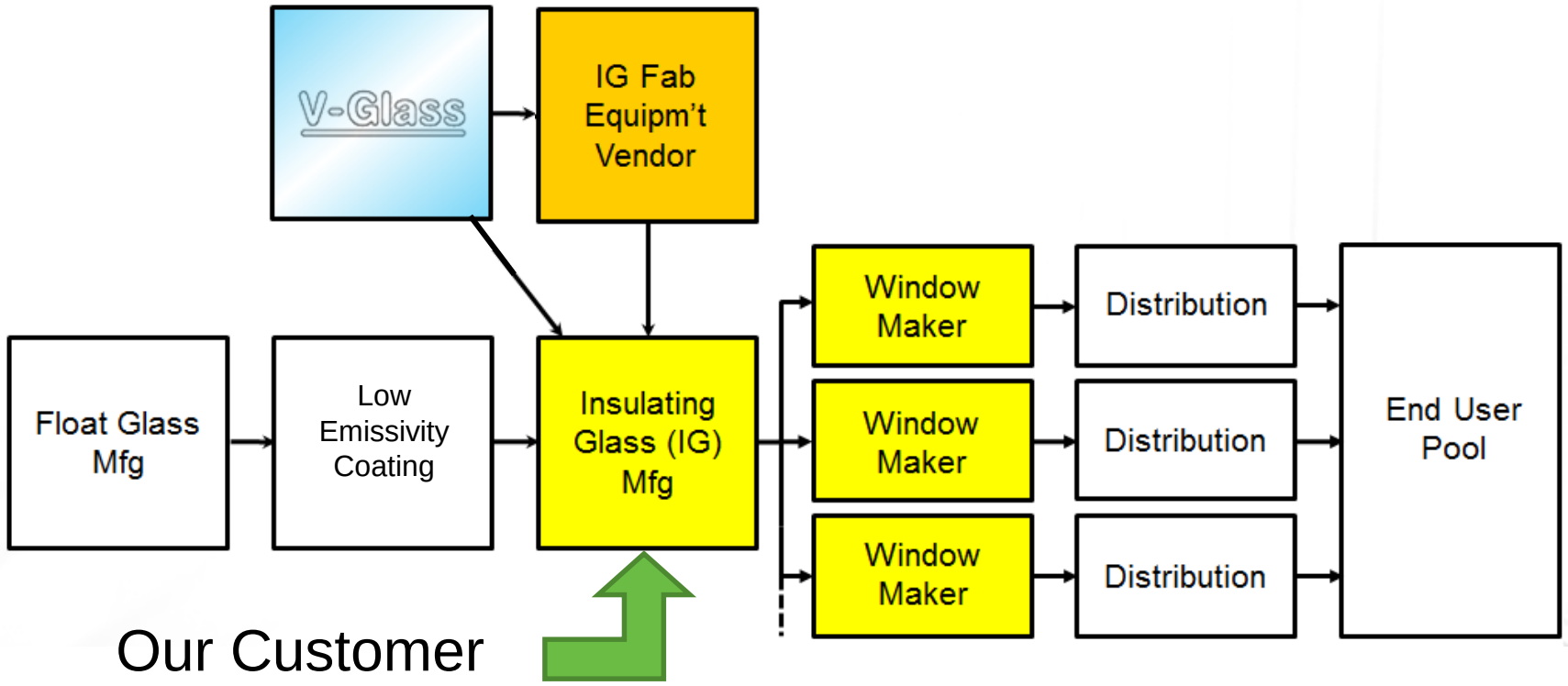
Cumulative grant funds to date: $2.88 million

Technology is still considered "too early stage" by venture capitalists.

