Dielectric Energy Storage Films

A Key to Unlocking Sustainable Fusion Energy

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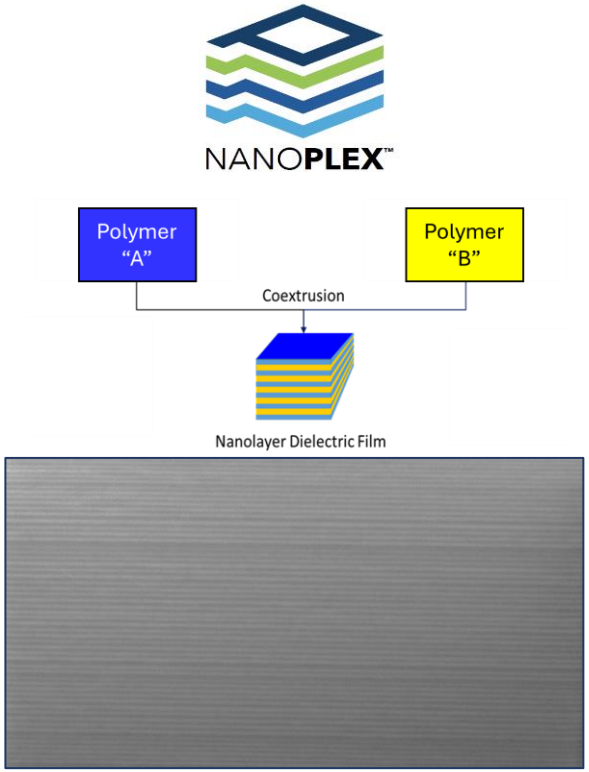
NanoPlex™ - Nanolayered Metamaterials



128-Layer NanoPlex capacitor film SEM image.

Millions of Metamaterials

NanoPlex is a family of nanoscale (1/billionth of a meter) metamaterials that can be programmed to meet various applications, including optics, energy storage, product packaging, and protective films, to name just a few.

Optics, Power & Space

Peak's nanoscale technology changes our ability to bend and block light, sound, and electromagnetic waves, conduct or insulate electricity, and control atmospheric conditions, ushering in previously unimaginable possibilities.

Over 20 Global Patents

NanoPlex is protected by over 20 global patents for our core technology, manufacturing processes, and product implementations, which creates a defensible and differentiated position in our markets.

100% US-based Supply Chain

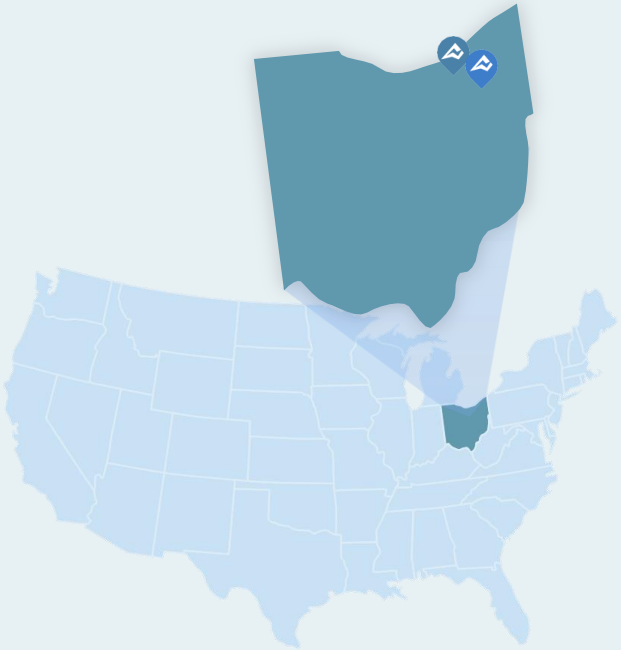
Peak technology and products are engineered and manufactured in the United States. We provide a strategic advantage to our customers, who must ensure they have secure supply chains.

peak
Films Facility

Valley View, OH

peak
Optics Facility

Macedonia, OH



Peak Film Facility

High Precision development and validation of application specific NanoPlex Films.

Peak Optics Facility

World Class facility for the processing, fabrication, and metrology of optics and optical systems.

peak

Film Markets and Supply Chain

peak

	EVs	EV Chargers	Power Grid	Mobile Power	Fusion Energy	Data Center	EMALS
							
Final Use Case Customer	TESLA	chargepoint	DUKE ENERGY	PG&E	Sandia National Laboratories	Microsoft	
Systems Customer	TESLA	ABB	GE VERNOVA	EATON	GENERAL ATOMICS	HELION	NASSCO
Capacitor Makers	TDK	TDK	EATON	EATON	GENERAL ATOMICS	HELION	GENERAL ATOMICS

