ZAP ENERGY

APEC

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Fusion Energy on the Horizon

The Key Role of Power Electronics to Commercial Fusion

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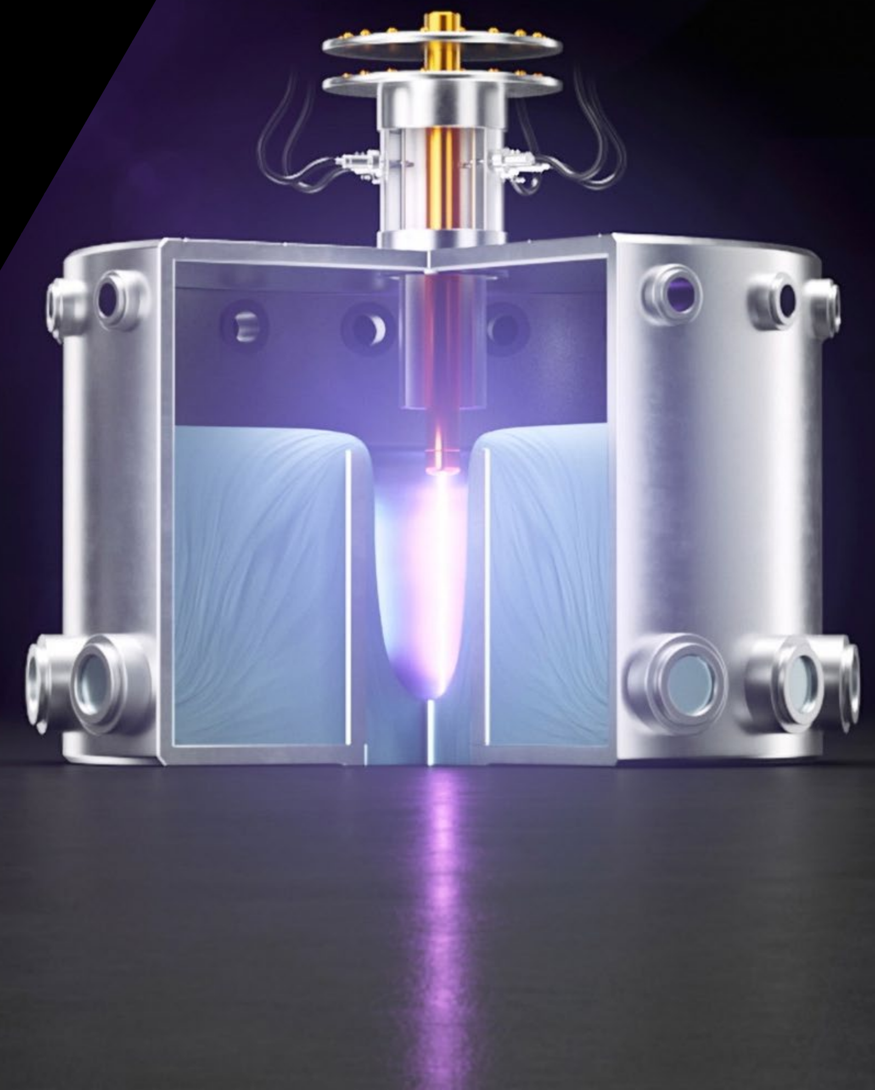
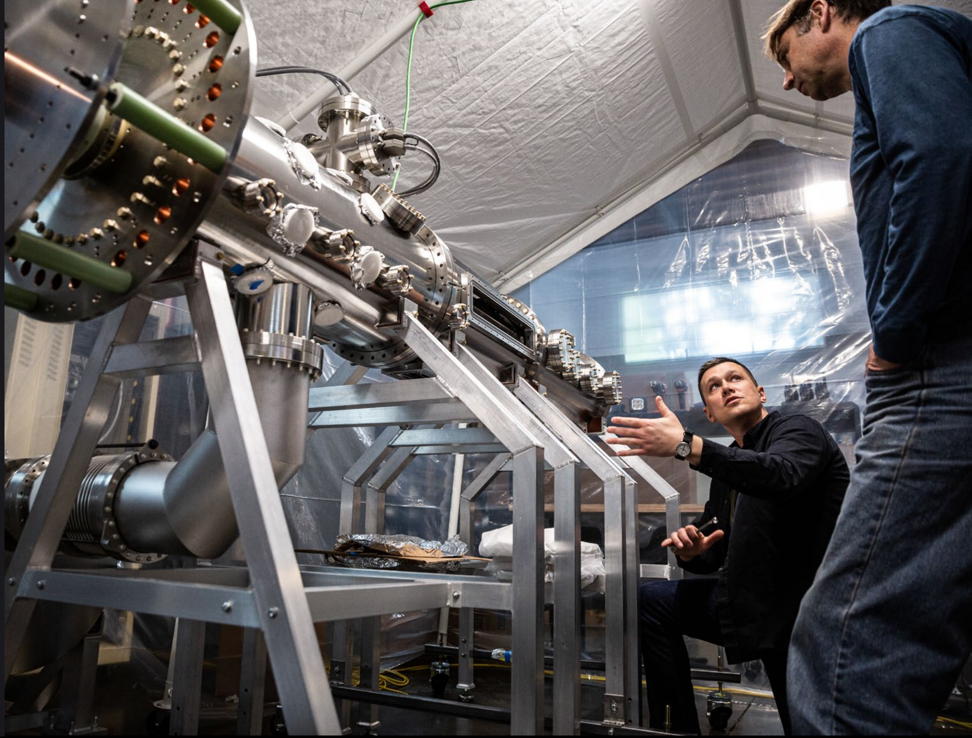
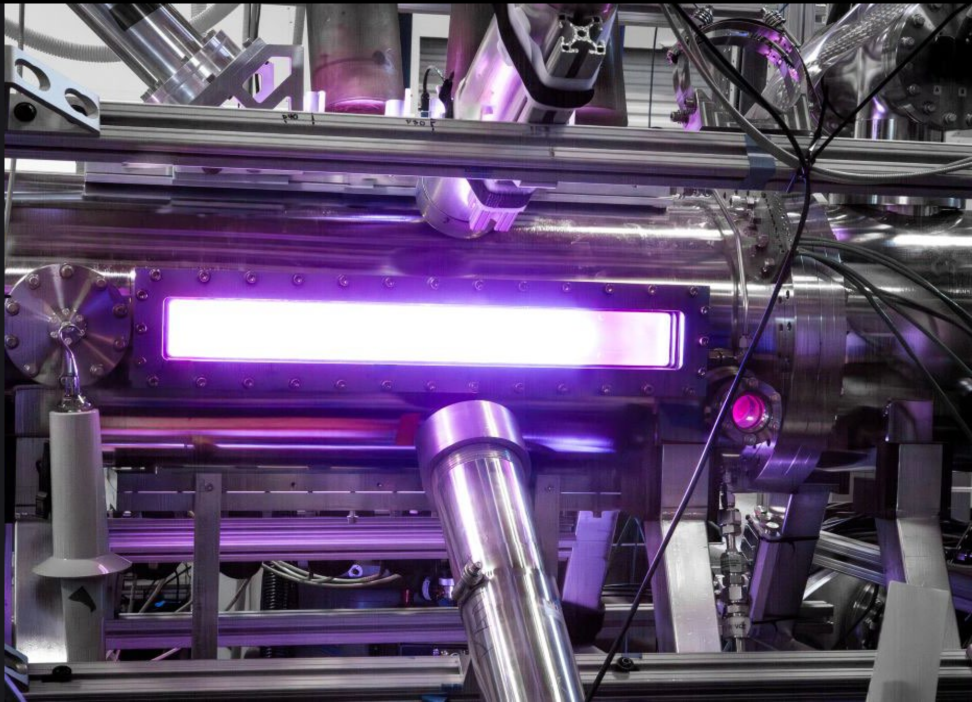