Remaining Project Work

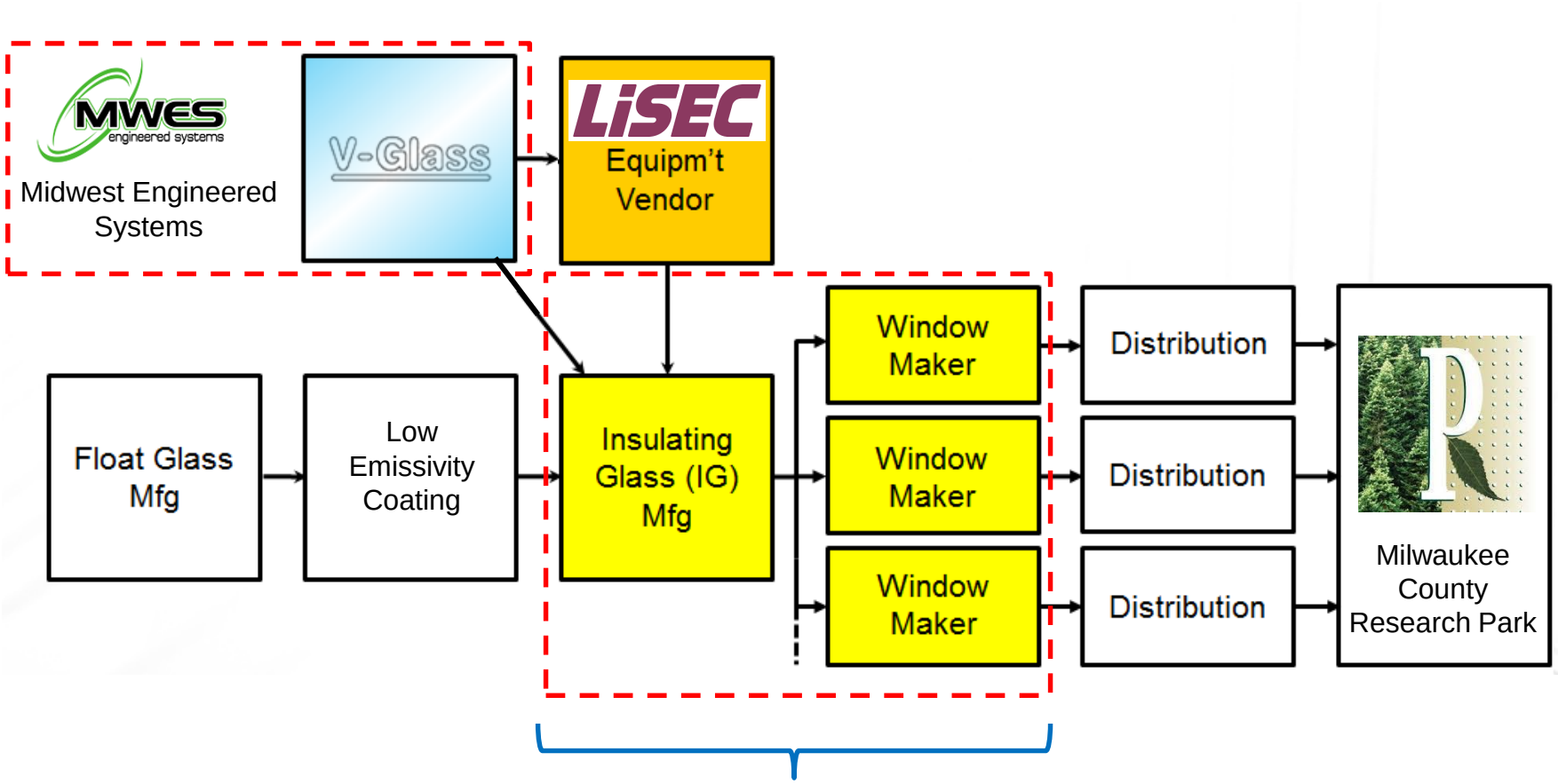


Stakeholder Engagement



Insulating Glass Supply Chain

Stakeholder Engagement



Confidential discussions have been held with most of the largest IG makers and window makers in our key global markets.