NanoPlex for Fusion

>3.8
HIGH DIELECTRIC CONSTANT

125°C
OPERATING TEMPERATURE

6-14µm
FILM THICKNES

NANOPLEX MATERIAL COMPOSABILITY

Dielectric Constants > BOPP-C

Additional Material Chemistries

Ultra Thin Film <3 Microns

Operational Temps up to 150°C

BOPP EQUIVALENT DIELECTRIC DISAPATION

125°C
OPERATING TEMPERATURE

3-12µm
FILM THICKNESS

2025 Fusion Landscape

70+

Fusion machines or plants under development in 2025

$8B+

Private investment in fusion energy through Q1 2025

$2B+

Public funds in fusion energy programs for 2024/2025

2035

FIA member expectation for electricity to the grid

51%

Of fusion companies are developing magnetic fusion

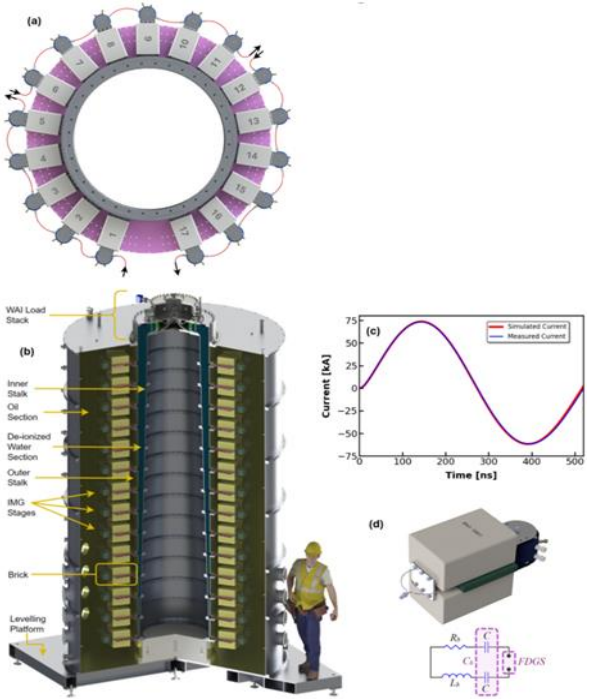
$50MWh

Target price for electricity to make fusion energy viable

https://www.llnl.gov/article/50616/llnls-national-ignition-facility-delivers-record-laser-energy | http://https//www.fusionindustryassociation.org/wp-content/uploads/2024/07/2024-annual-global-fusion-industry-report.pdf
https://www.fusionindustryassociation.org/wp-content/uploads/2024/07/2024-annual-global-fusion-industry-report.pdf | https://cfs.energy/news-and-media/building-trust-in-fusion-energy
https://ignitionresearch.com/reports-fusion-energy-worldwide-demand-market-report// | https://fusionenergybase.com/ | https://thefusionreport.substack.com/publish/posts/detail/160339203?referrer=%2Fpublish%2Fposts

Fusion: a Developing Capacitor Film Market

1. Fusion Energy Systems Background
2. Industry Timeline Toward Fusion Plants
3. Fusion Capacitor Film Needs
4. Capacitor Supply Chain Challenges
5. Closing remarks

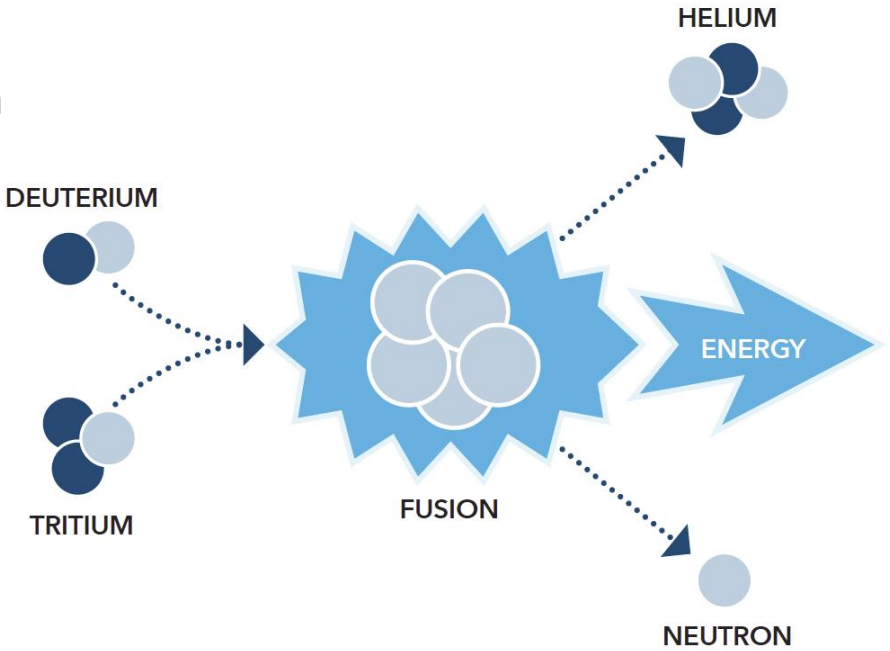


Capacitors powering an impendence matched Marx Generator for the Fuse Titan Fusion system[Ref].

Ref: V. Damideh et. Al. "Experimental results of a 330 GW impedance-matched Marx generator. Nature Scientific Reports, 14, 16889. Available online - https://www.nature.com/articles/s41598-024-67774-4)

What is Fusion Energy?

- Fusion Energy is the same process that powers the Sun.
- Fusion combine two light atomic nuclei to form a single heavier nucleus, releasing energy.
  - Example Deuterium + Tritium -> Helium
- High Temperature Process
  - Combining light nuclei to form a heavier nucleus at over 100 million ℃.
- Fusion Ignition is Based on Lawson's Criterion
  - Temperature
  - Electron Density
  - Confinement time



Why Fusion?

NOT A HYDROCARBON

Hydrocarbons are finite and fusion energy is infinite.

Fusion fuels are based primarily on version of hydrogen from sea water and can create tritium during the fusion process.

CLEAN PROCESS

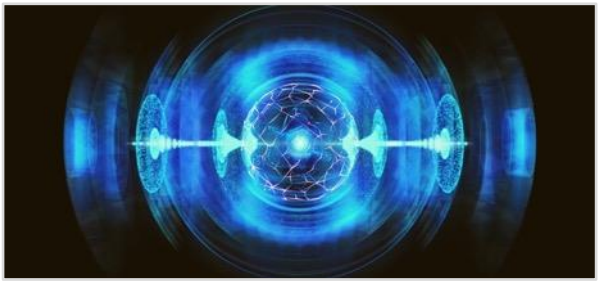
The fusion process do not produce harmful waste products

Fusion energy is a safe and clean process the is easily showdown as required and does not produce pollution.