About Zap

- Founded in 2017
- Headquartered in Everett, WA (north of Seattle) with offices in San Diego and Denver
- The only fusion company focused on sheared-flow-stabilized Z-pinch
- Roughly 150 employees; 80% technical
- Built on research at the University of Washington and Lawrence Livermore National Laboratory dating back to the 1990s
- $200M+ in funding by strategic investors

ADDITION
Breakthrough Energy Ventures
LOWERCARBON CAPITAL
Chevron
ENERGY IMPACT PARTNERS
DCVC
VALOR EQUITY PARTNERS
Shell Ventures





Fusion will be vital to meet future energy needs

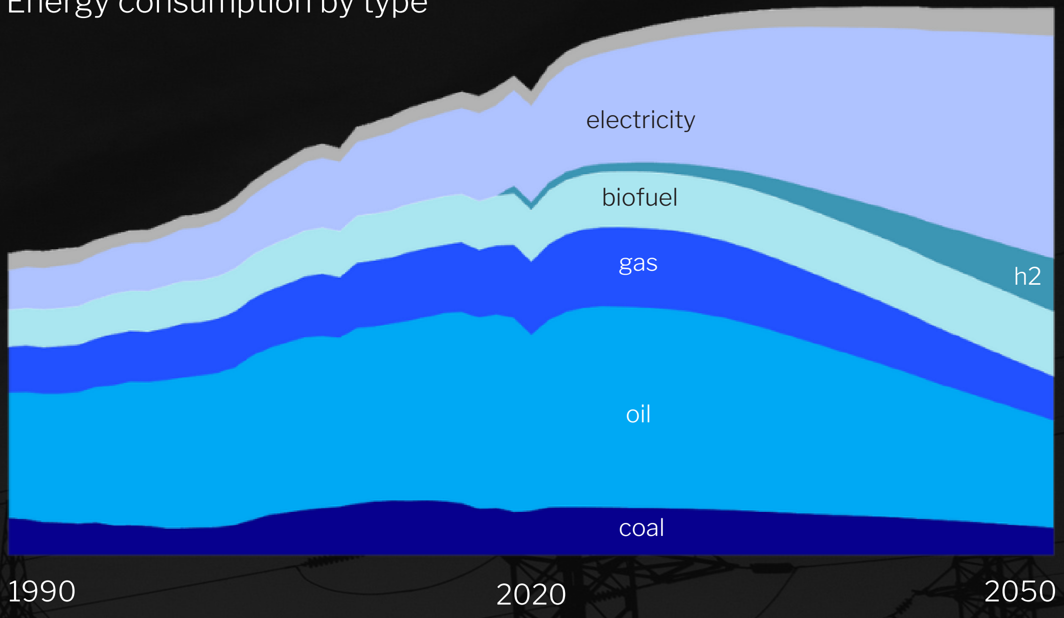
Growth in energy demand and intermittent renewables in addition to electrification are creating a premium market for emissions-free baseload power sources

Climate change has raised the stakes. A net-zero energy transition is expected to require $110 trillion through 2050 [2]

More than 40 private fusion companies have raised over $6B to date, mostly in the last few years, adding talent and innovation [3]

Fusion leadership will be a national imperative. The federal government has begun to step up more broadly to support the nation's competitive position [4]

Energy consumption by type [1]



By 2050:

3x

electricity demand

43%

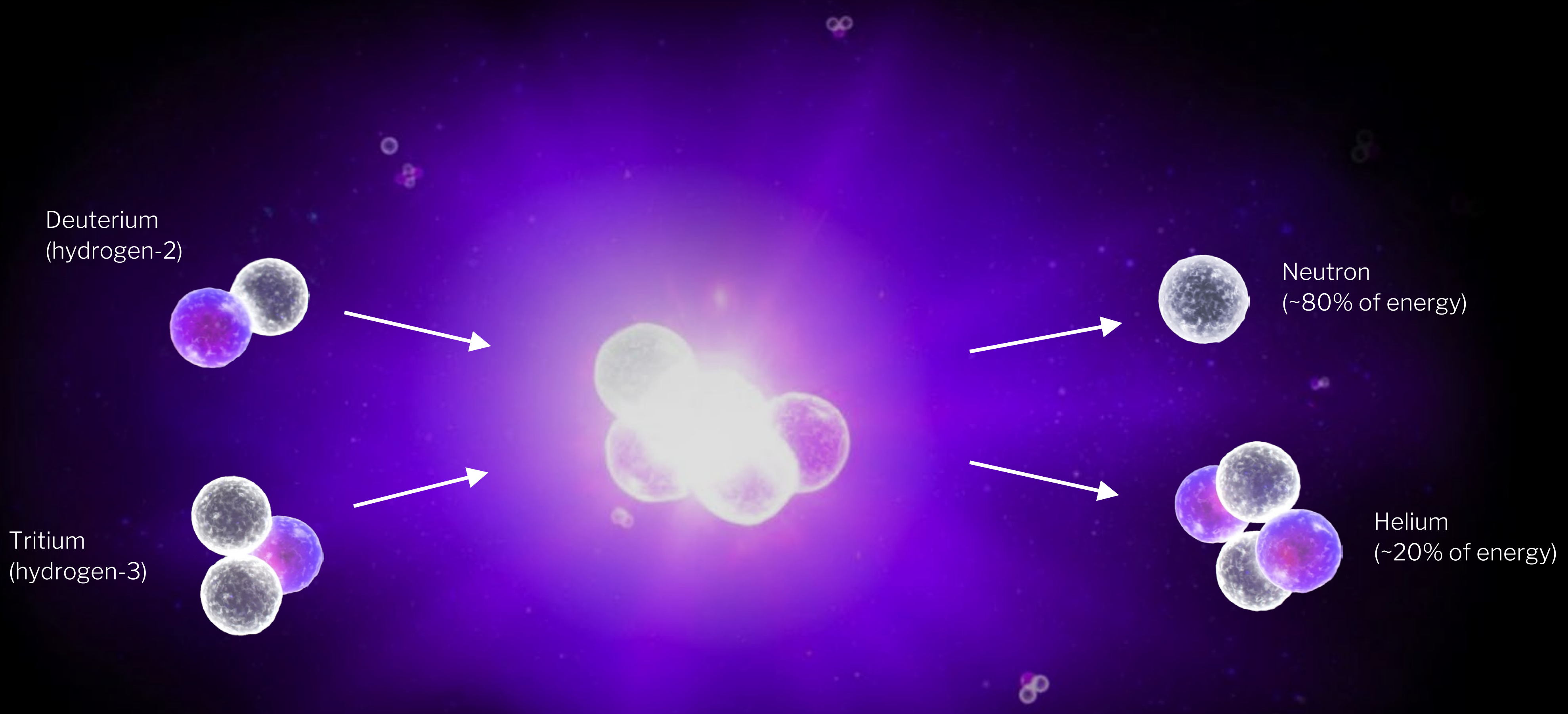
of global energy use remains fossil fuels

1) McKinsey & Co., *Global Energy Perspective 2022*
2) Energy Impact Partners, *Impact & Performance Report 2022*
3) Fusion Industry Association, *Annual Report 2023*
4) American Institute of Physics, *Federal Pivot to Supporting Commercial Fusion Energy Underway*

Why fusion?

On Demand / Baseload	Capable of high uptime and load balancing
Clean / Carbon-Free	No emissions or long-lived radioactive waste
Fuel Price & Abundance	Fuels are cheap and globally dispersed
Safety	No risk of meltdown or significant public health hazards
Land Efficiency	Can be flexibly sited, with a similar footprint to existing power plants
Public Acceptance	Clean slate, bipartisan support

Fusion fundamentals



The case for medium density fusion

Big Magnets

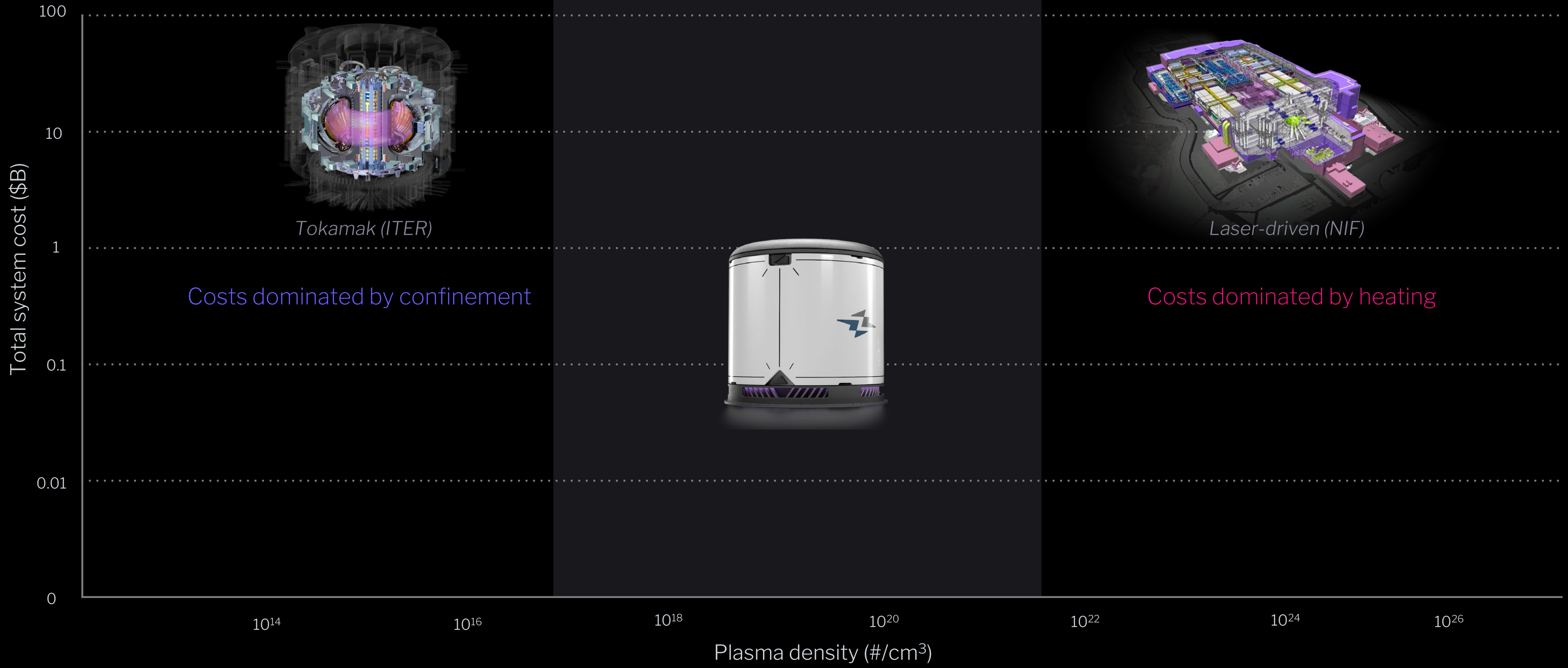
Continuous operation of low-density plasmas requires big, expensive devices