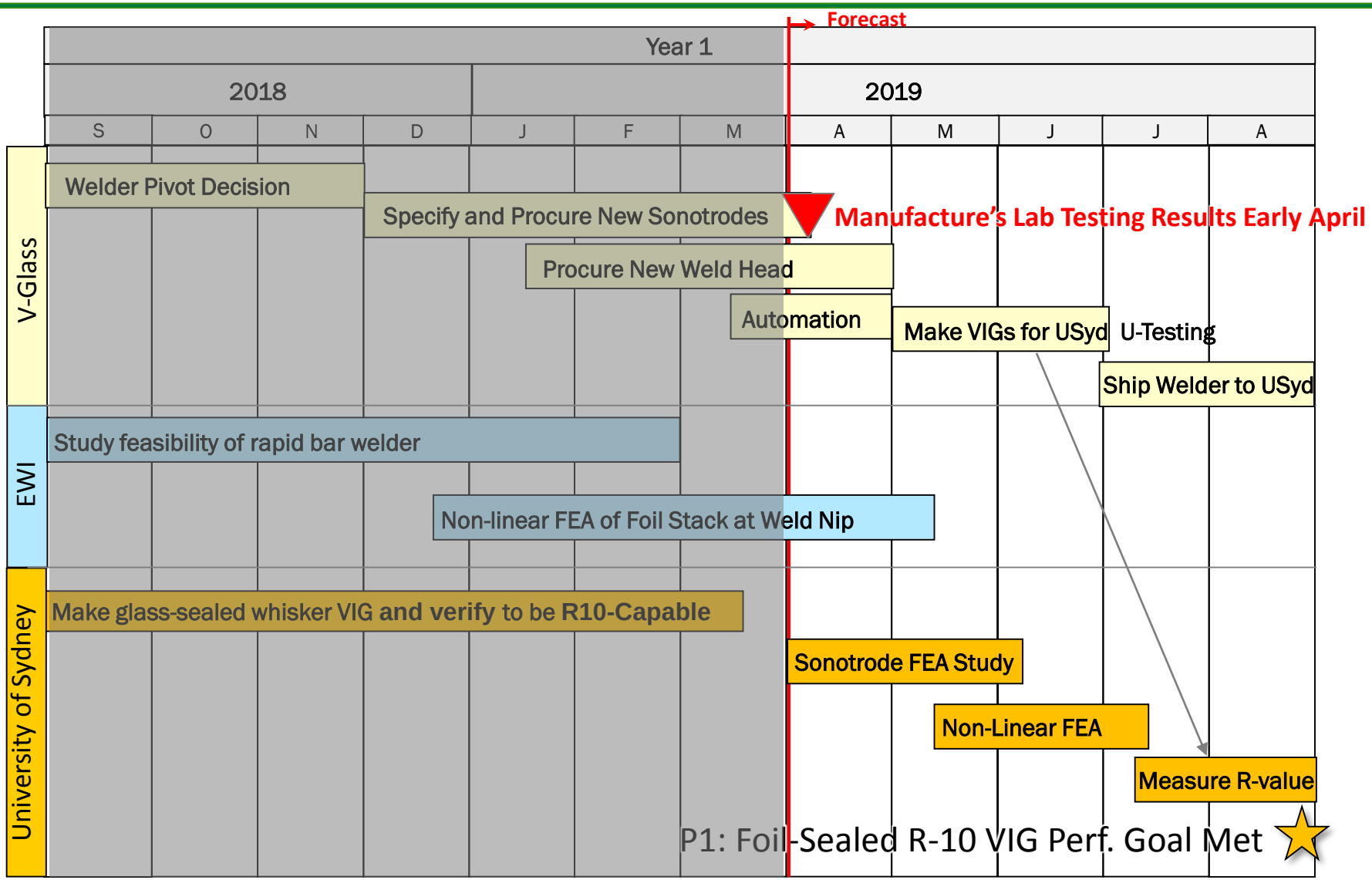
One U.S. firm is evaluating our VIGs to consider entering a Joint Development Agreement.