COMPACT FOOTPRINT

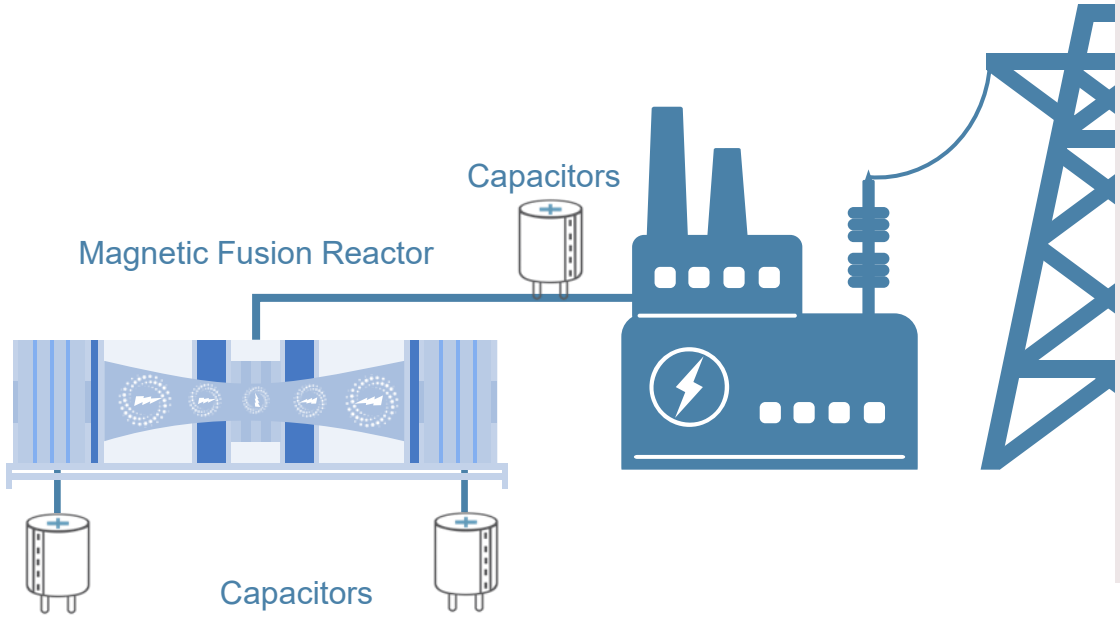
Fusion machines can be deployed in small footprints for many applications

Fusion power systems can be as small as a microwave for transportation uses and as large traditional power plant to power cities.



Magnetic Plasma Based Fusion

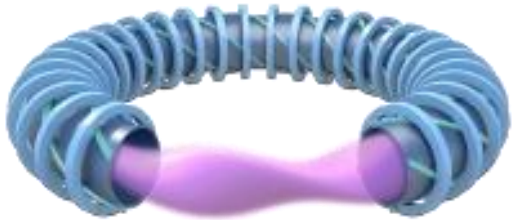
1. Deuterium and Tritium are heated to plasma conditions by magnets using a field reverse condition
2. Magnets accelerate the plasma to force it to collide in the middle of the chamber
3. The merged plasma is compressed by magnetic forces, forcing it to be heated to 100 million centigrade, which causes the fusion reaction to occur
4. When the plasma expands again it reverses the magnetic field, which creates an electric current that is used to generate electricity.



Fusion Flavors: Magnetic confinement

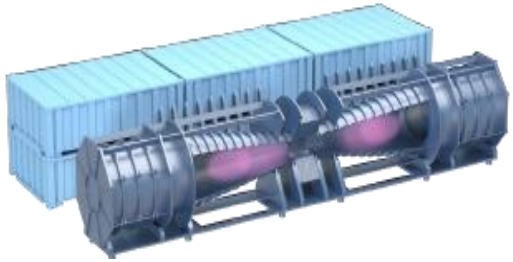
TOKAMAK

- Commonwealth Fusion Systems
- Tokamak Energy



STELLARATOR

- Proxima Fusion
- TYPE ONE ENERGY

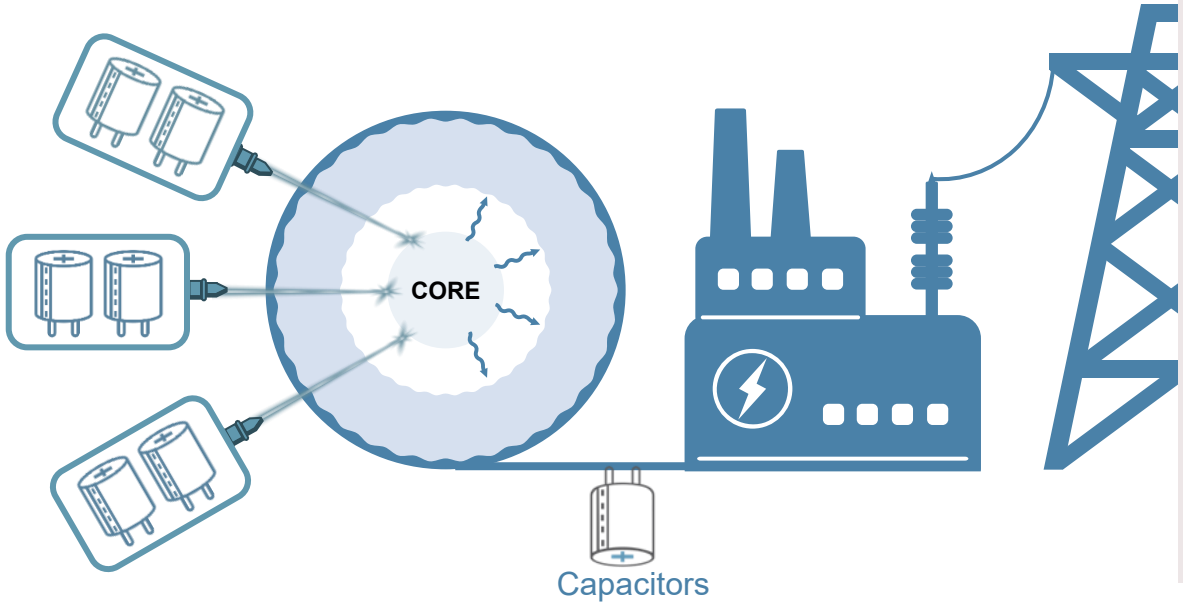


MAGNETIC MIRROR

- HELION
- REALTA FUSION

Interial Confinement Fusion (ICF) Energy

1. Capacitors super-charge lasers
2. Lasers recreate the heat of the sun, and causes the fusion of hydrogen into helium
3. The fusion process produces clean energy



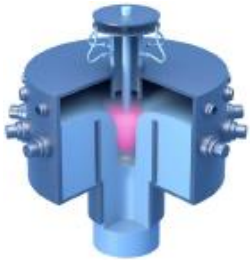
Fusion Flavors: Inertial confinement (ICF)