Zap

Medium-density, repetitive cycles offer thermal efficiency at lower cost

Big Lasers

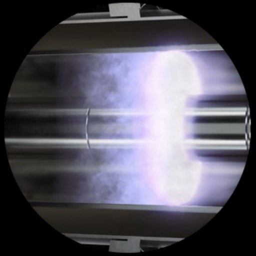
High-density, explosive energy release requires high cost of power



Z-Pinch fusion: magnetic confinement without magnets

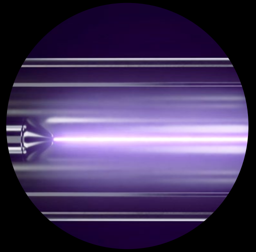
1. Ionize

Deuterium gas injected and ionized into plasma



2. Accelerate

Plasma accelerates down coaxial accelerator

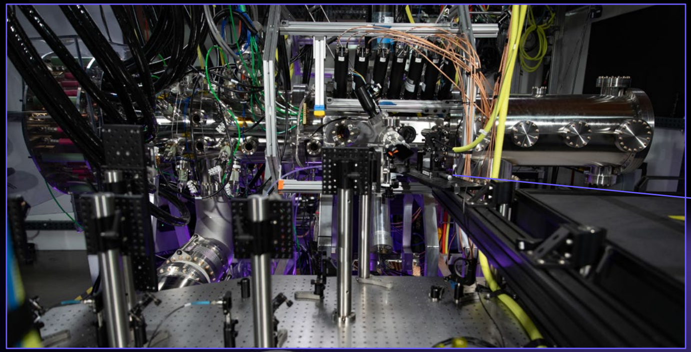


3. Pinch

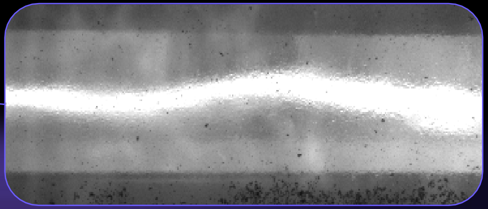
Z-pinch plasma column assembles on axis and compresses

4. Fuse

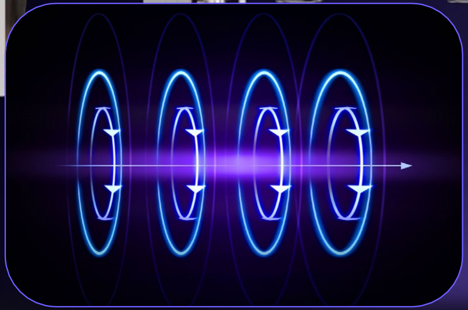
Fusion neutrons detected to diagnose fusion reactions



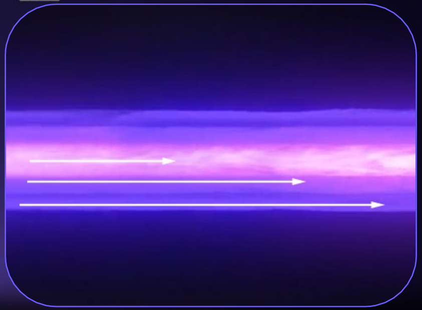
High-speed image



Plasmas ~50cm long last tens of microseconds



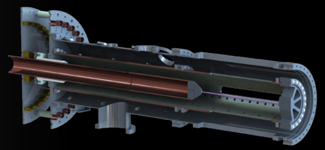
Z-pinch compression creates fusion



Embedded sheared flow provides stabilization

SFS Z-pinch plasmas lead to better power plant economics

Size of Device	~25 m^3 core size for 50 MWe
Complexity	No magnets, cryogenic or lasers
Iteration Speed	Single-year cycle
Fuel	Deuterium-tritium
Neutron Damage	No solid first wall, resilient liquid metal design
Plant Design	Modular, factory-built cores



