EXECUTIVE SUMMARY

INTRODUCTION

Conceptual designs and assessments have been completed for two inertial fusion energy (IFE) electric power plants. The detailed designs and results of the assessment studies are presented in this report. Osiris is a heavy-ion-beam (HIB) driven power plant, and SOMBRERO is a Krypton-Fluoride (KrF) laser-driven power plant. Both plants are sized for a net electric power of 1000 MWe. Key design features and operating parameters are given in Table I.

OSIRIS POWER PLANT

Osiris Chamber Design

- The Osiris chamber features a flexible, porous carbon fabric first wall and blanket that contains the molten salt, Flibe, which serves as the tritium breeding material and primary coolant. The first wall radius at the nearest point to the target is 3.5 m.

- A thin layer of Flibe coats the first wall to protect it from x-ray and debris damage.

- A spray of Flibe at the cold-leg temperature (500°C) is injected at the bottom of the chamber to condense the Flibe that is vaporized with each pulse.

HIB Driver Design

- The HIB driver uses linear induction accelerator technology. Twelve beams of 3.8 GeV Xe^{+1} ions deliver a total of 5 MJ to an indirect drive target at a pulse repetition rate of 4.6 Hz.

- The driver is designed to carry the maximum transportable current at every point along the accelerator in order to minimize cost.

- The driver efficiency is 28%, and the power consumption is 82 MWe.

- The design is conservative in that it does not use beam combination, beam separation, or recirculation.

- High performance Nb_3Sn superconductors in the quadrupole focusing magnets improve performance and reduce cost.

Osiris Balance of Plant

- The reactor building is quite compact and features a movable shielding wall for access to the maintenance building.

- The power conversion system uses a double reheat rankine power cycle with a gross electric conversion efficiency of 45%. After accounting for driver and auxiliary power consumption, the net efficiency of the power plant is 40%.

SOMBRERO POWER PLANT

SOMBRERO Chamber Design

- SOMBRERO features a carbon/carbon first wall and blanket structure with a granular Li_2O breeding blanket. The Li_2O granules flow through the blanket region of the chamber and serve as the primary coolant.

- The first wall is protected from x-ray and debris damage by xenon gas at 0.5 torr.

- Low pressure He is used to remove tritium from the breeding blanket and also to transport the Li_2O granules to and from the intermediate heat exchangers.

KrF Laser Design

- The KrF laser uses e-beam pumped amplifiers and angular multiplexing for pulse compression. Sixty beams deliver a total of 3.4 MJ to a direct drive target at 6.7 Hz.

- The non-intercepting e-beam cathode technology promises long-life operation and improves the system efficiency.

- The laser design achieves an overall system efficiency of 7.5% and has a total power consumption of 304 MWe.

Power Conversion and BOP

- SOMBRERO requires a large (110 m diameter) reactor building to accommodate the final focusing optics for the laser. The entire building is a vacuum structure filled with 0.5 torr of xenon used for first wall protection.

- The sensitive dielectric optics are protected from neutron damage by the use of grazing incidence metal mirrors (GIMMs). While the lifetime of the dielectric optics is very uncertain, present assumptions indicate that they could last for the life of the power plant. The life of the GIMMs depends on the degree to which radiation damage can be annealed by heating.

- SOMBRERO uses the same intermediate coolant loop and steam power cycle as Osiris. The gross efficiency is 47% and includes a credit for using waste heat from the laser in the feedwater heaters. After accounting for laser and auxiliary power consumption, the net plant efficiency is 35%.

TARGET SYSTEMS

Target Production Facility

- The target production facility design uses controlled microencapsulation for shell production, cryogenic injection fill for fuel loading, and a combination of cold-gas jets and pulsed laser heating to establish a uniform fuel layer.

- The design is 100% redundant to improve reliability and minimize the need to store extra targets and the associated tritium inventory.

- The DT-fill and layering techniques minimize production time and thus minimize tritium inventory.