ICF INDIRECT

- XCIMER
- MarvelFusion

ICF DIRECT

- PACIFIC FUSION
- FOCUSED ENERGY



ICF PINCH

- ZAP ENERGY
- generalfusion

Fusion in 2025: Q>1

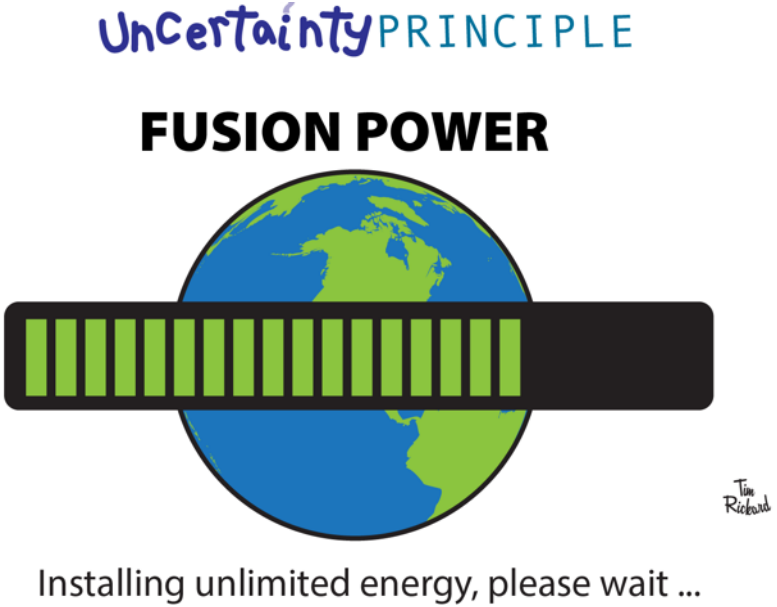
Reaction is net positive – so the engineering is working…..

Overall reactor and GRIN interface system is not yet positive

Ref 1. https://www.llnl.gov/article/49301/shot-ages-fusion-ignition-breakthrough-hailed-one-most-impressive-scientific-feats-21st
2. https://euro-fusion.org/eurofusion-news/dte3record/
3. https://www2.yicaiglobal.com/news/chinas-energy-singularity-makes-fusion-energy-breakthrough

Why is Fusion Taking So Long?

- Fusion research has been running since WWII atomic programs, so what's the hold-up?
  - Answer: It's hard!
- Requires multiple, multi-disciplinary engineering breakthroughs:
  - Ignition science and supply chain for tritium targets
  - Control of pulsed energy/plasma onto tiny 0.5 to 5 mm hydrogen targets
  - Materials that withstand extended exposure to high reaction temperatures/energy release
    - > 100 million degrees or 7X hotter than the sun
  - Need high efficiency energy capture and transfer to GRID



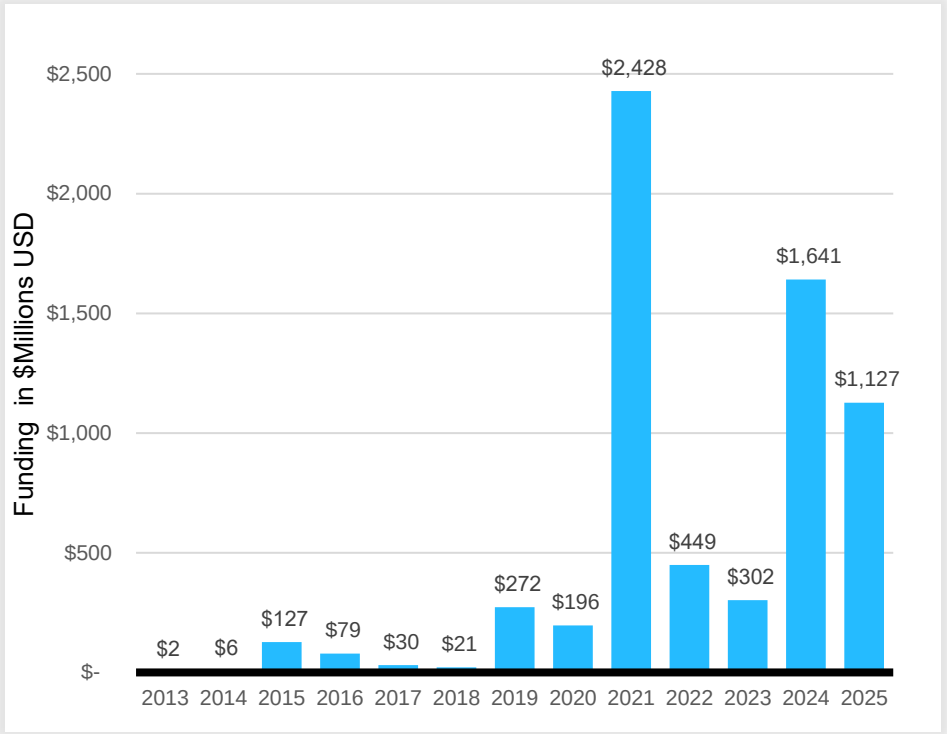
If Fusion Were As Easy As Rocket Science, It Would Have Been Done In The 1960's

Fusion Energy Investments have Upped the Anti

>$8+ Billion of private investment to develop and *demonstrate* operational fusion plants since 2021.