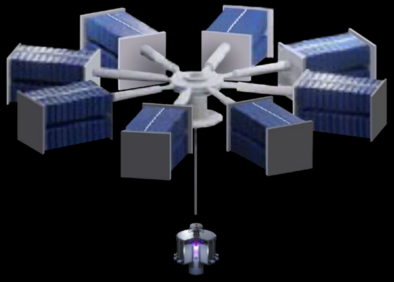
R&D Prototype

Integrated Demonstration

Commercial Systems

Beyond physics: developing power plants

High rep-rate pulsed power

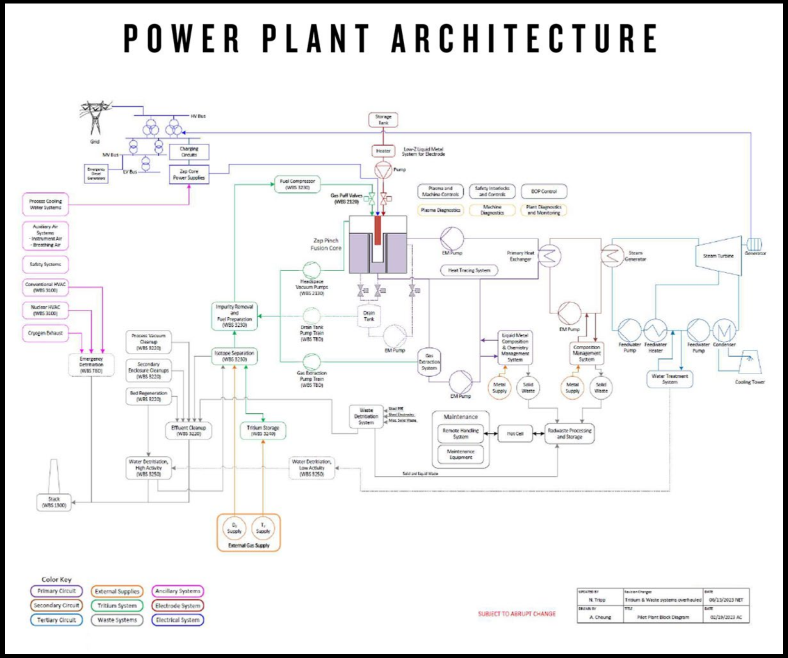


First-gen advanced power source subsystem

Circulating liquid metal

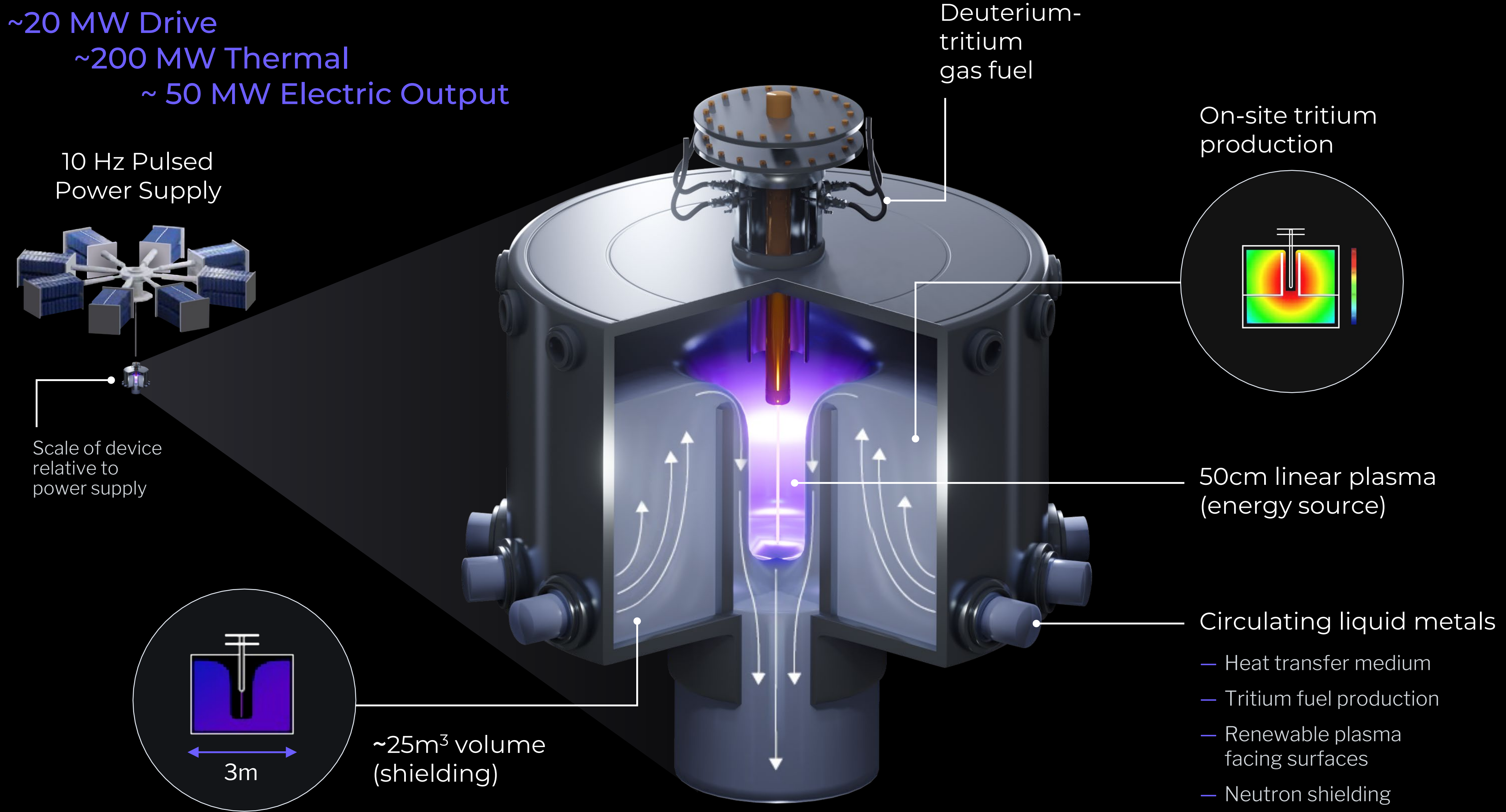
