IEC P-B11 FUSION TORCH

Closing the Cycle

From Use to Reuse

A Road to a Sustainable Future

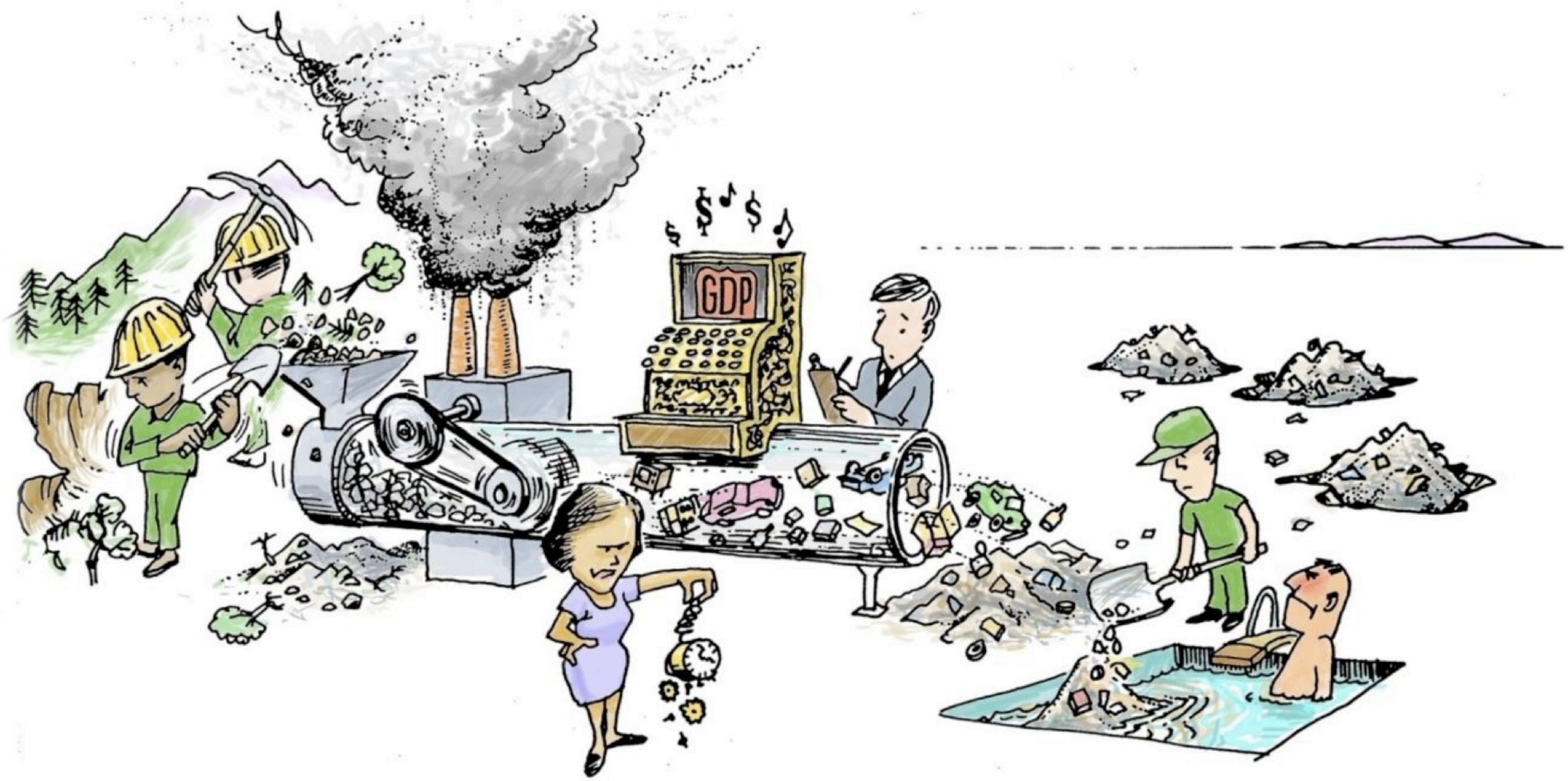
William C. Gough and George H. Miley

Artistic Contributions -- Bob Bourdeaux and Leon Hugo

With recognition of many contributions by the late Ben Eastlund

Ecology a subsystem of Economy

Today’s Open Economy

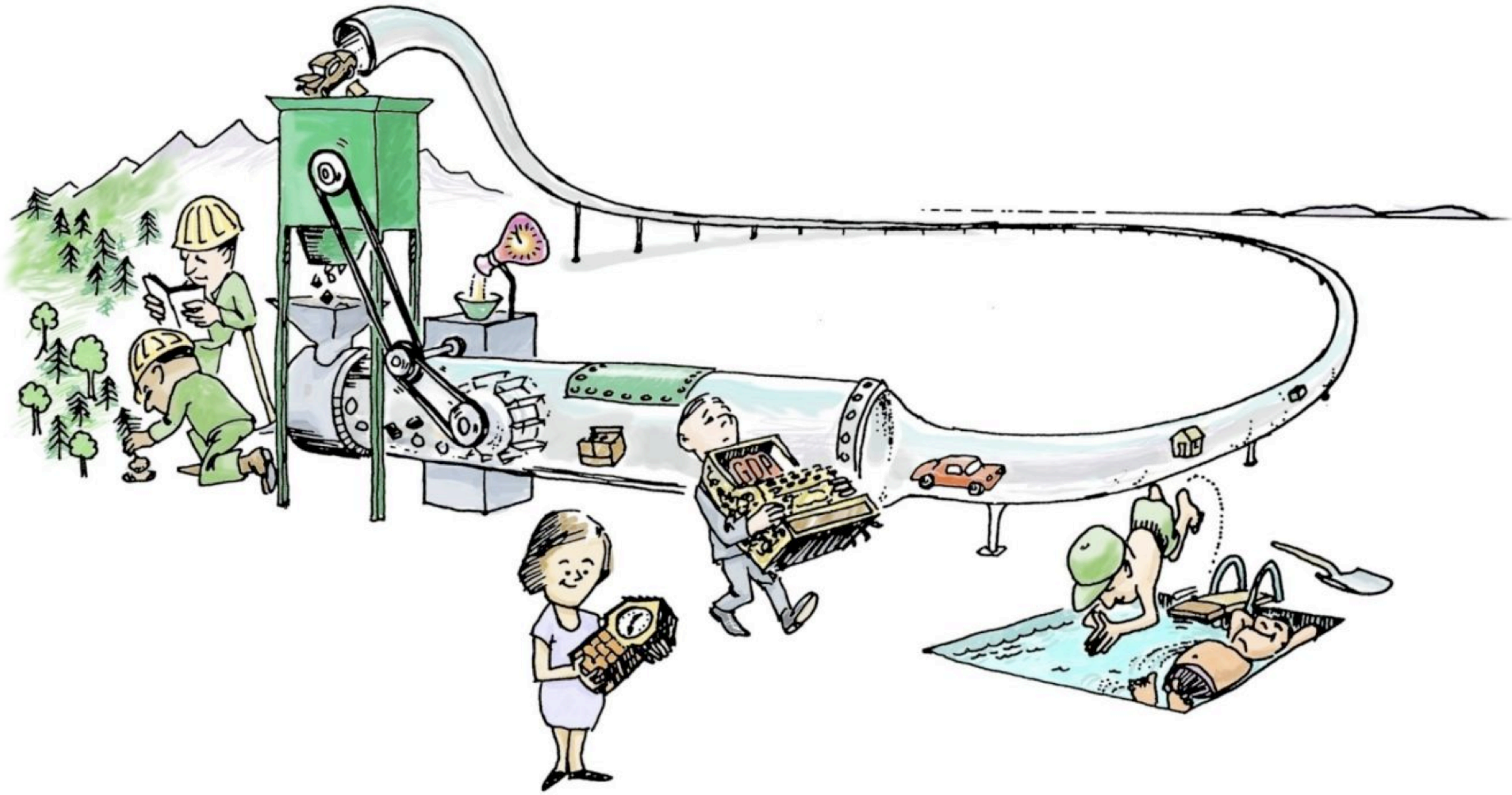


CLOSING THE MATERIALS CYCLE

Economy a subsystem of Ecology

CLOSING THE MATERIALS CYCLE

Closed Materials Economy

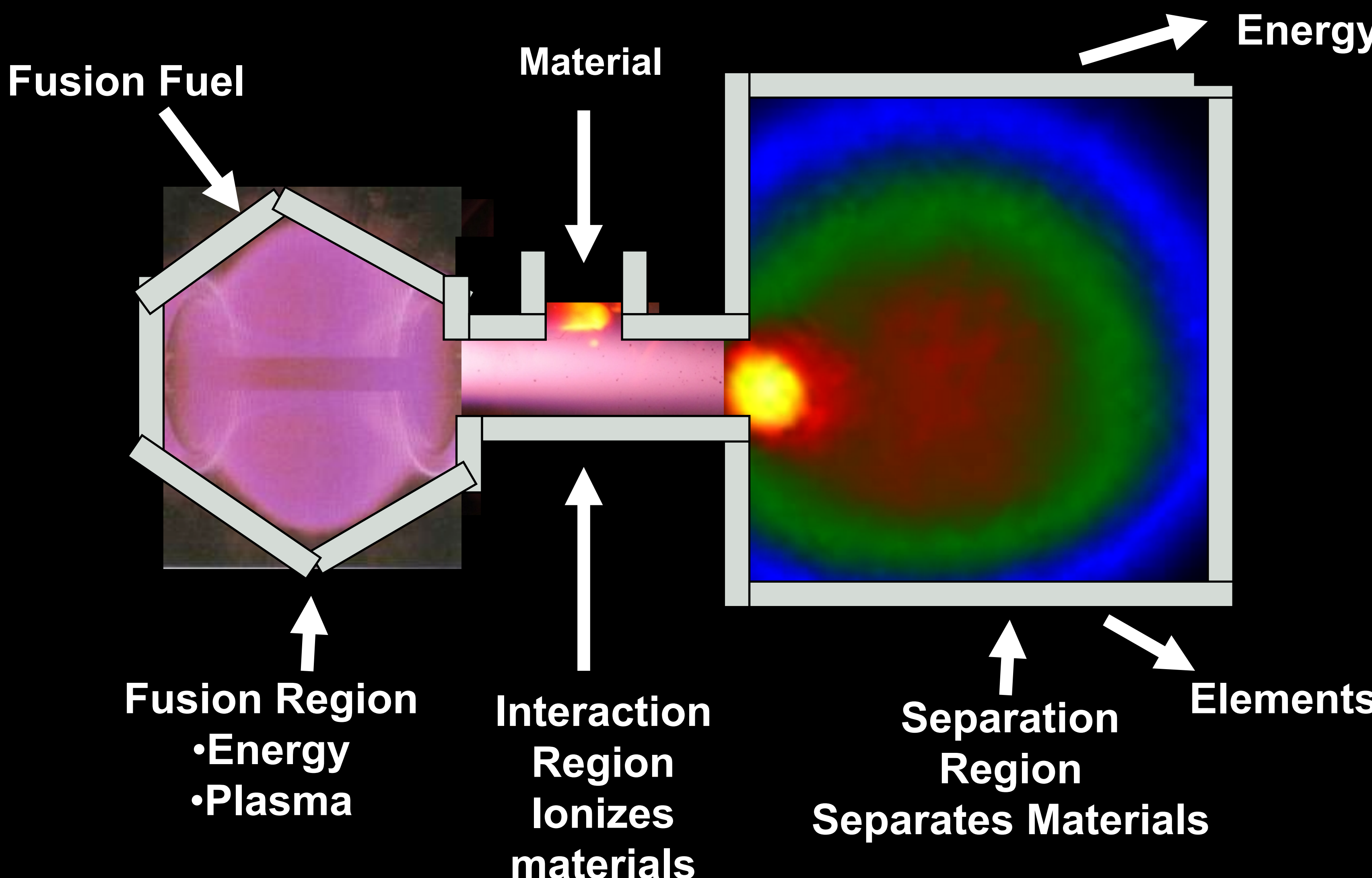


CLOSING THE MATERIALS CYCLE

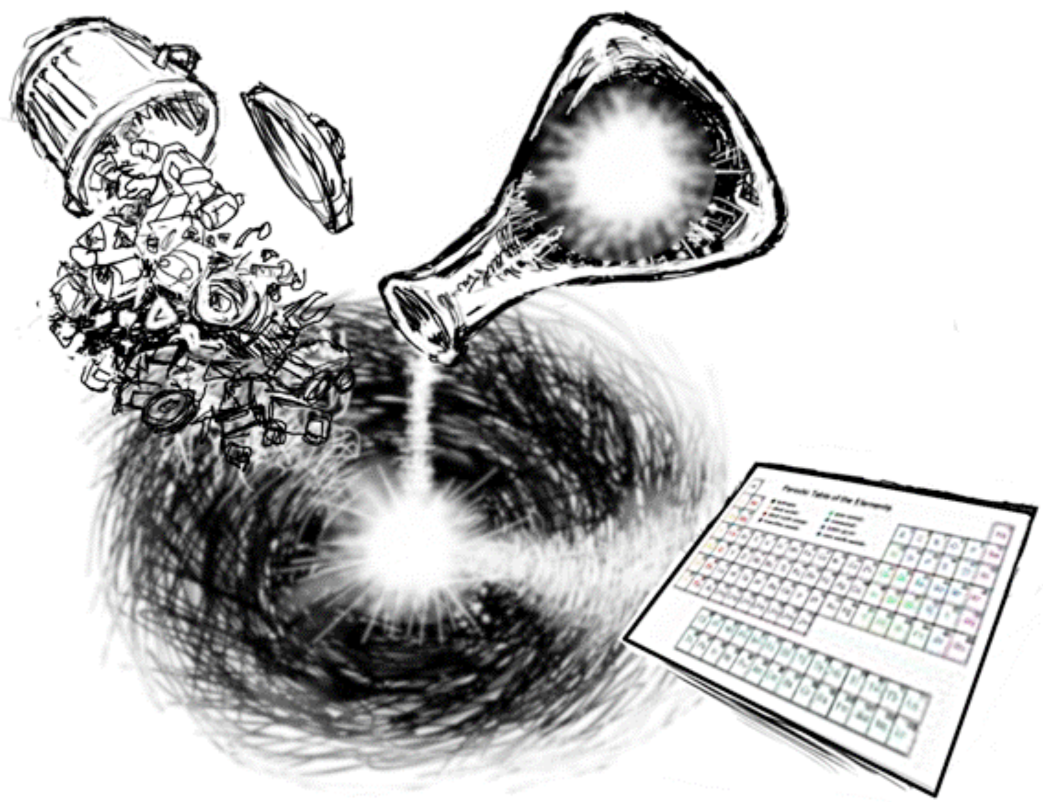
Strategic Issues are Drivers to Develop Boron Fusion Torch

- If Materials' Cycle is Not Closed, Increasing Worldwide Demand for Resources Will Lead to Conflicts and Wars
  - Energy/Material Resources Unevenly Distributed
  - Uncertain Future Supply and Price