TOP FUSION COMPANIES BY FUNDING — THE FUSION REPORT

Company	Fusion Type	Founding Year	Total Funding ($M)	Investors	Link
Commonwealth Fusion Systems	Magnetic Confinement (Tokamak)	2018	$2,000.0	Breakthrough Energy Ventures, Google, Khosla Ventures, Tiger Global Management	www.cfs.energy
tae	H-B11 field-reversed configuration	1998	$1,200.0	Google, Chevron, Sumimoto, Venrock, Vulcan Capital, RUSNANO, Reimagined Ventures, TIFF	www.tae.com
HELION	D-He3 magneto-inertial fusion	2013	$1,000.0	SoftBank Vision Fund 2, Lightspeed Ventures, Sam Altman, Mithril Capital, Capricorn, Good Ventures, Newcor	www.helionenergy.com
PACIFIC FUSION	Pulsed magnetic fusion	2023	$900.0	General Catalyst, Eric Schmidt, Breakthrough Energy Ventures, Lowercarbon Capital, John Doerr	www.pacificfusion.com
generalfusion	Liquid metal magnetic compression	2002	$455.0	BDC, Braemer Energy Ventures, Segra Capital Management, Jimco, Chrysalis Venture, Khazanah Nasional, SET Ventures	www.generalfusion.com
SHINE	Unstated	2005	$414.0	Baillie Gifford, Fidelity, Koch Disruptive Technologies, Government of the Netherlands	www.shinefusion.com
Tokamak Energy	Magnetic Confinement (Tokamak)	2009	$335.0	East X Ventures, Lingotto inverment Management, British Patient Capital, Furukawa Electric, BW Group, Sabanci Climates	www.tokamakenergy.com
ZAP ENERGY	Sheared-flow-stabilized Z-pinch	2017	$327.0	Soros Fund, Lauren Powell Jobs, Addition, Breakthrough Energy Ventures, Chevron Technology Ventures, DCVC, Energy Impact Partners	www.zapenergy.com
MarvelFusion	H-B11 laser inertial confinement	2019	$123.0	HV Capital, Earlybird Venture Capital, Athos Venture, Primepulse, Plural Platform, Deutsche Telecom	www.marvelfusion.com
first light	Projectile-based inertial fusion	2011	$114.0	Braavos Capital, Hostplus IP Group, Oxford Sciences, Tencent, invesco, Sandaire, ParkWalk Advisors	https://firstlightfusion.com/
XCIMER	D-T laser inertial confinement	2021	$100.0	Breakthrough Energy Ventures, Lowercarbon Capital, Prelude Ventures, Emerson Collective, Gigascale Capital, Starlight Ventures	https://xcimer.energy/

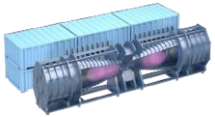
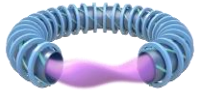
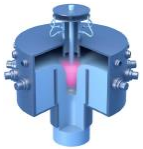


Global Fusion Market Development & Goals

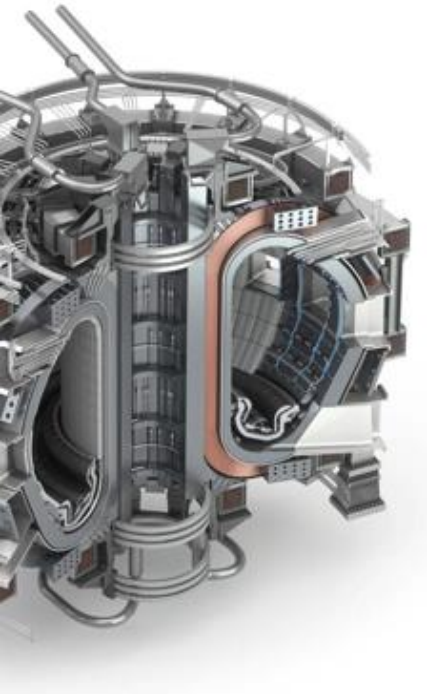
2025-2028	2025-2028	2028-2032	2032-2038	2045-2050
Global Regulatory NRC1, UKAEA and other national regulation are set.	Fusion Prototypes National Labs and private companies Up to 100MW	Commercial Fusion Systems Microsoft & Nucor placed orders. Up to 400MW	Utility-Level Fusion Systems TVA, Duke, Sempra are early supporters clusters and 1+GW	10% of the Grid Fusion Systems Global Brown Field and Green Field deployments

1: https://www.fusionindustryassociation.org/us-senate-passes-advance-act-including-legislation-to-codify-us-fusion-regulations/

Commercial Fusion Plants Breaking Ground

							
	Tokamak	Magnetic Mirror	Stellarator	ICF Direct	Z-Pinch	Tokamak	ICF Direct
Fusion Company	Commonwealth Fusion Systems	HELION	TYPE ONE ENERGY	PACIFIC FUSION	generalfusion	Tokamak Energy INC.	FOCUSED ENERGY
Partner(s)	Dominion Energy	Microsoft	TVA TENNESSEE VALLEY AUTHORITY; OAK RIDGE National Laboratory	Lawrence Livermore National Laboratory	Innovation, Science and Economic Development Canada	UK Industrial Fusion Solutions	RWE
Capacitor Flim	250,000 Pounds	5,000,000 Pound	250,000 Pounds	1,000,000 Pounds	250,000 Pounds	300,000 Pounds	1,000,000 Pounds
Power Produced	400MW 2035	400MW 2028	350MW 2030s	100MW 2030s	400MW 2030s	40MW 2030s	100MW 2035
	Source Link	Source Link	Source Link	Source Link	Source Link	Source Link	Source Link