Circulating liquid metal test stand

System integration and pilot plant design

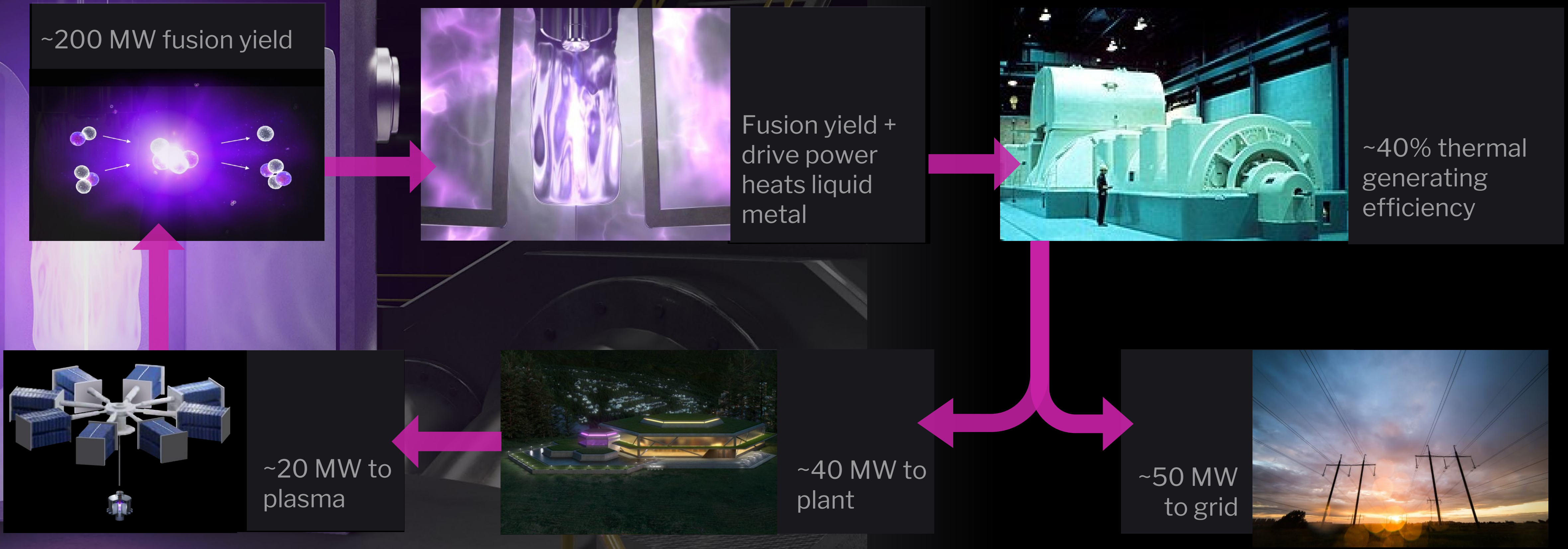


Preliminary power plant design schematic

Engineering paradigms

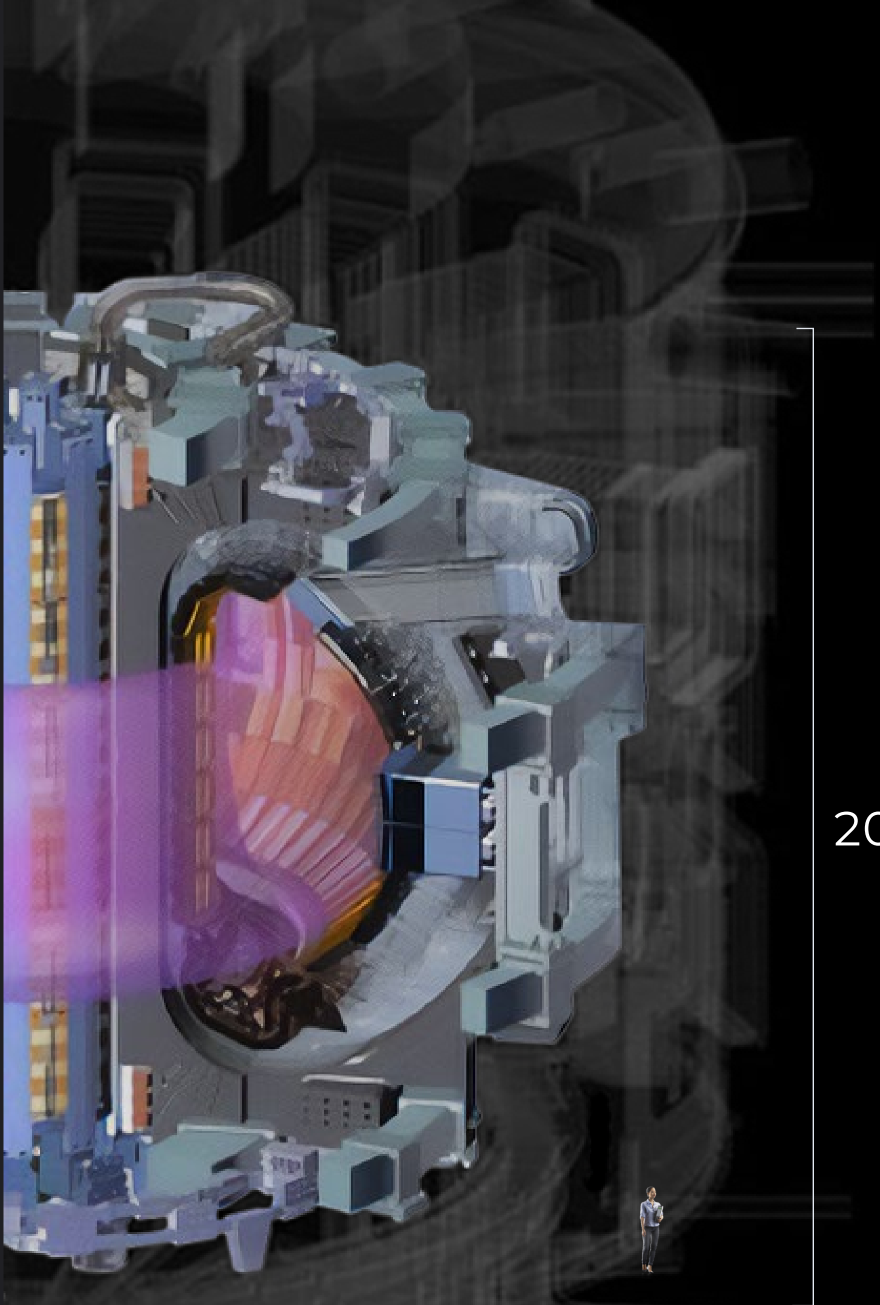


Fusion and recirculating power



Tokamaks vs. Z-pinch

Zap requires far fewer plasma subsystems



Tokamak core (ITER)