Stakeholder Engagement

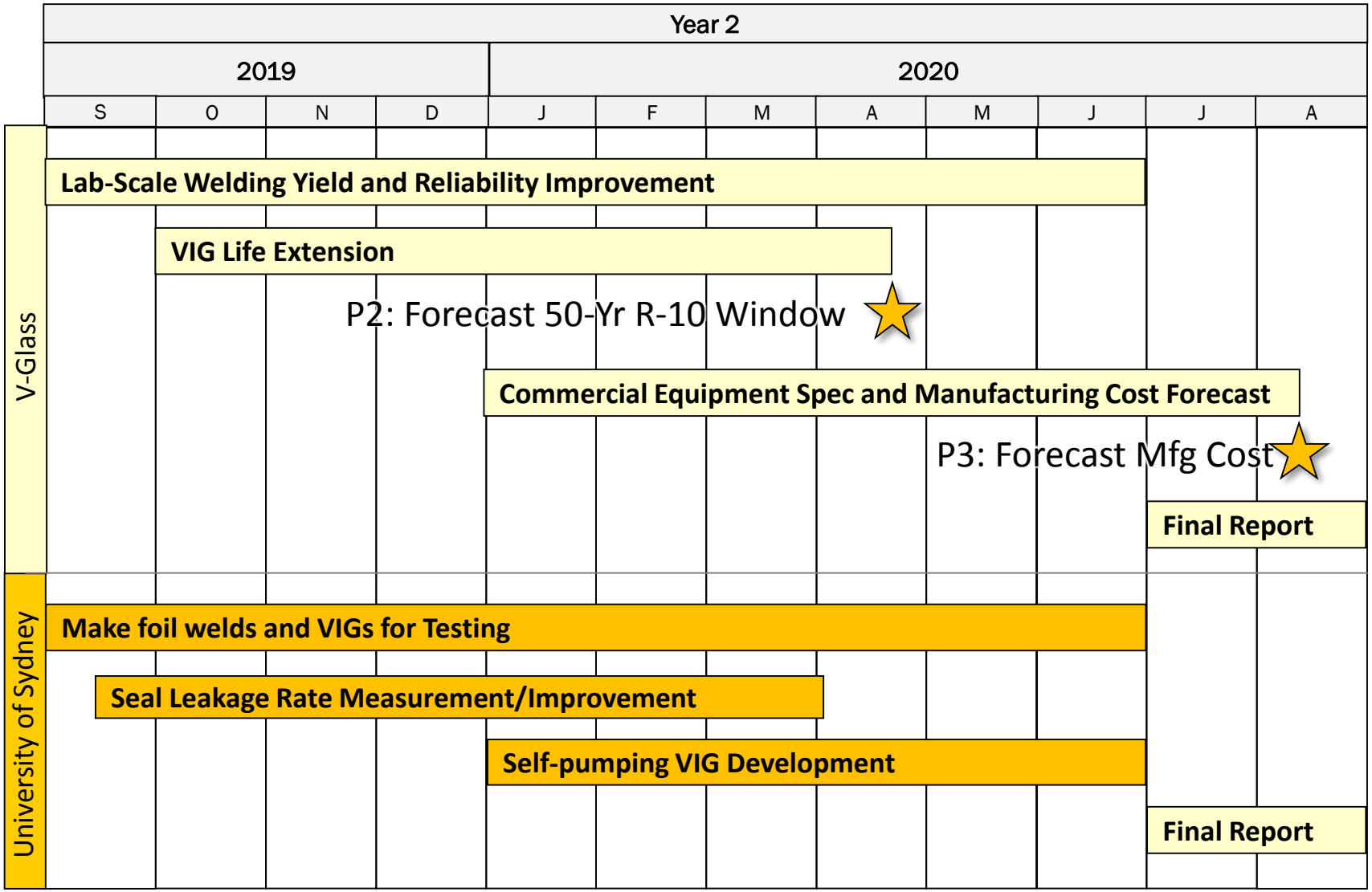
V-Glass was an invited speaker at the First International Vacuum Glass Conference in Qingdao, China, July 26, 2018.

Major IG and VIG makers in Asia-Pacific market were in attendance.

Remaining Project Work (Year 1)



Remaining Project Work (Year 2)



Thank You

V-Glass LLC

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peter.petit@swingresearch.com

Michael Petit, CEO
757-619-9843
mjpetit@aol.com

REFERENCE SLIDES

Project Budget

Project Budget: $1,007,593
Variances: Task 2a, Non-linear FEA, was added. Work was started by and adder to EWI, and will be completed with the USyd subaward.
Cost to Date: 30%
Additional Funding: Other funding provided by V-Glass and a $100K grant from the State of Wisconsin SBIR Advance program.