- With Fusion Torch There Will Be Ample Resources on Earth to Permit ALL Nations to Reach High Standards of Living

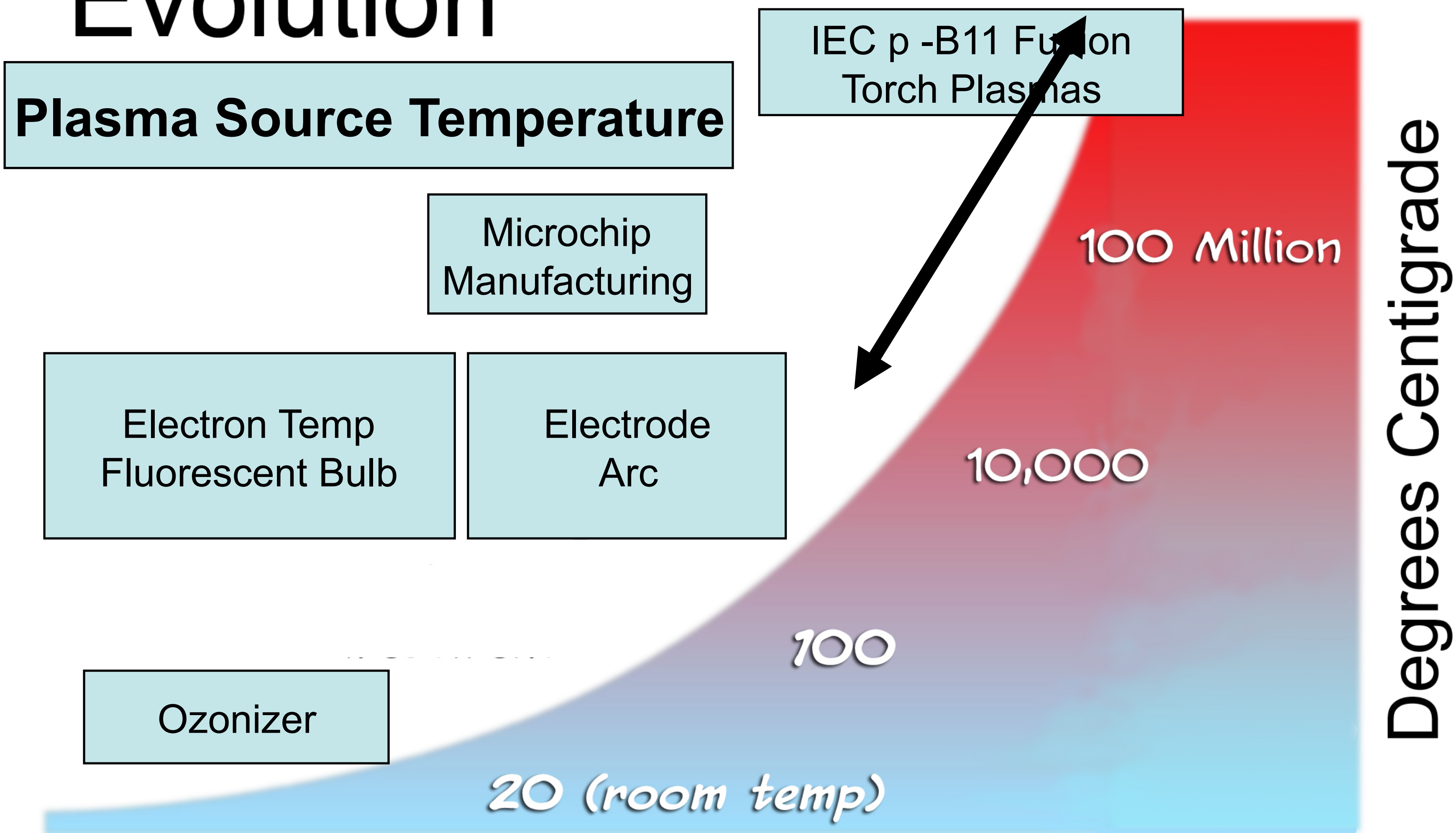
Conceptual Fusion Torch Schematic



Boron Fusion Torch



Evolution


Plasma Source Temperature
IEC p -B11 Fusion
Torch Plasmas
Microchip
Manufacturing
Electron Temp
Fluorescent Bulb
Electrode
Arc
Ozonizer
100 Million
10,000
100
20 (room temp)
Degrees Centigrade

Requirements for Solid Waste Recycling

Torch Energy Required to Convert
200 million tons/year of Municipal Waste
to Saleable Elements is 0.3 quad

Total U.S. Energy Consumption is 100 quad

Due To Impurity Buildup Traditional Recycling
Steadily Degrades Original Material

BORON FUEL SUPPLY

- Boron supply is abundant and ubiquitous
  - 80% of Boron is B11
  - World production over 84 quad (10^{18} BTU); U.S. production over 20 quad.