Tokamak major subsystems

- Vacuum
- Magnetic Coils
- Cryogenic Plant
- Auxiliary Heating

Power Supplies:

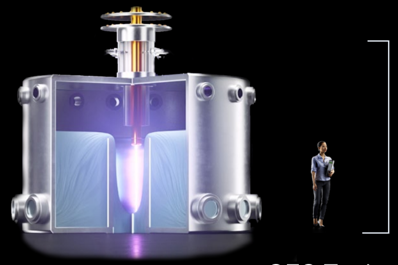
- Toroidal Field Coils
- Poloidal Field Coils
- Power Management
- Energy Storage
- Breakdown
- Real-Time Control
- Auxiliary Heating
- Diagnostics
- Facility

SFS Z pinch major subsystems

- Vacuum

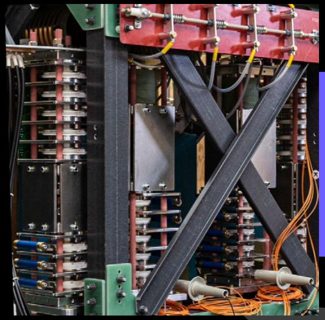
Power Supplies:

- Power Management
- Energy Storage
- Breakdown
- Diagnostics
- Facility



SFS Z-pinch core (Zap)

Power electronics in Zap power plants



High Power Driver

Pinch-driven fusion needs GW peak power switches with fast rise times

SCADA, safety, automation

Recirculating

Power conditioning, conversion, etc.

Fusion Core

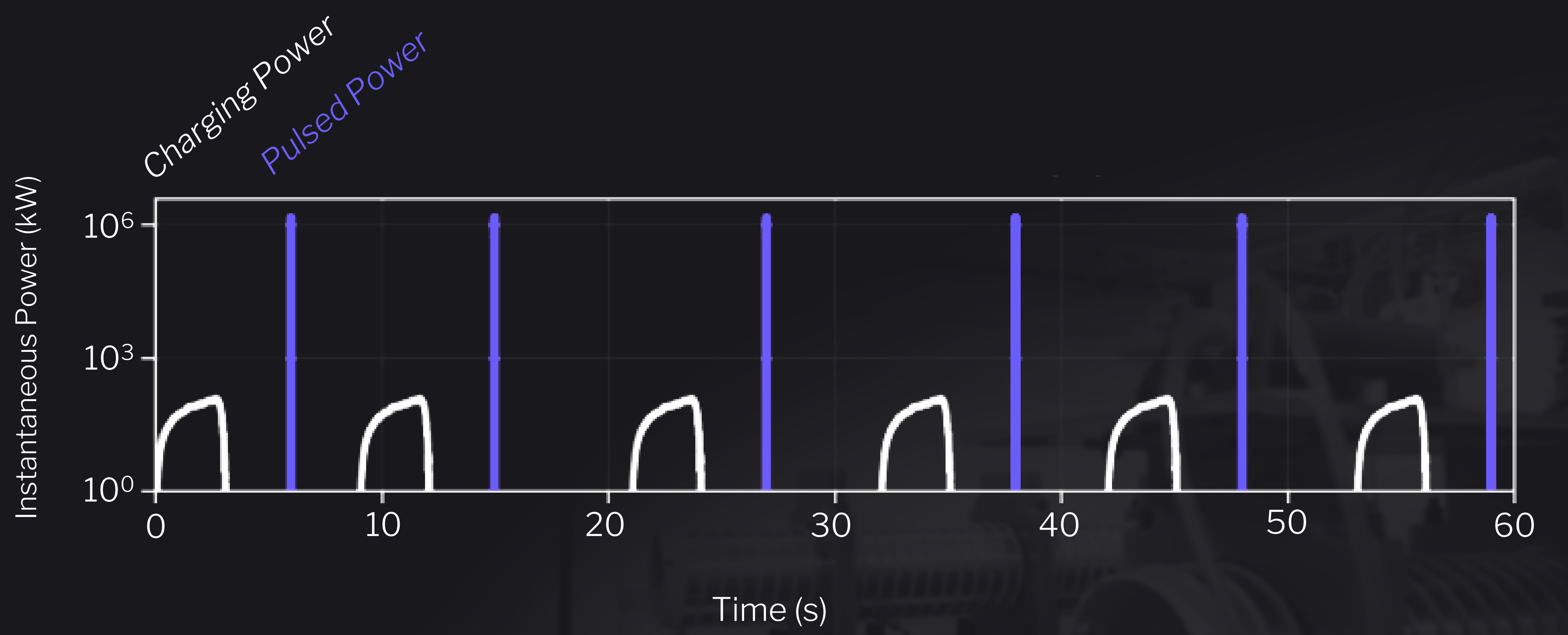
Harsh environment sensing technologies (high voltage, heat flux, pressure, radiation, etc.)