Fusion Energy Scalability Challenges

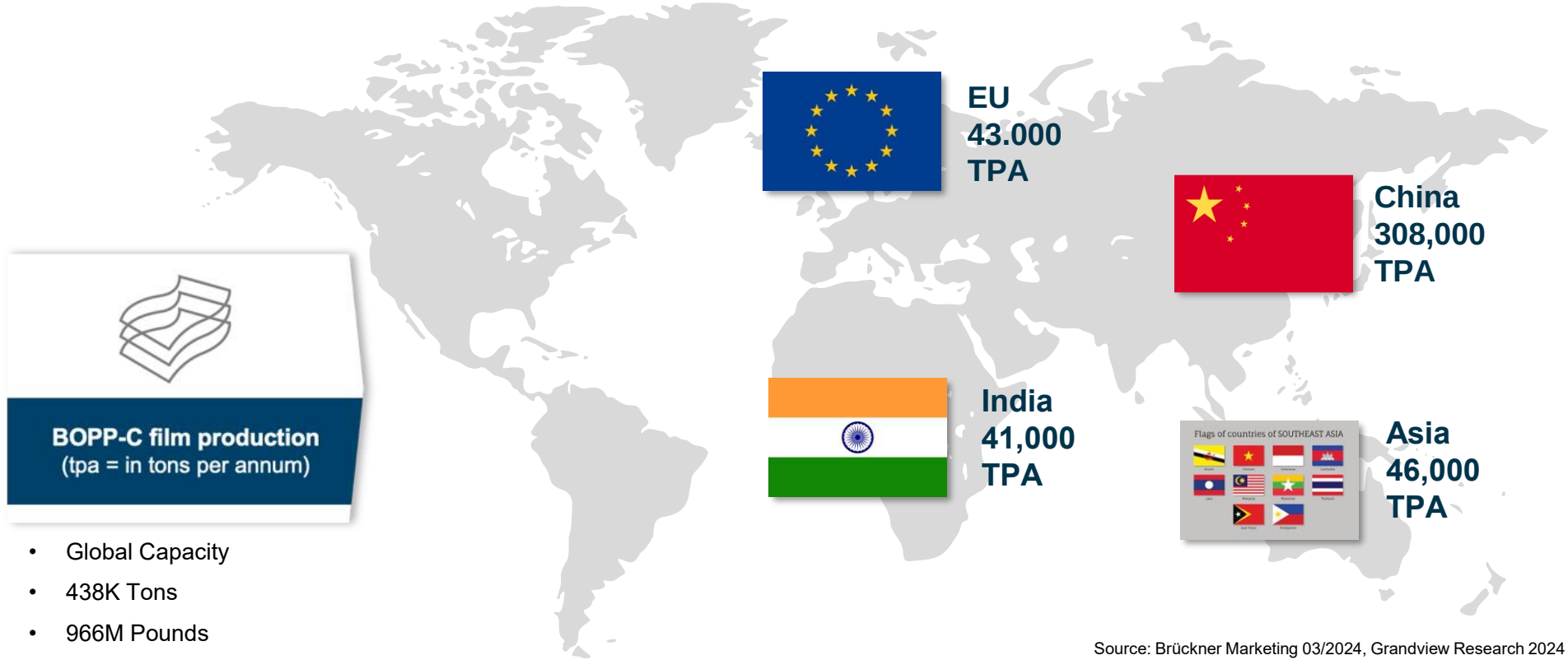


Fusion Scalability Challenges

1. Fusion still needs to reach close to 24/7 plasma containment
2. We still have to transfer the heat from fusion into steam for generators
3. Tritium fuels supply are very limited and tritium blanket are not yet the answer
4. Over 70 different plant designs makes a scalable supply chain very difficult
5. China tariffs threaten required critical minerals, materials and BOPP-C Film

* BOPP = Biaxially Oriented Polypropylene

Global BOPP-C Production: The world is ready right…….

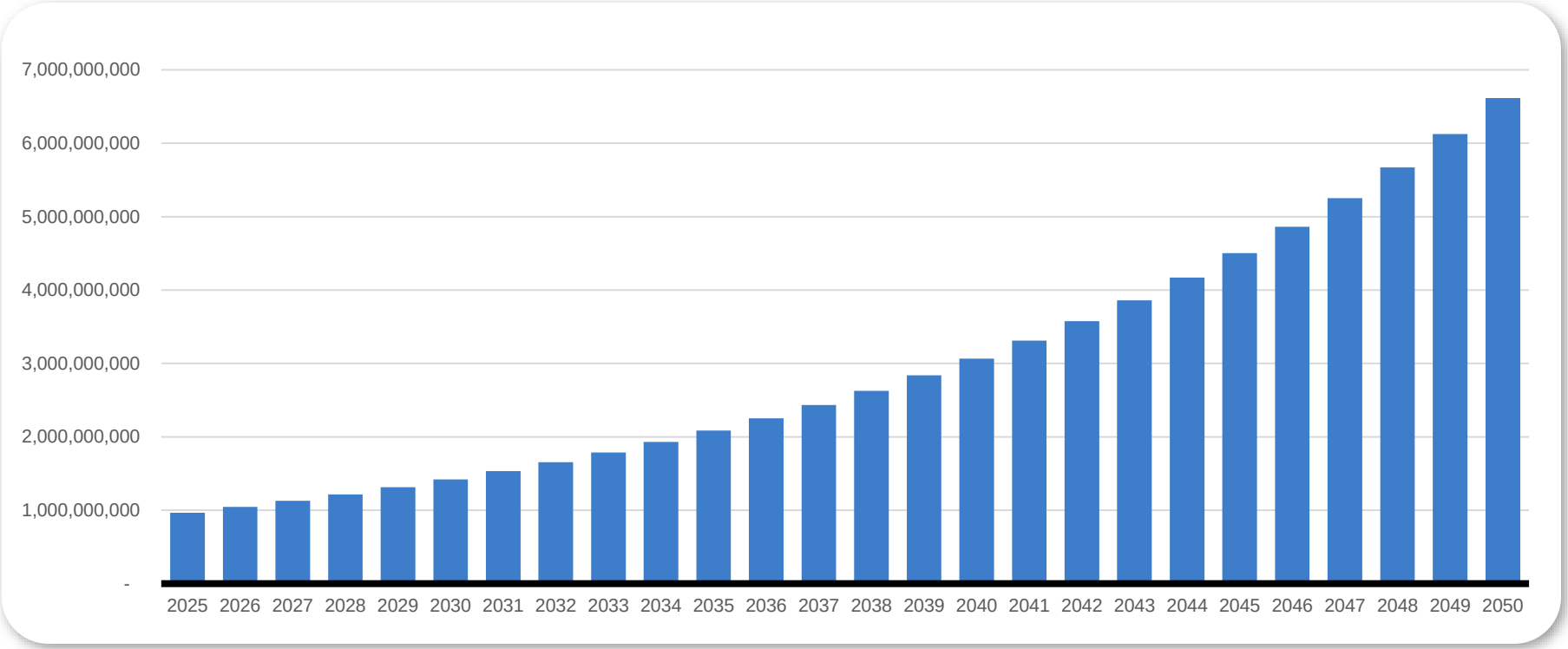


BOPP-C film production
(tpa = in tons per annum)