- The total estimated tritium inventory of the target factory is only 300 g.

Target Injection, Tracking, and Beam Pointing

- A gas gun injector accelerates targets at 130 g's over a distance of 9 m to a final velocity of 150 m/s.

- A laser Doppler interferometer and laser diode tracking stations measure the target trajectory and provide pointing information to the drivers.

- Active beam pointing is proposed for both the HIB and KrF-laser drivers.

ENVIRONMENTAL AND SAFETY ASPECTS

- Only low activation materials are used in the first walls, blankets, breeding materials, and chamber structures of both the Osiris and SOMBRERO designs.

- Both power plants achieve a Level of Safety Assurance of 1.

- Structures and shielding for both designs qualify for Class A shallow land burial. Osiris breeding material qualifies for Class A while SOMBRERO breeding material qualifies for Class C shallow land burial.

- Nuclear grade construction is not needed for either design.

MAINTAINABILITY

- The first wall and blanket structure for Osiris are removed as a single unit by first draining the blanket of Flibe and then lifting the internal components out the vacuum vessel with an overhead crane.

- The SOMBRERO chamber is constructed of 12 first-wall / blanket units. To replace a segment, it is lowered to a transport carriage and moved to the maintenance building.

TECHNOLOGY DEVELOPMENT NEEDS

- To realize the attractive features of these designs, technology development is needed in several areas.

- Driver technology should be given the highest priority in both cases. Beam delivery systems (heavy-ion-beam transport and final optics for lasers) are important research areas.

- Economical automated target production techniques are required for both designs.

- For Osiris, technology development and experiments are needed to prove the feasibility of the operation of the first wall protection scheme and chamber operation in a rep-rated mode.

- For SOMBRERO, the development of large-structures made of low activation material is needed.

ECONOMICS

- The estimated constant dollar cost of electricity (COE) for Osiris is 5.6 ¢/kWh, while the COE for SOMBRERO is 6.7 ¢/kWh. Both COEs compare favorably with reported COEs for magnetic fusion energy reactors.

CONCLUSIONS

- The conceptual designs developed in this study show the potential promise of IFE for electric power production. We have developed technically credibly concepts with environmental, safety, and economic characteristics that are every bit as attractive as magnetic fusion energy reactors designs. Realizing IFE potential will require continued research and development in the areas of target physics, driver technologies, heavy ion beam transport, laser optics, chamber phenomenology, low activation materials, and automated target production.

Table I. Key Design Features for Osiris and SOMBRERO

	Osiris	SOMBRERO
Driver		
Driver Energy (MJ)	5.0	3.4
Rep-Rate (Hz)	4.6	6.7
Driver Efficiency (%)	28.2	7.5
Target		
Type	Indirect Drive	Direct Drive
Target Gain	86.5	118
Yield (MJ)	432	400
Chamber Design		
First Wall Material	Woven Graphite Fabric	4-D C/C Composite
X-ray and Debris Protection	Liquid Flibe	3.25 torr-m of Xe
First Wall Radius, m	3.5	6.5
Estimated First Wall Life (fpy)	1.8	5
Breeding Material	Molten Flibe	Li_2O Granules
Tritium Breeding Ratio	1.24	1.25
Power Conversion System		
Primary Coolant	Flibe	He w/ Li_2O granules
Intermediate Coolant	Lead	Lead
Secondary Coolant	Water / Steam	Water / Steam
Power Conversion Eff. (%)	45	47
Power Balance		
Fusion Power (MW)	1987	2677
Total Thermal Power (MWt)	2504	2891
Gross Electric Power (MWe)	1127	1359
Driver Power (MWe)	82	304
Auxiliary Power (MWe)	45	55
Net Electric Power (MWe)	1000	1000
Net Plant Efficiency (%)	40	35
Environmental & Safety		
Waste Disposal Ratings	A	A & C
Level of Safety Assurance	1	1
Economics		
Cost of Electricity (¢/kWh)	5.6	6.7