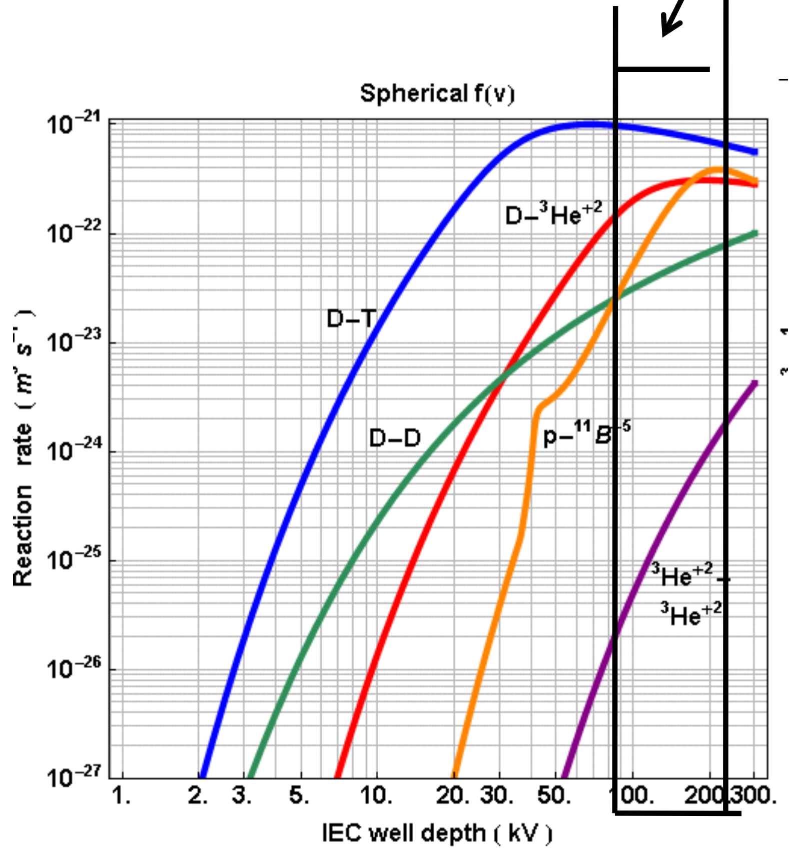
- Total U. S. energy consumption is 100 quad from:
  fossil fuels (85 quad)
  nuclear fission (8 quad)
  hydro (4 quad)
  solar, wind, geothermal (3 quad)

- U. S. energy supply could be self sufficient

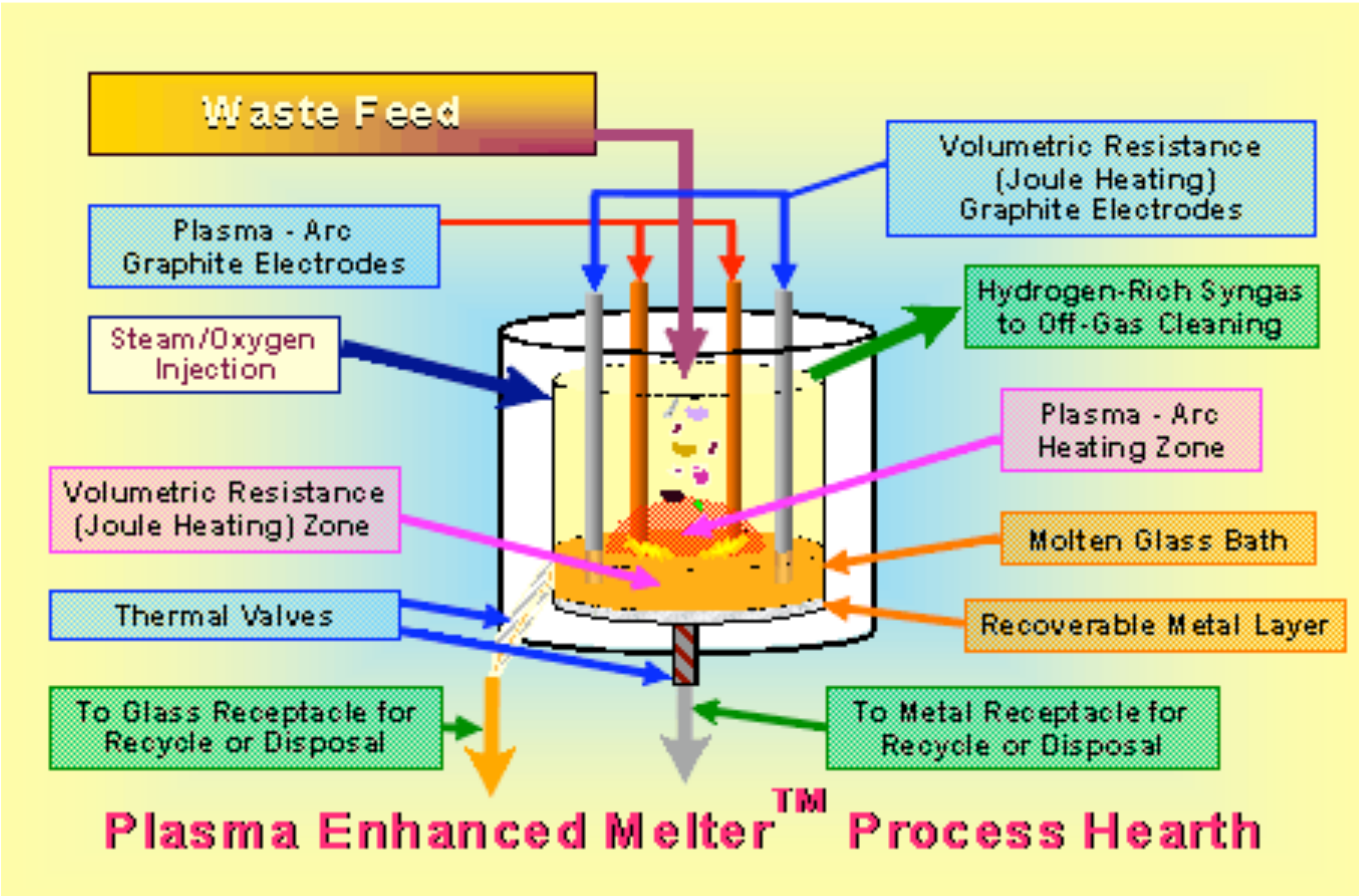
IEC Can Match Fusion Cross Sections Requirements
-Has already exceeded 150kV ions.
-Needs added confinement

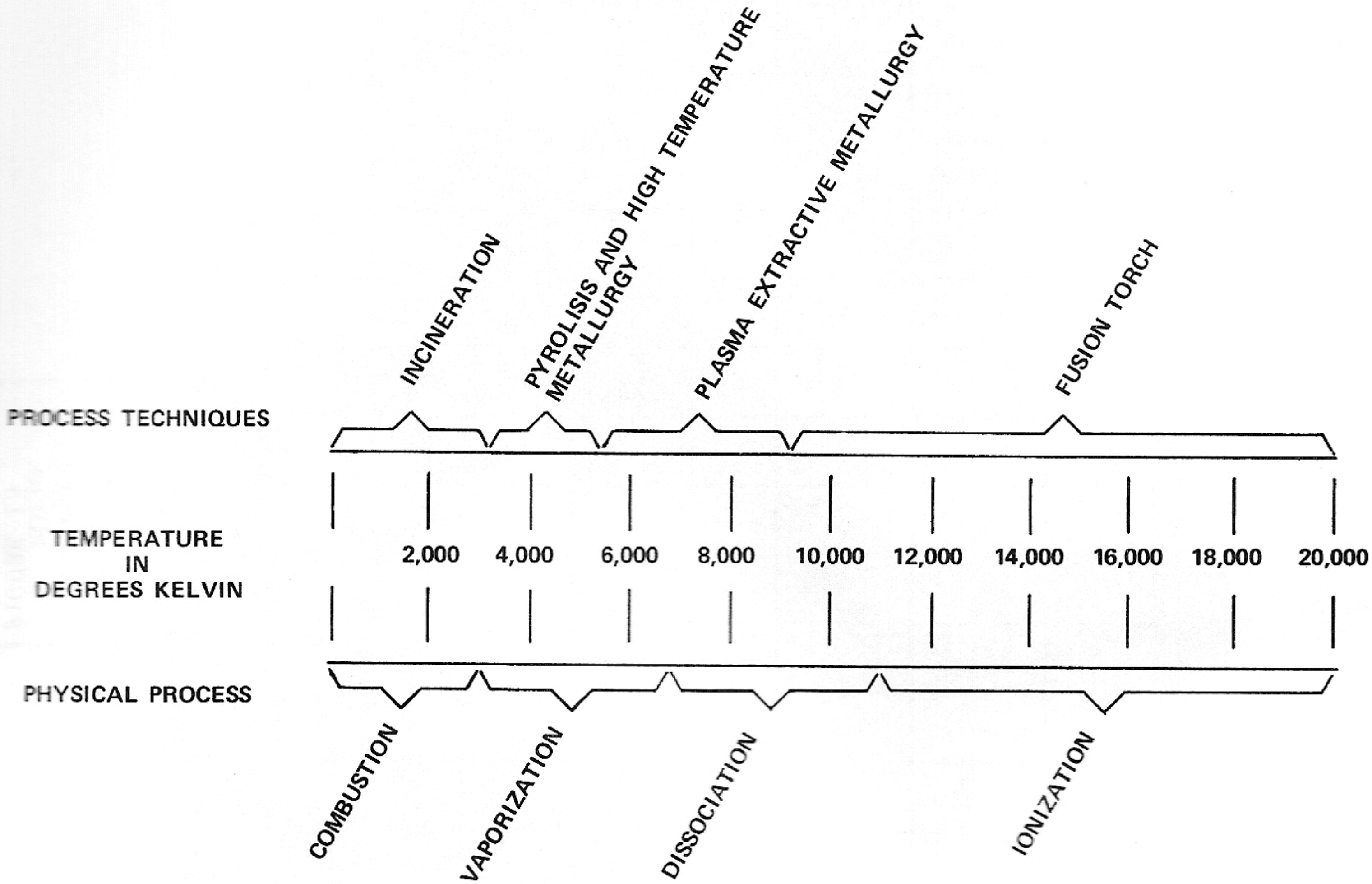
Region of interest

<σv>(E)



Cross Sections from John Santarius, Fusion Technology Institute, University of Wisconsin


Waste Feed
Plasma - Arc Graphite Electrodes
Volumetric Resistance (Joule Heating) Graphite Electrodes
Steam/Oxygen Injection
Hydrogen-Rich Syngas to Off-Gas Cleaning
Plasma - Arc Heating Zone
Volumetric Resistance (Joule Heating) Zone
Molten Glass Bath
Thermal Valves
Recoverable Metal Layer
To Glass Receptacle for Recycle or Disposal
To Metal Receptacle for Recycle or Disposal
Plasma Enhanced Melter™ Process Hearth