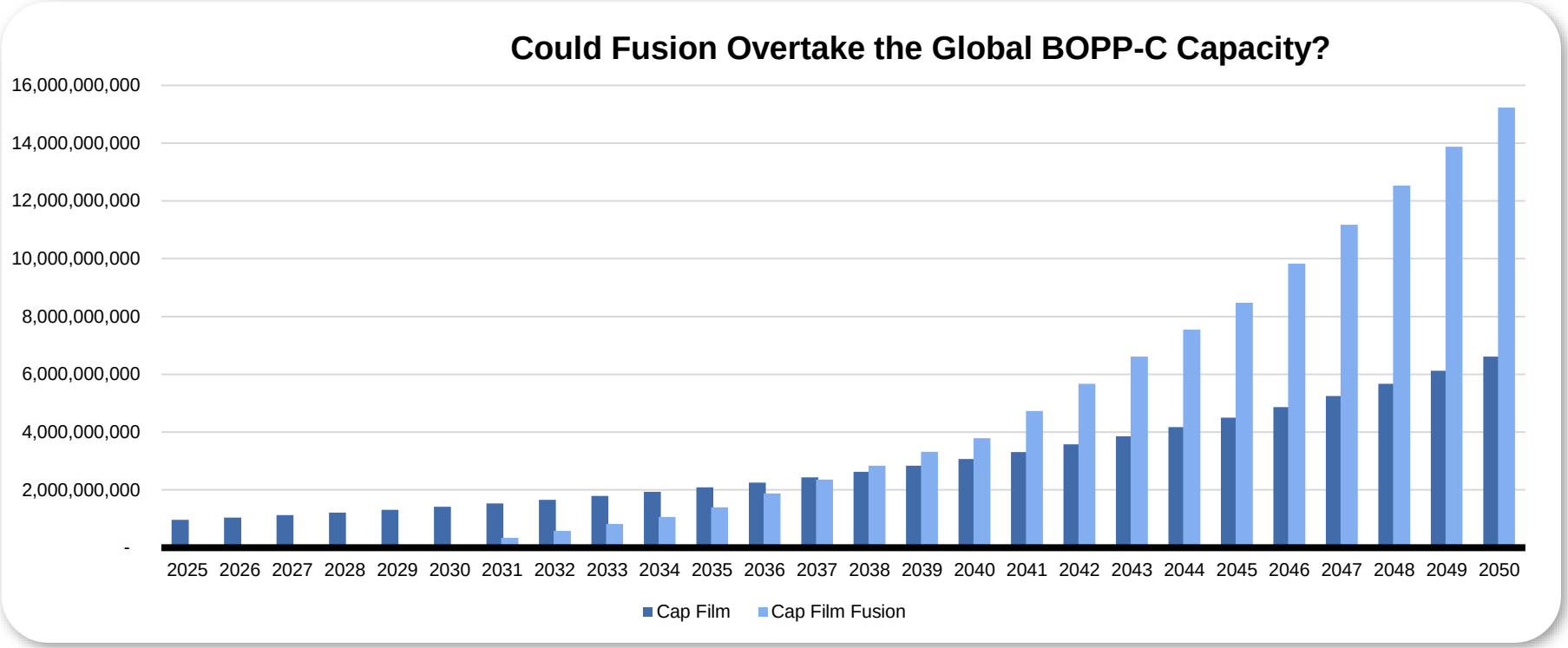
- Global Capacity
- 438K Tons
- 966M Pounds