Power Conversion

Thermal to power conversion, industrial motor drives, output efficiency

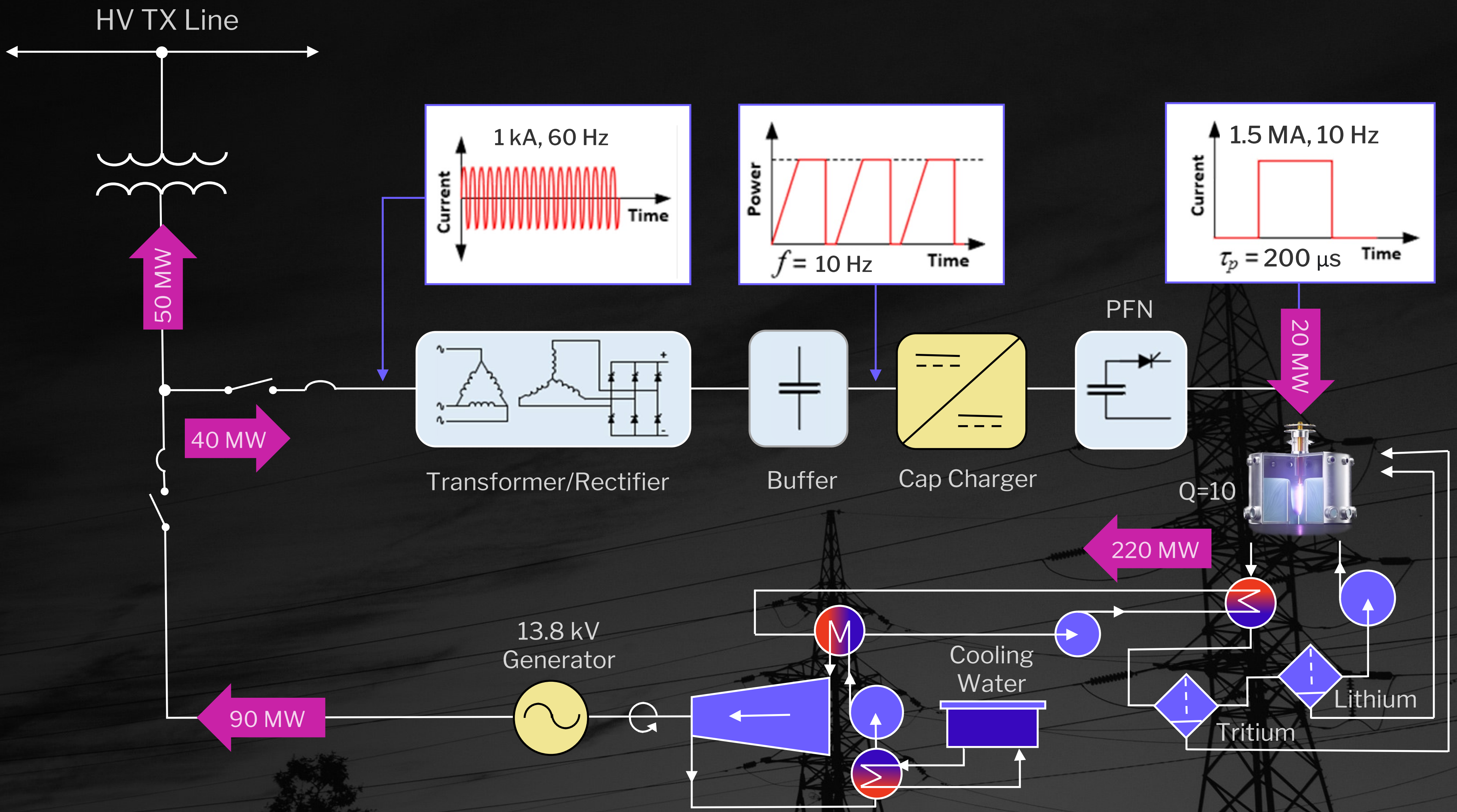
Power to grid

Z-pinch driver circuits compress power pulses



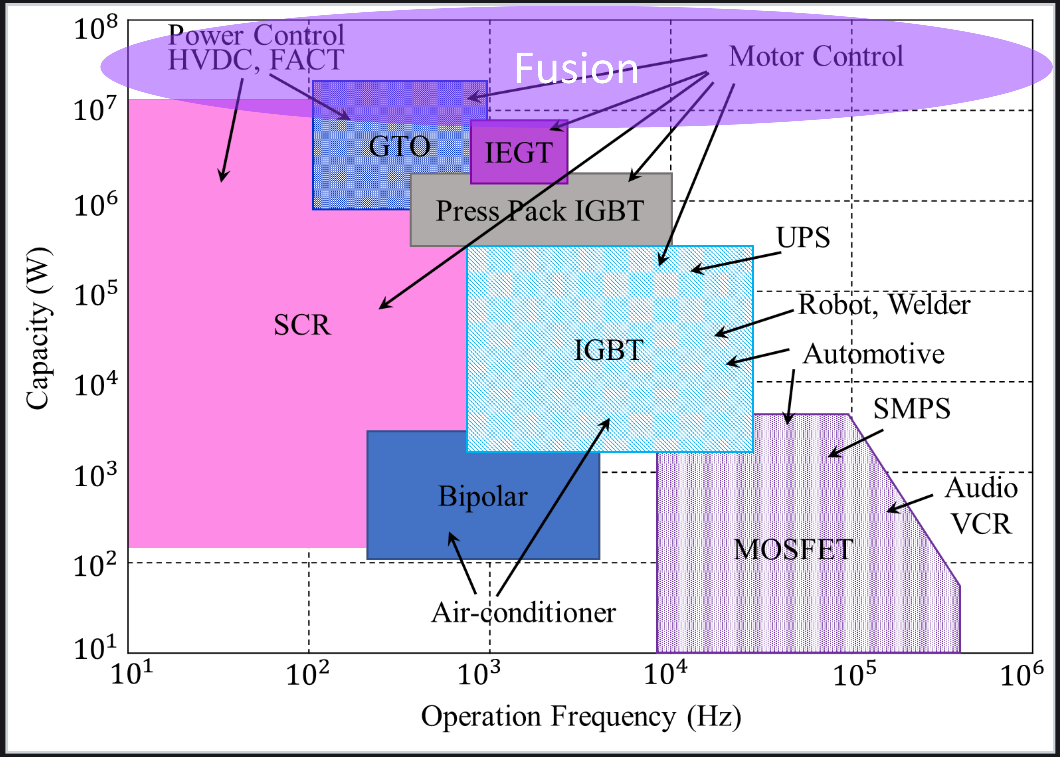
Data from our prototype repetitive Z-pinch driver

Plant electrical system



Technological Challenges: Semiconductor switches

- Repetitive pulsed power is not a traditional semiconductor switch application
- Cost-effective advancements needed in peak power capability
- Development in this field would unlock faster fusion progress and switch market growth



Application areas of classical discrete power semiconductors

Adapted from *Design, characterization and implementation of an integrated CMOS gate driver circuit for GaN components*, Nguyen, 2016 www.zap.energy