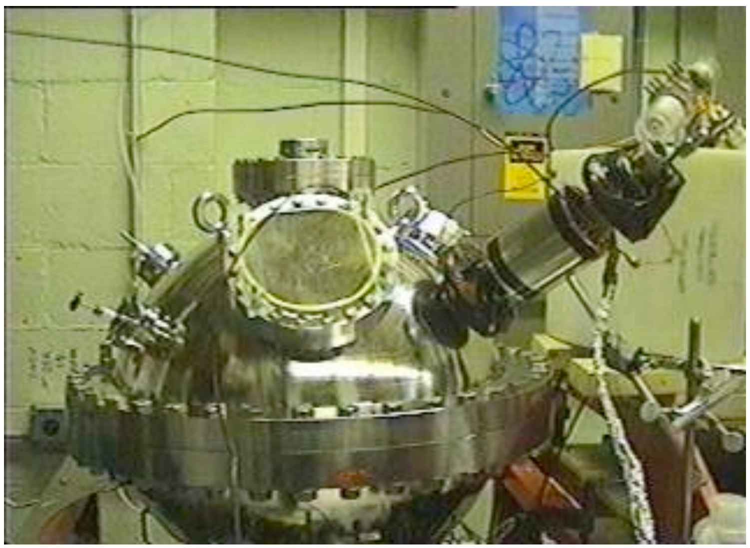


OPERATING TEMPERATURES FOR INCINERATION
AND EXTRACTIVE TECHNIQUES

IEC for p-B11Fusion Torch

- Non-Maxwellian plasma and 150 kV temperature required for p-B11 achieved.
- Deep potential wells needed are possible with ion injection using programmed angular momentum.
- Jet plasma exhaust allows for fusion torch processing section.
- Simple construction, small size, & high power density units. Gives fast learning curve with low R&D costs.
- Electrically driven waste processing possible in near-term (for syngas production from garbage and food wastes).

Ion injected IEC provides way to increase potential well depth and volume



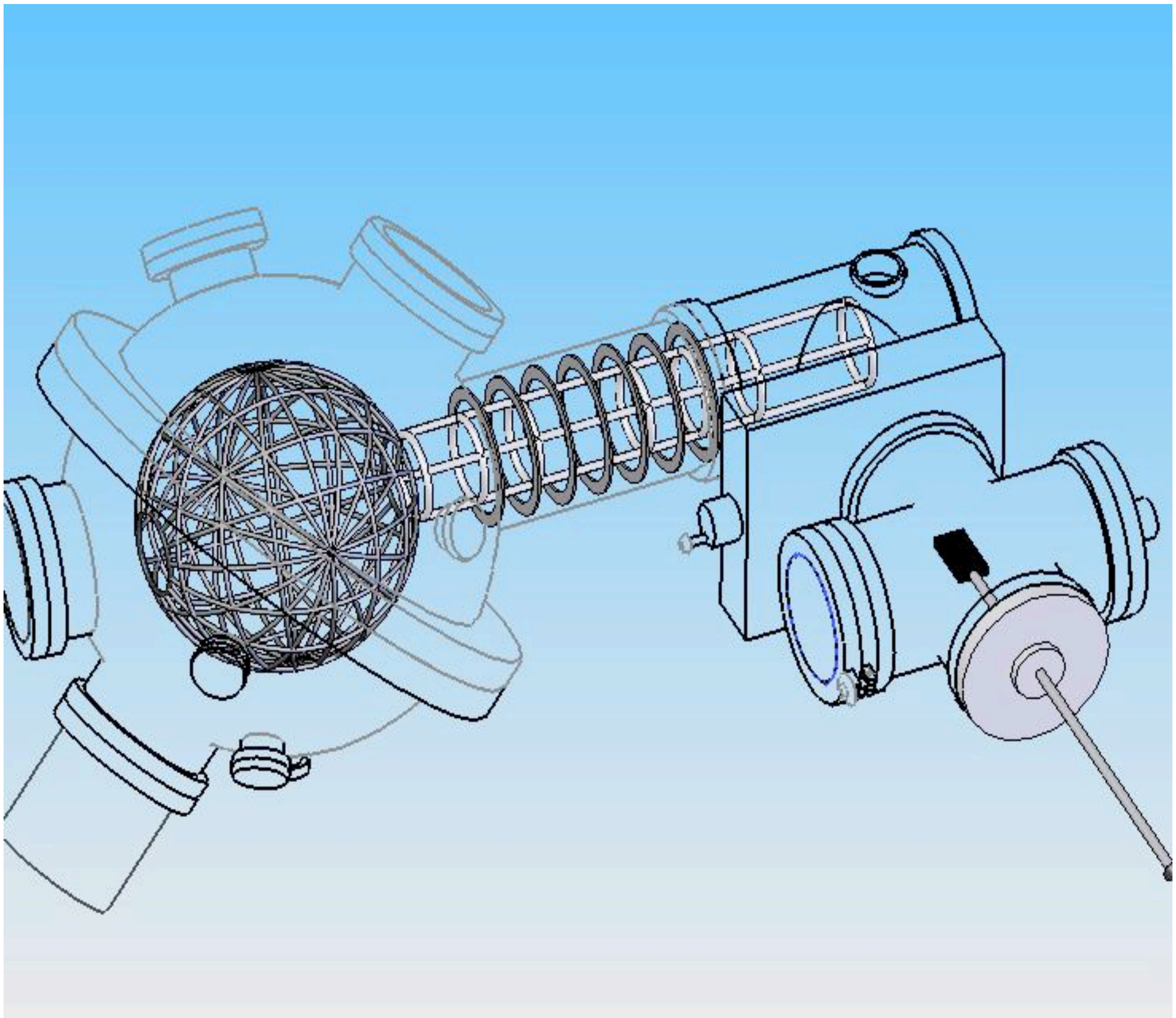
Present single gun device

With 6 guns Q can be increased to ~ Q = 0.1 providing a proof-of-principle for the ion injected IEC p-B11 concept. (Q=1 is “breakeven”)

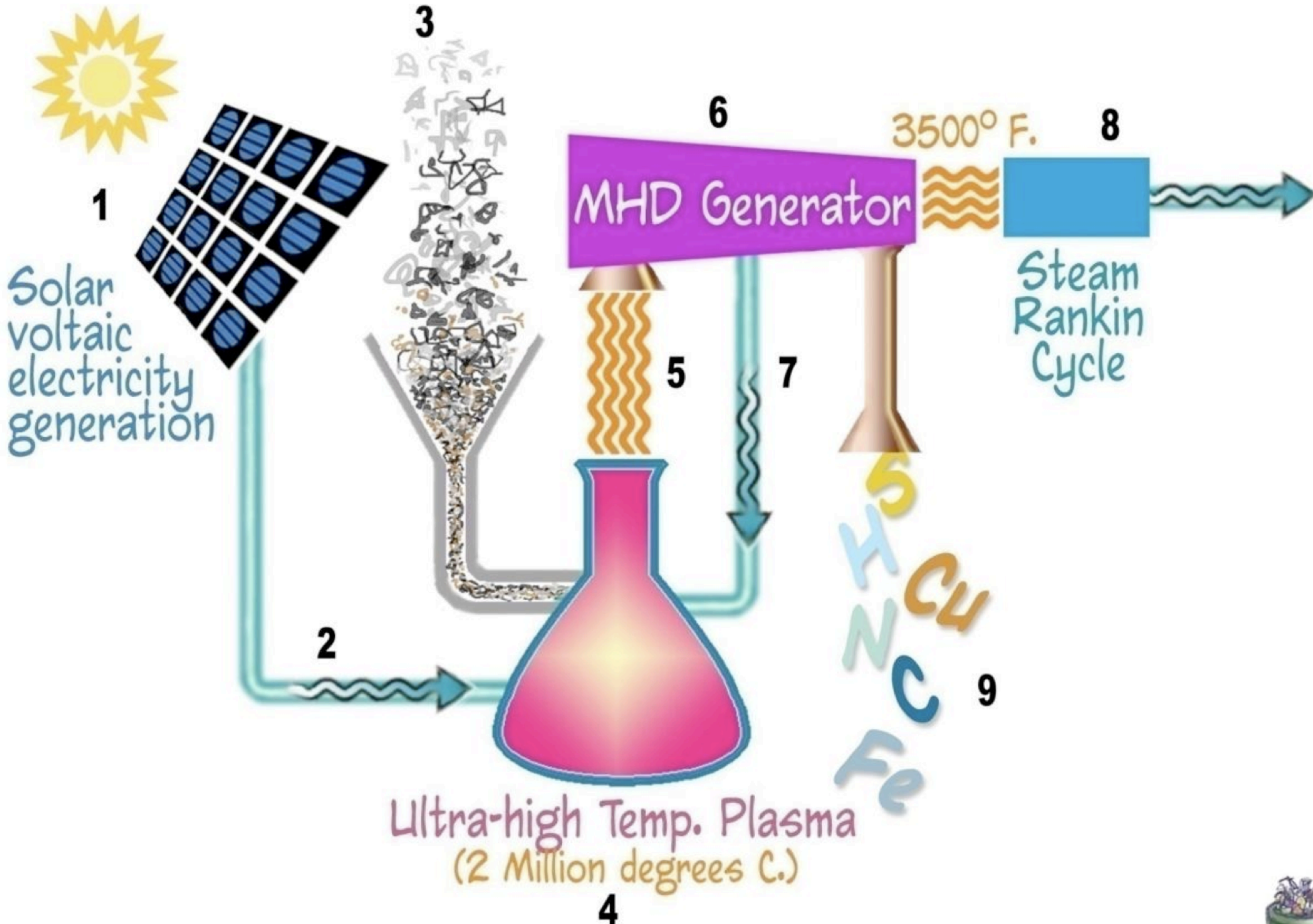
This would increases Q by a ~million compared to the prior gun experiment.

If successful this would establish the physics basis for scale-up to power producing devices.