Source: Brückner Marketing 03/2024, Grandview Research 2024

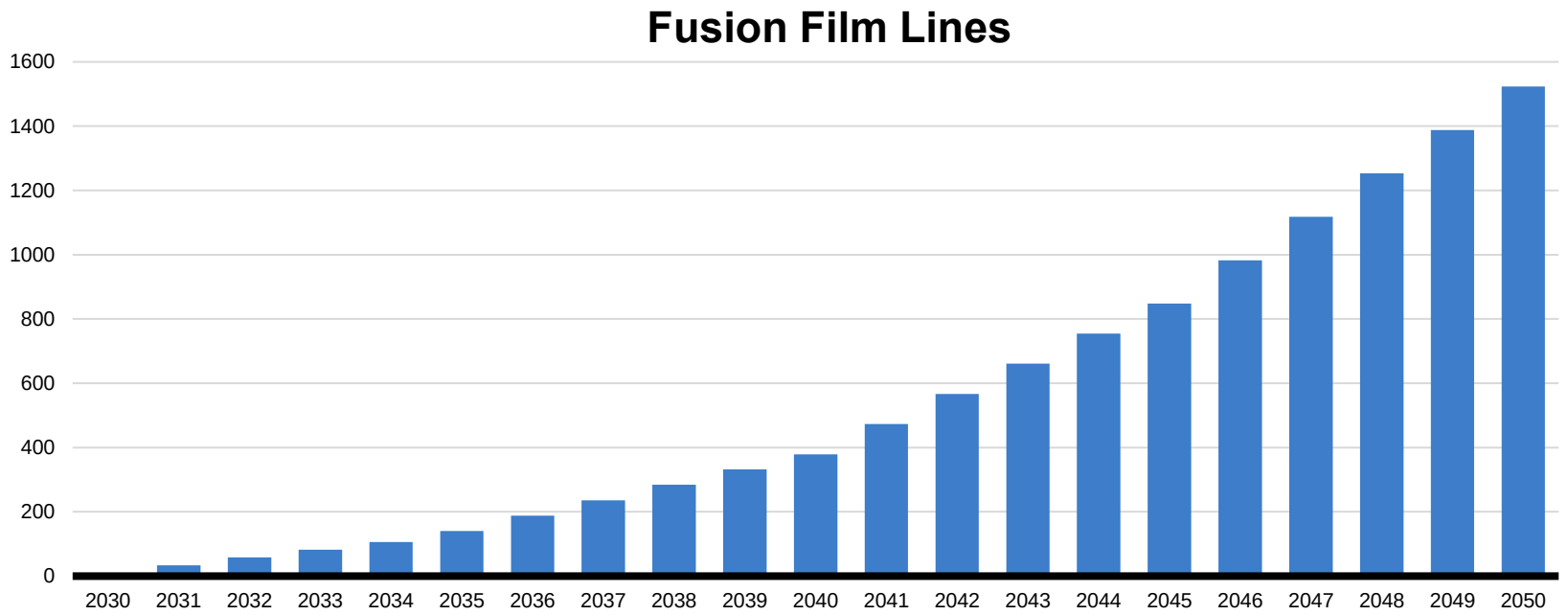
Projected BOPP-C Film Growth in Pounds



Fusion Will Exceed World Capacity in 2037

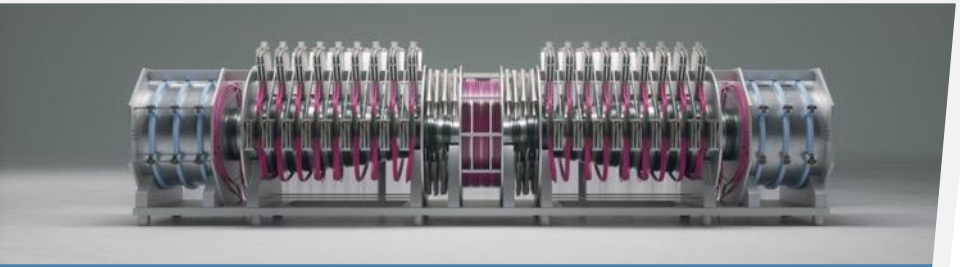


Fusion Energy Film Lines @ 7.5M/Line

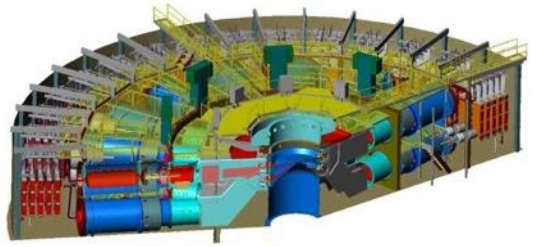


Sources: Brückner Marketing 03/2024, Grandview Research Report 2024, and Ignition Research Report 2024

We Need More Power!



50 MJ Helion fusion reactor with associated capacitor bank (structure behind).
2024 design of potential capacitor bank contains roughly 1.2 million pounds of film.



Next Gen. 2035 Fusion Reactor

- 91 meters wide
- Capacitors increase from 2,100 -> 13,500
- Dielectric cap. film from ~180K -> 1-1.5 Million lbs.

Schematic representation of Sandia's planned next generation reactor, which projects to use between 1 and 1.5 million pounds of capacitor film to pulse its lasers.

Current Fusion landscape is in the "show me'" phase

- Goals are "demonstrator" scale fusion systems

Discussions starting for "Power Plant" sized (> 100 MJ) Fusion System and schedules

- ARPA-E presentation[1] on potential 10-year DOE ICF Program targeted for 2035 operations

Company	Approach	Name	Size	Target Date:
General Fusion	Magneto Fusion (MTF)	LM26		2026
Helion	Magneto-Inertial fusion		50 MJ	2028
Commonwealth/MIT	Magneto Fusion (MTF)	SPARC	50-100 MJ	2025
NIF/LLNL	Inertial Fusion Energy (IFE)		20-150 MJ	2009-2024
Sandia	Inertial Fusion Energy (IFE)	Z	up to 300 MJ	1996-2024

1. Ahmed Diallo presented at IEEE Fusion Workshop, June 2023.

“I’m Giving it All I Got” – Supply Chain Challenges

Building multiple demonstrator or any “power plant” fusion systems need supporting technology advances & increased capacity to succeed

Key supporting system components

High Speed Switches: All options needed at higher production rates and lower costs than currently offered

- Spark gaps – low lifetime
- Solid state – insufficient current/voltage rating
- SiC based – low current/voltage and high cost

Energy Storage:

- Needs include longer lifetime (move from million to billion shot lifetimes)
- Require higher energy densities in ICF systems
- Overall volume of required caps (2,000+/yr. per fusion system) require paradigm shift in manufacturing process and infrastructure

Capacitor Scaling Case Study	
Ask: Support 100 Fusion power plants (100 MW)	
Capacitors required per year for 1 fusion plant	10,000
Annual U.S. high voltage cap. mfg. capability	12,500
Capacitor lead time for 1 plant	0.8 years
Capacitor lead time for 5 plants	6.3 years
Capacitor lead time for 25 plants	20.0 years
Capacitor lead time for 100 plants	80.0 years

Global Supply Chain Landscape

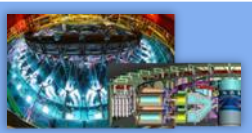
Global capacity of key components is not equal
(Case study: capacitor dielectric film)

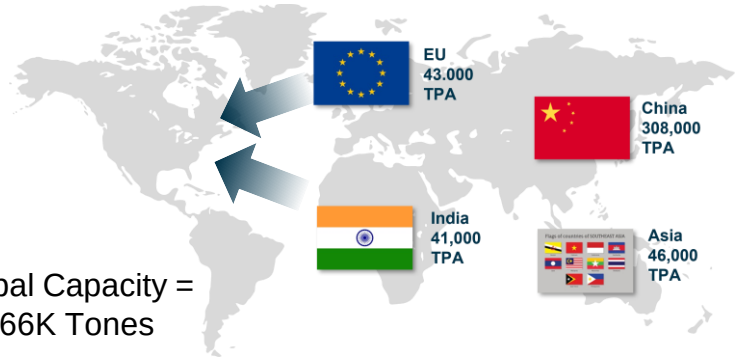
What is a Pulsed Power Capacitor?

Crude Oil Refineries → Plastic Resin Reactors → Capacitor Film Extrusion → Film Metallization → Capacitor Winding & Fabrication → Capacitor System Integrators







Global Capacity = 366K Tones

Today, North America is 100% dependent on foreign sourcing of dielectric films to fabricate capacitors.

Global electrification efforts are leading an increased demand for energy storage film

- Films markets: GRID storage, EV, power conditioning, renewables, fusion
- Capacity models are predicting a global film shortage as earlier as 2028

Fusion growth has the potential to become growth leader and highest volume consumer of dielectric film in a market with tightening supply

Ahmed Diallo presented at IEEE Fusion Workshop, June 2023.

Closing Thoughts

- Fusion is proven to work at “lab” scale
- Scale-up is the next challenge
  - Reactor and overall system engineering challenges to increase efficiency
  - Supply chain is becoming a priority for companies involved
- Over $8B in private capital through Q1 CY2025
  - $7.1B FIA in 2024
  - & 2025 Q1 The Fusion Report
- Fusion on the Grid Timeline
  - Helion Deployment in 2028
  - CFS/Dominion in mid 2030s
  - TypeOne/TVA in mid 2030s
- We All Need More Bruckner Capacitor Film Lines!

Thank You Brueckner!

- Questions?
- Follow-up questions to Peak:
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      Chief Science Officer
      mponting@peaknano.com
      216 - 374 - 5190
  - Marketing & Sales:
    - Shaun Walsh
      Chief Revenue Officer
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      949 - 922 - 7472


peak