Budget History					
8/27/18 – FY 2018 (past)		FY 2019 (current)		FY 2020 – 8-26/20 (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$166,531	$0	$508,000	$0	$333,062	$0

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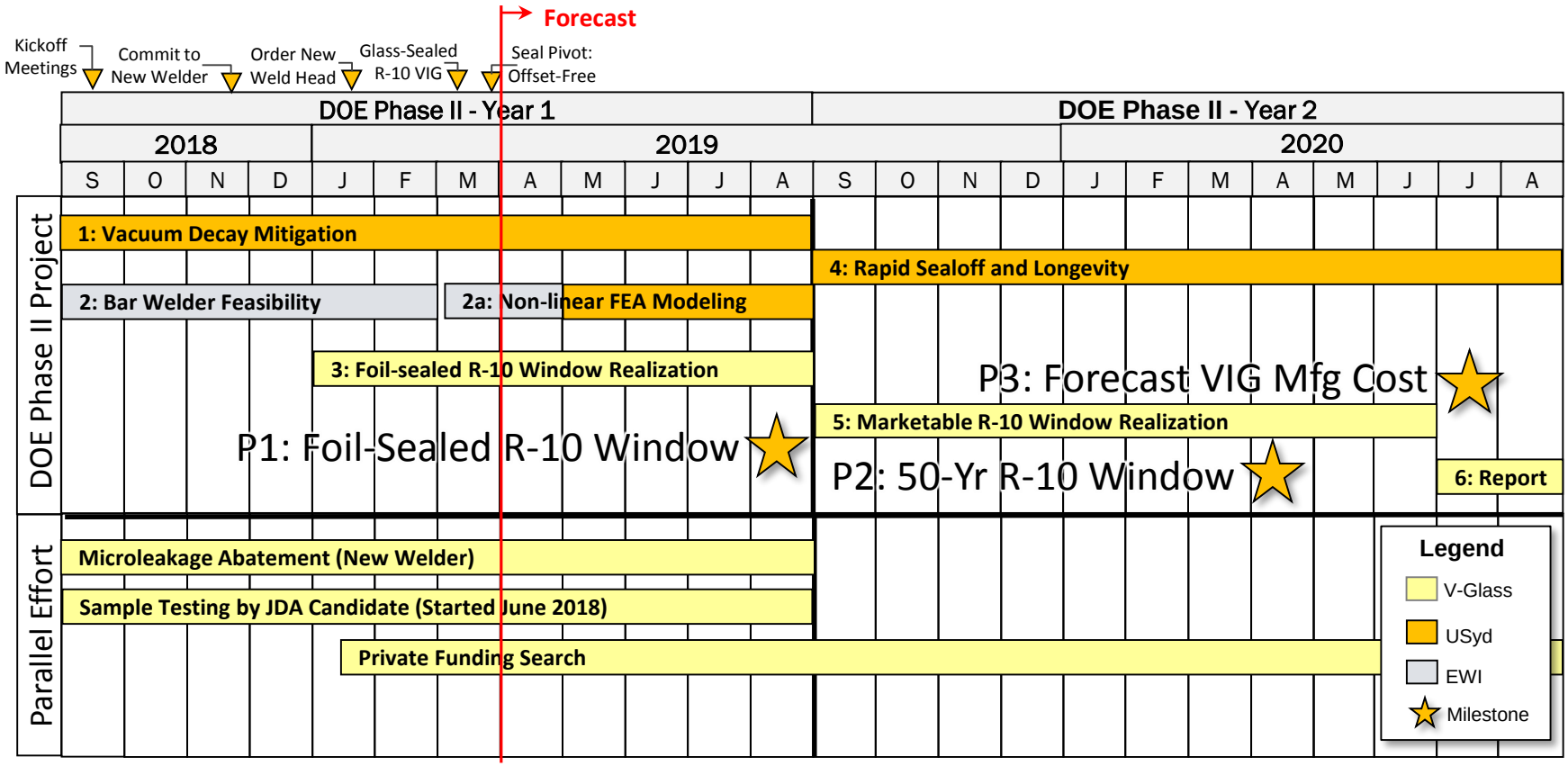
Project Plan and Schedule



Project Start: 8/27/2018 Project End: 8/26/2020

Current Status (4/1/2019):

- Glass-sealed VIG demonstated R-10 capability using whisker spacerettes. On track to achieve **Milestone P1** by end of Yr 1.
- Design/Build of new weld system (part of Parallel Effort) is on track to accept new weld head in May.
- USyd is evaluating leakage rate of single-weld samples using improved protocol.
- EWI rapid bar welder feasibility study was inconclusive. Pursing improved-speed seam welder (alternate).
- Non-linear FEA (Task 2a) has been added, and is providing useful insights.
- Pivot: Change from offset-pane seal design to offset-free seal to reduce risk and increase seal reliability