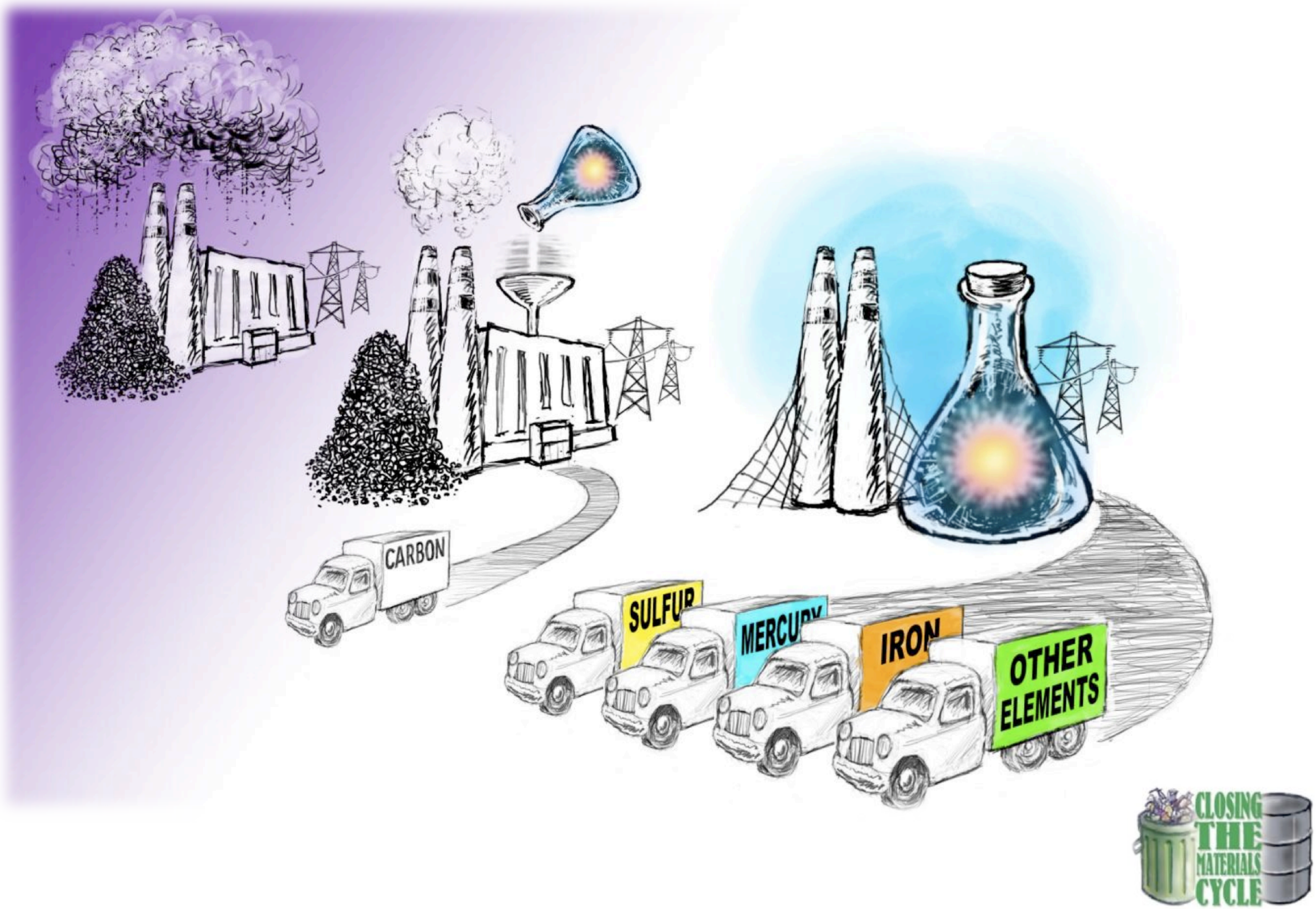
IEC Plasma Torch Waste Reprocessing Lab Scale Experiment to demonstrate concept and establish benefits of higher temperature plasma

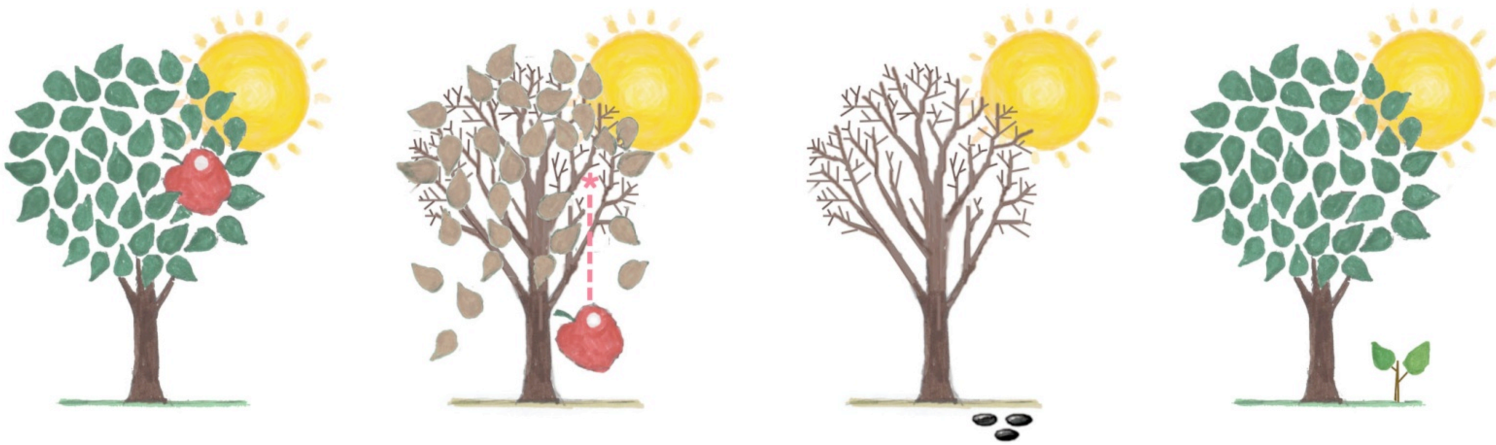


Near Term Electrically Driven Applications – Going to Element Separation - Materials Recovery System



Evolution: Near Term Electrically Driven Applications to p-B11 Fusion Torch





Closing the Materials Cycle.

Thanks for your attention

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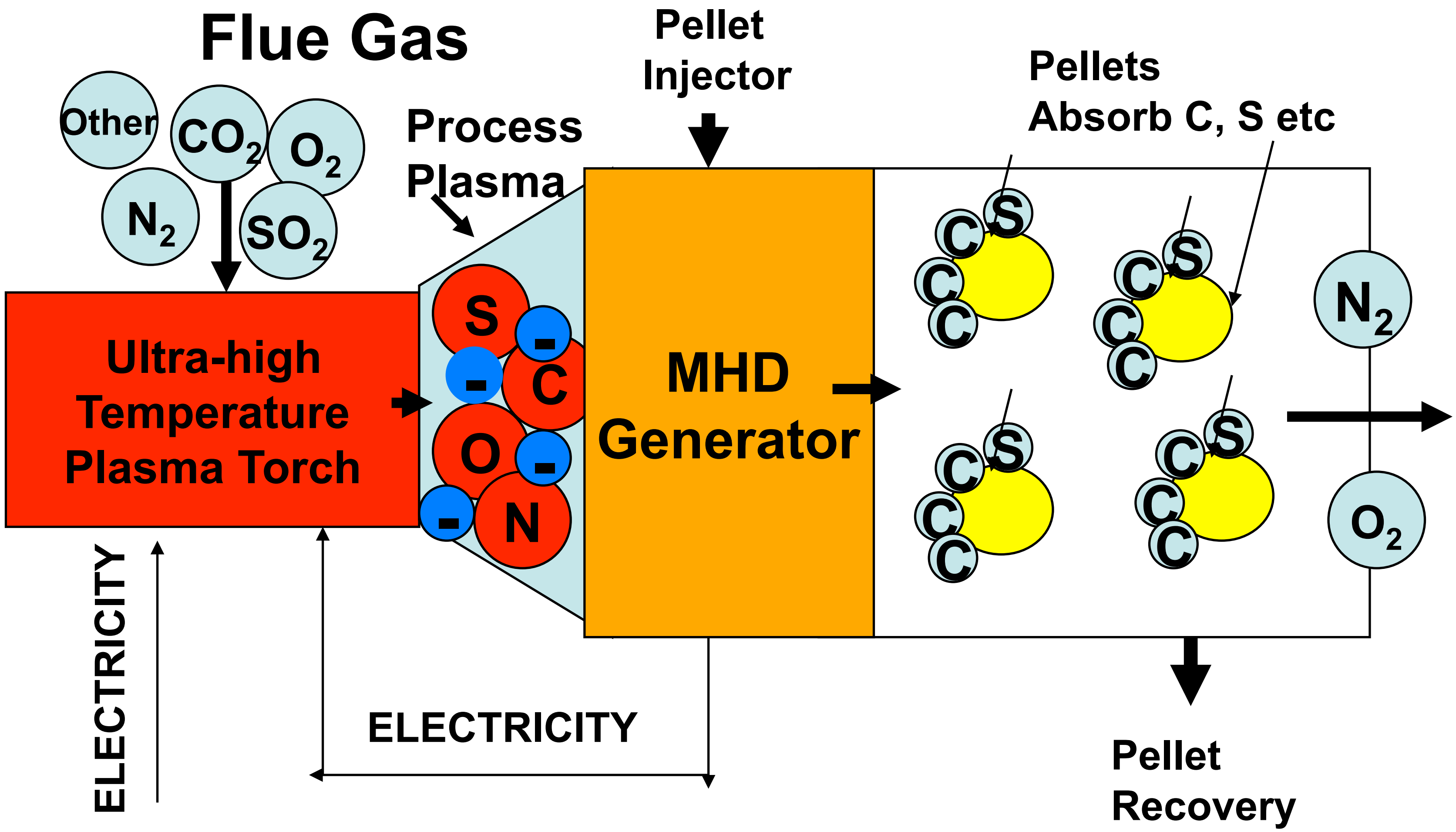
Fusion Torch and the Elimination of Greenhouse Gases

Example - Flow Diagram of Solid Carbon Recovery with Ultra-High Temperature Plasma Torch Using Electrical Input



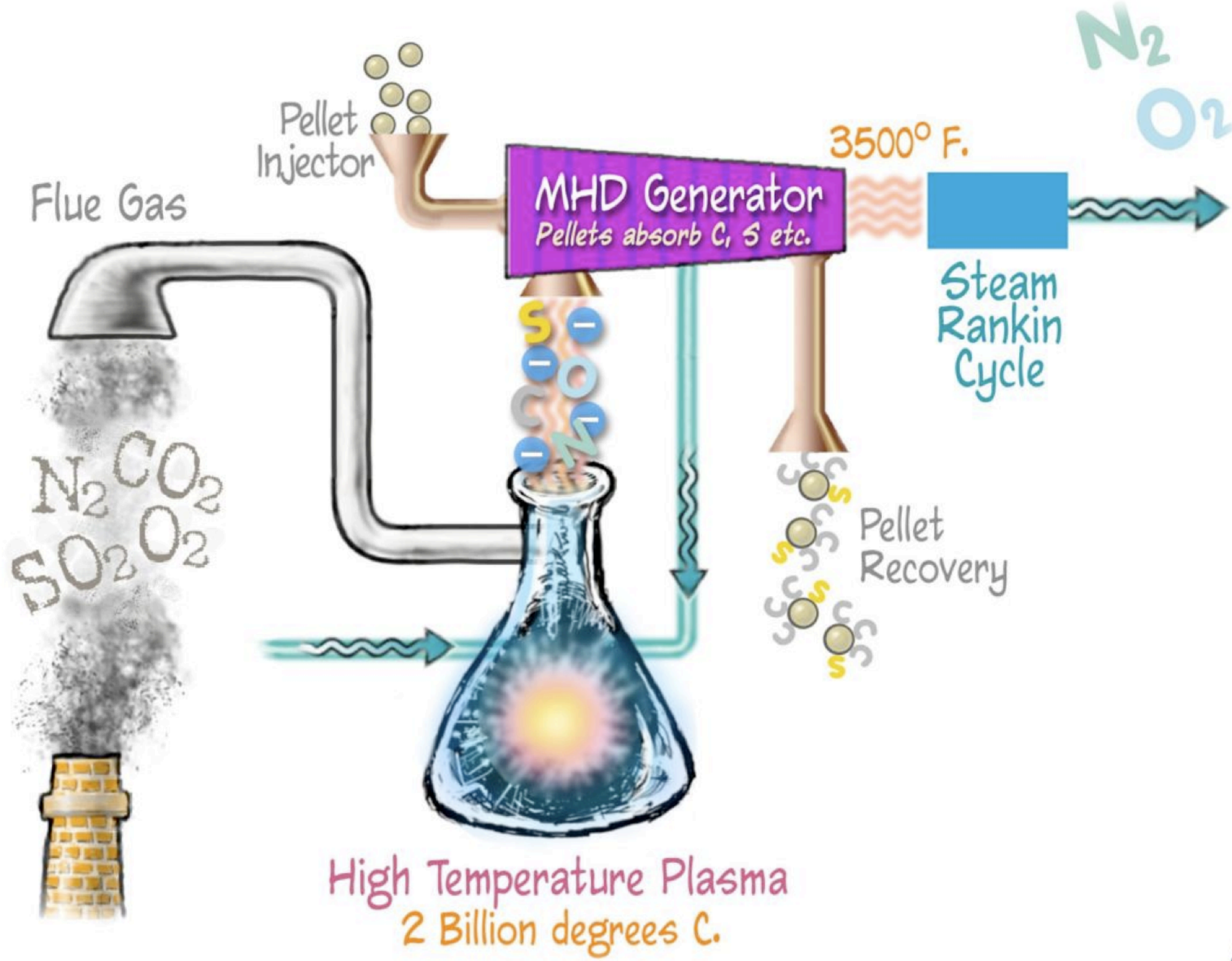
Energy Requirements of Ultra-High Temperature Carbon Recovery System

- Process electrical power equivalent balance in Kcal(e)/gMole of recovered carbon in flue gas estimate with different MHD efficiencies.

	High	Low
– Fusion Torch process	-15.8	-47.5
– Rankin Steam cycle	+17.0	+17.0
– Solid carbon equivalent	+18.0	+18.0
Net electrical power	+19.0	-12.5

Source for Rankin Cycle and solid carbon equivalent data: *Engineering and Economic Evaluation of CO2 Removal from Fossil-Fuel-Fired Power Plants,* IE-7365, Fluor Daniel, Irvine, CA., IEA, France, EPRI, Palo Alto, CA. (1991)

Coal Plant Cleanup



Additional Slides

Element Separation is Key Aspect of Torch

Plasma, the 4th state of matter, provides multiple options.

•Elements can be separated by mass, charge, electronic state, or by combinations.

•Over 9 different separation processes applicable.

Status of p-B11 Fusion

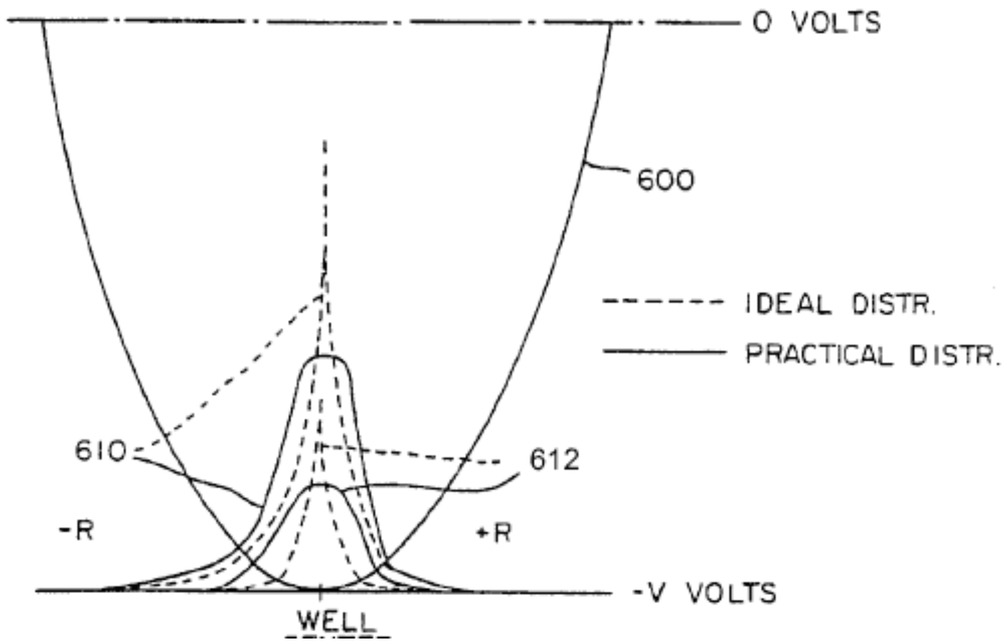
Theoretical studies confirm that p-B11 fusion is possible with high Ti/Te plasmas and n-tau about 100x DT.

Temperatures (T ~ 150keV) required for p-B11 fusion have been achieved in IEC devices which offer non-Maxwellian beam-beam type ion fusion

Present experimental IEC confinement n-tau is orders of magnitude too low, but future devices are expected to achieve the needed improvement through ion injection and deep well formation

Ion Physics – the key to IEC fusion is a deep potential well

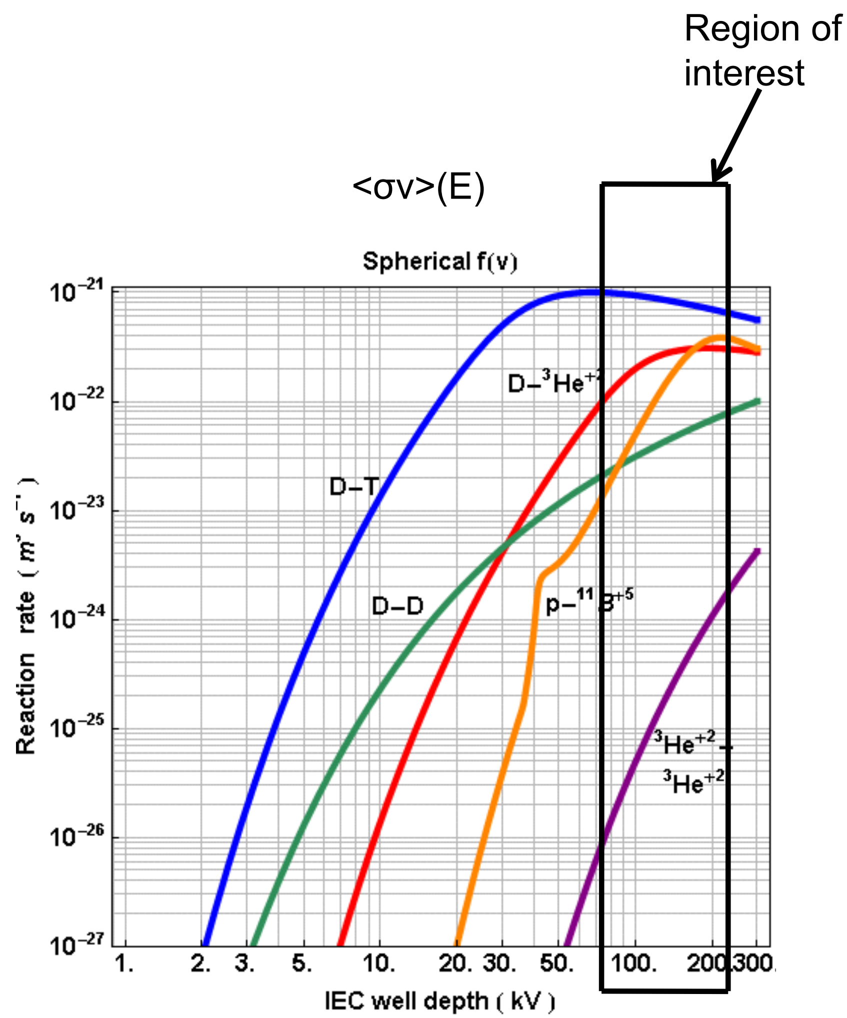
FIG. 7A



1. Ions form deep potential well ($\Phi \sim E_{injection}$)
2. Electrons confined by the electrostatic potential
3. Ion distribution is strongly non-thermal
4. Ions coming to edge of well fall into the interior
5. Ion density strongly peaks at r=0
6. Bulk distribution fuses, not just the high energy tail
7. Ion convergence allows attractive reactor

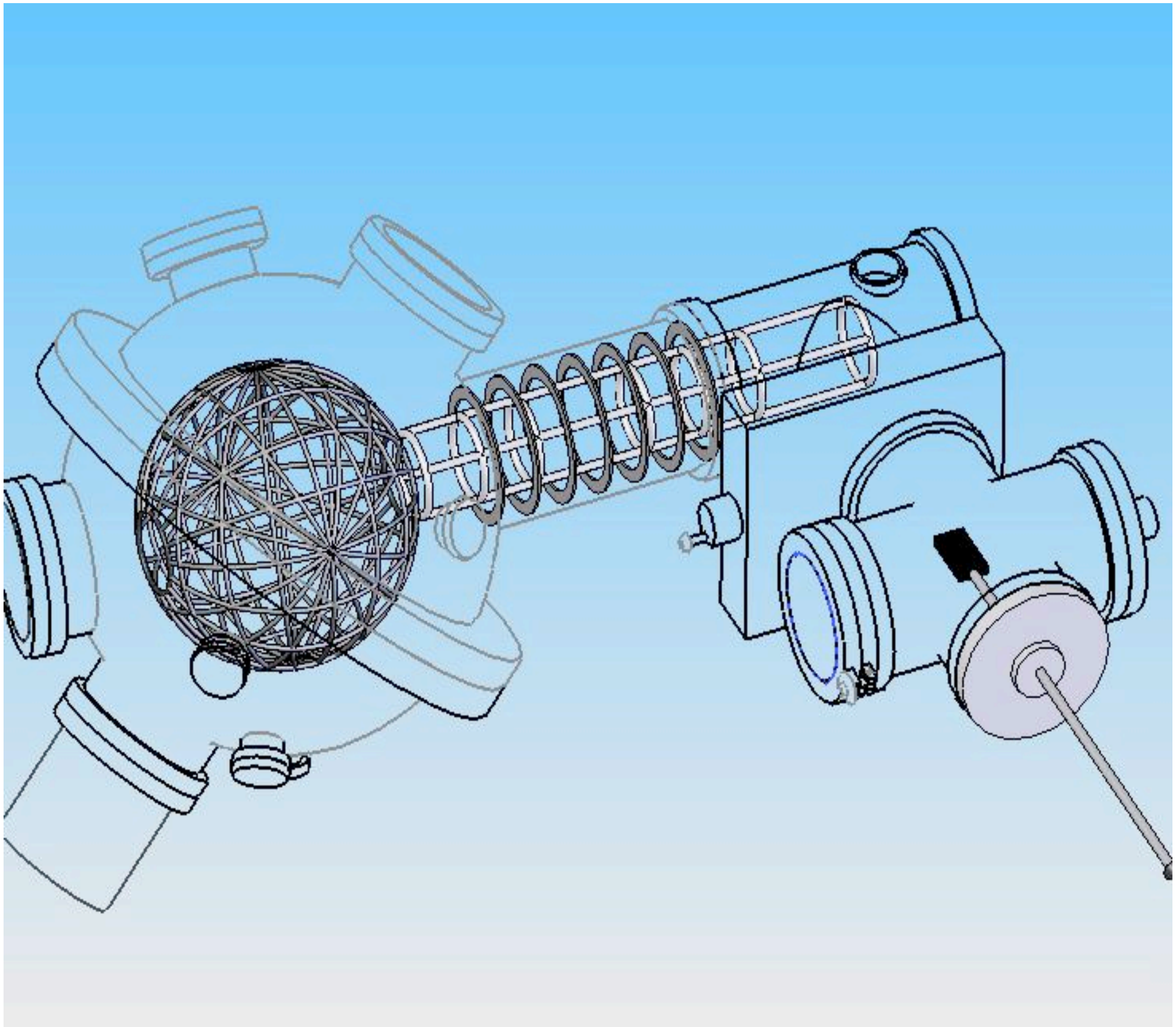
Diagram from US patent application 11/527,906, “Method and Apparatus for Controlling Charged Particles”, R.W. Bussard, (2006).

IEC Can Match Fusion Cross Sections Requirements

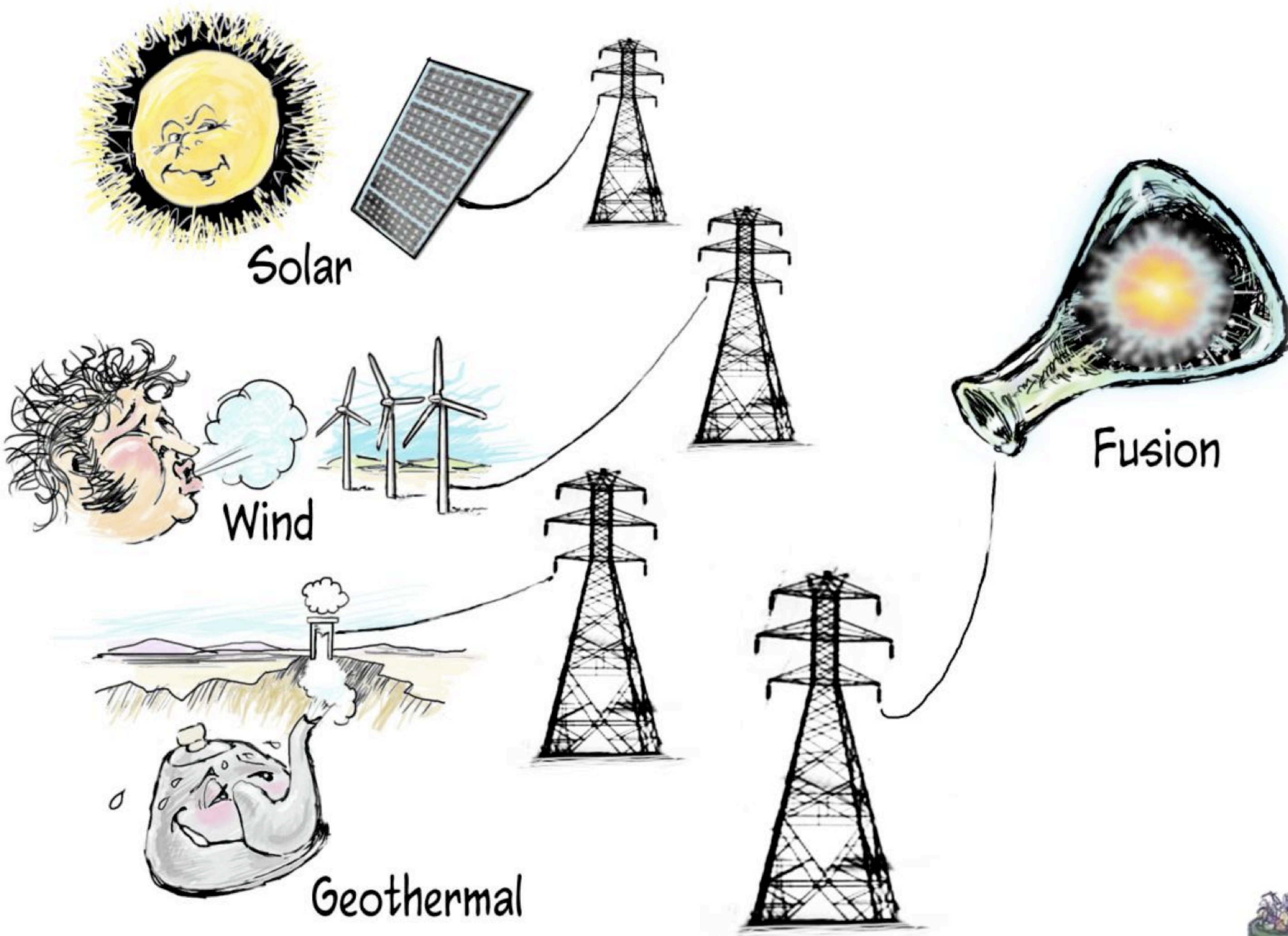


Cross Sections from John Santarius, Fusion Technology Institute, University of Wisconsin

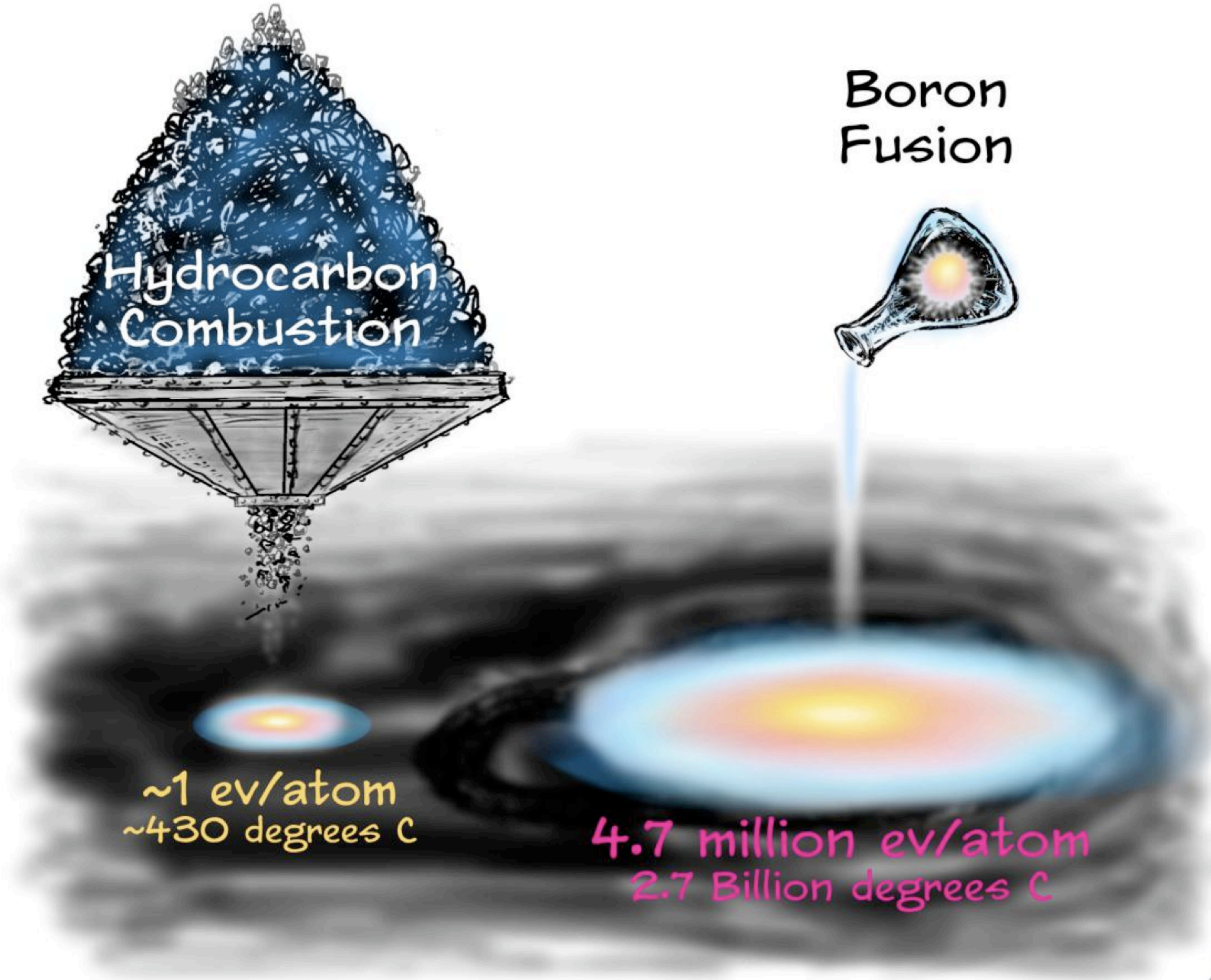
2-kW experimental unit to demonstrate the IEC plasma jet. The jet plasma enters a chamber on the right where a waste sample has been inserted (sample show in withdrawn position in sketch). Off-gases produced exit through tubing at the top of the interaction chamber and enter the collection system . Sludge is collected on a tray at the bottom of the interaction chamber for removal and analysis. Baffling along the jet guide helps prevent gas backflow.



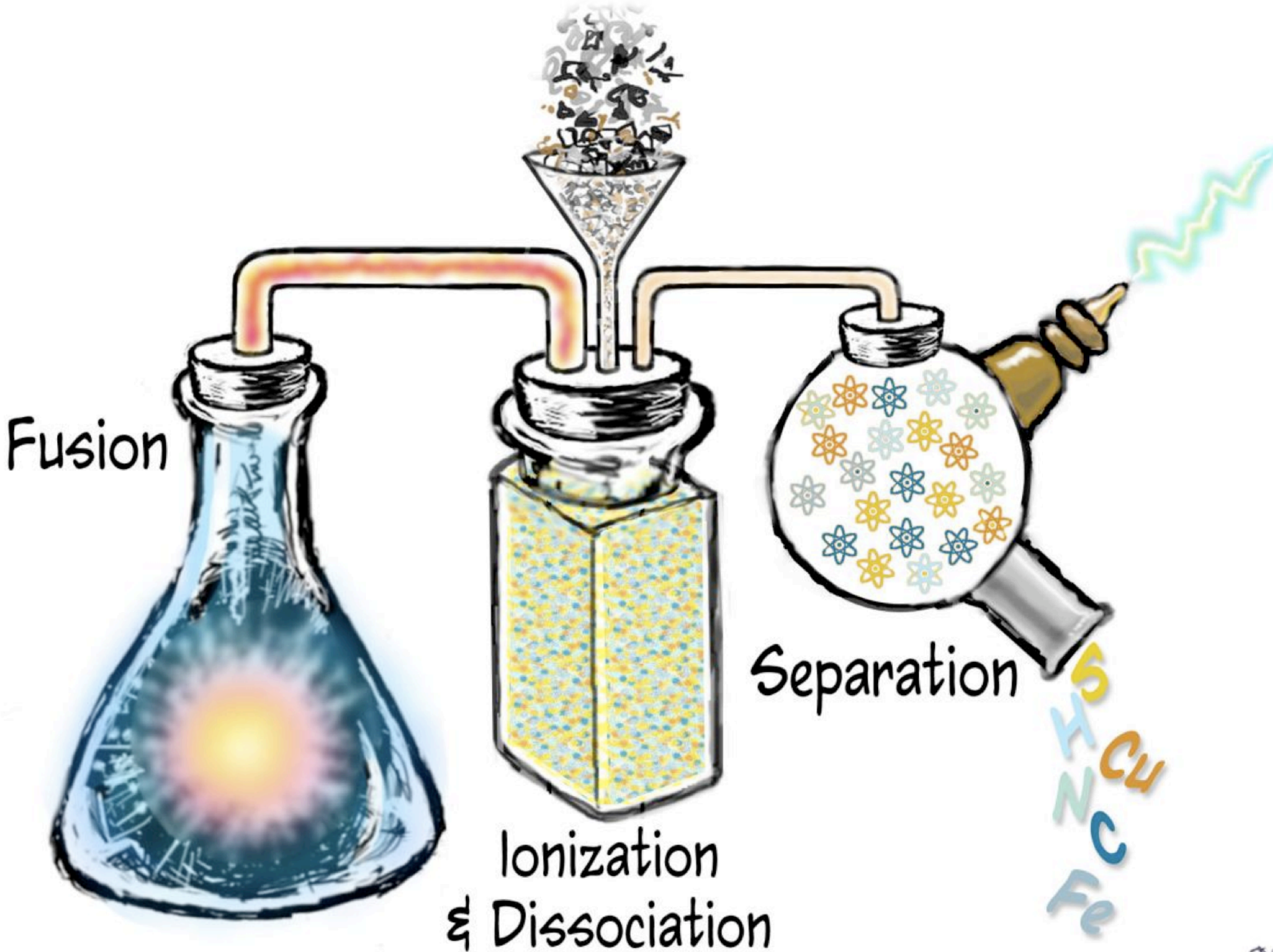
Clean Energy Sources



Comparative Energy Output



Fusion Torch Schematic



CLOSING THE MATERIALS CYCLE

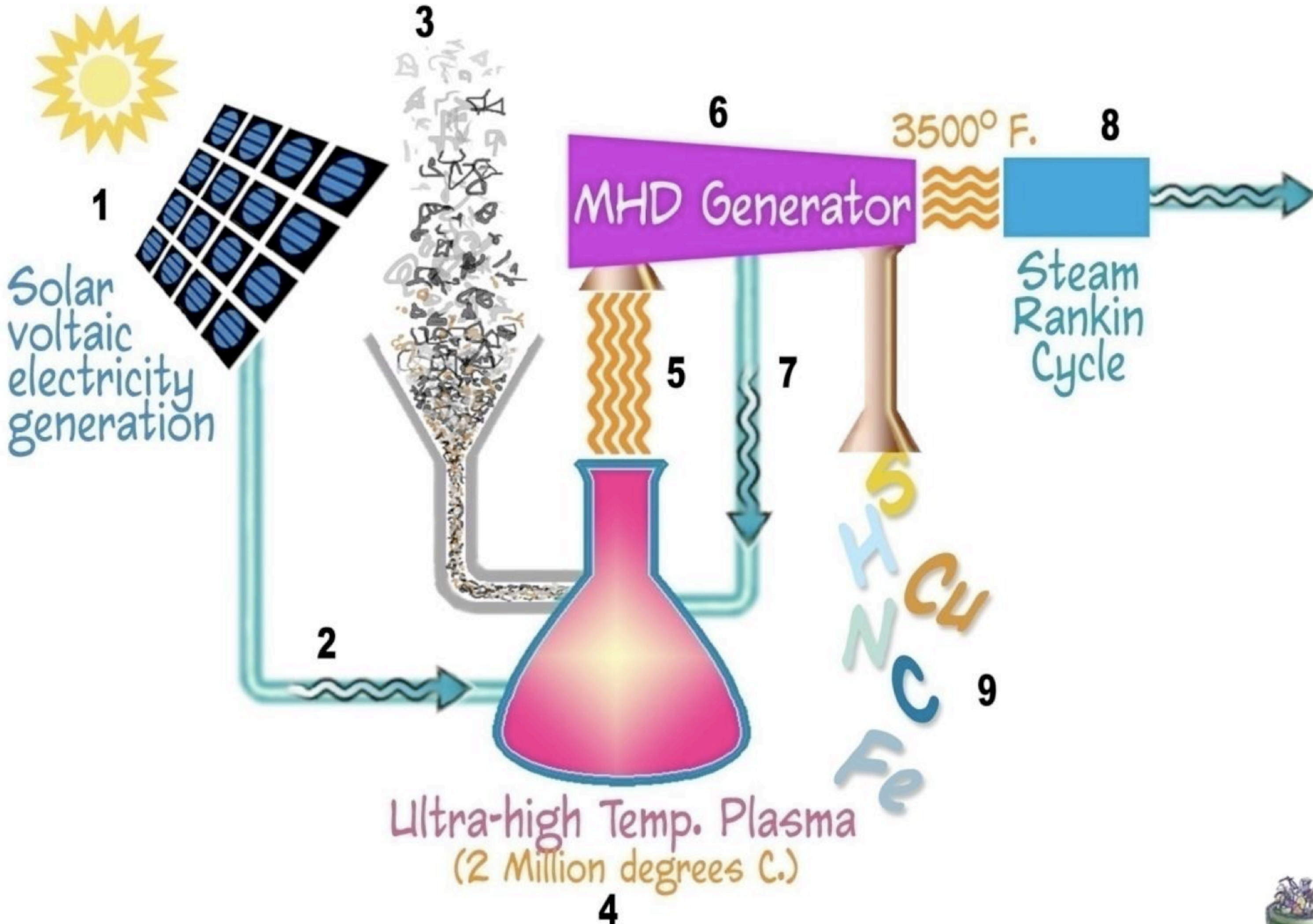
Outline

- Strategic Issues for Developing the p-B11 fusion torch
- Development issues
- P-B11 reactor issues
- Near term electrically-driven version for waste processing

Plasma processing of wastes without elemental separation is a near-term application

- Plasma arc processing now in several commercial sites
- Use of IEC plasma Jet (electrically driven, but same geometric configuration as IEC p-B11 torch) offers impromeny due to much hight temperature plasma

Materials Recovery System



Six injector IEC experiment to demonstrate physics for Q(equivalent) = 0.1 p-B11

- With 6 guns Q can be increased to ~ Q = 0.1 providing a proof-of-principle for the ion injected IEC p-B11 concept. (Q=1 is "breakeven")
- This would increases Q by ~10^6 compared to the prior gun experiment.
- If successful this would establish the physics basis for scale-up to power producing devices.