Novatron
Proprietary Report

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Contents

1 Background to the Fusion Concept

1.1 Mirrors

This section presents an overview of key literature in the development of magnetic mirror fusion reactors. This includes their early development, early confinement challenges, how the concept was sidelined in favour of tokamak development, and how there has been a recent return to the concept, with exciting new prospects.

- In "Fusion Research in Open-Ended Systems", 1969, by T.K. Fowler, the focus is on low-beta fusion research in open-ended magnetic geometries, known as magnetic mirrors [?]. This work provides an overview of magnetic mirror research, discussing methods, achievements, and rationale. It introduces magnetic mirrors for the confinement of hot fusion plasmas in configurations where plasma is held between a pair of coils, creating stronger magnetic fields near the coils. The configuration allows for the escape of certain velocity particles, known as the mirror loss cone, and contrasts with closed systems like toroidal configurations.

- In "Concept for a High-Power-Density Mirror Fusion Reactor", 1973, R.F. Post, T.K. Fowler, J. Killeen, and A.A. Mirin propose a new mirror-type fusion reactor design [?]. Utilizing advancements in neutral-beam technology, this concept improves plasma stability, power density, and the energy gain factor (Q) over previous designs.

- "Mirror Reactor Studies", 1976, by R.W. Moir and colleagues at Lawrence Livermore Laboratory introduces a fusion mirror reactor with 150-keV neutral-beam injectors, providing over 1 GW of continuous power [?]. The reactor features a three-stage modularized Venetian blind plasma direct converter with a 59% efficiency and a novel method for removing the lune-shaped blanket, addressing the challenge of low Q and high recirculating power.

- In "Improved Tandem Mirror Fusion Reactor", 1979, D.E. Baldwin and B.G. Logan discuss barrier potentials in tandem mirror reactors to reduce ion energy and density requirements [?]. This innovation, involving raising the plug-electron temperature, marks a significant advancement in magnetic mirror fusion technology.

- In "Magnetic Mirror Fusion - Status and Prospects", 1980, Post compares the concept of magnetic mirror fusion to closed magnetic systems like tokamaks [?]. It is explained that mirror confinement, an open system, features magnetic field lines extending beyond the confinement area, contrasting with closed systems where these lines are contained. The importance of the magnetic mirror effect for longitudinal confinement is highlighted, with emphasis on the necessity for particles to have sufficient rotational energy for effective trapping. The "loss cone" in velocity space, influenced by the mirror ratio and particle energy ratio, is also described. The paper notes that the imbalance in electron and ion loss rates is compensated by the development of a positive ambipolar potential, affecting the overall plasma loss rate. It is concluded that higher temperatures, which reduce ion-ion collision rates and boost fusion rates, could improve the fusion power balance in mirror confinement systems.

- "Experimental Progress in Magnetic-Mirror Fusion Research", 1981, by Thomas C. Simonen emphasizes the progression from basic mirror cells to advanced designs in magnetic mirror systems like tandem mirrors [?]. It discusses improvements in plasma containment and the reduction of end losses, along with the technical aspects of magnetic mirror confinement.

- "The Engineering of Magnetic Fusion Reactors", 1983, by Robert W. Conn delves into the construction of magnetic fusion reactors using the tandem mirror method, highlighting challenges and techniques in maintaining plasma temperature and energy capture [?].

- "Mirror-Based Fusion: Some Possible New Directions", 1999, by Richard F. Post highlights innovative approaches in magnetic mirror fusion - offering several benefits, including suppression of interchange-type MHD instability modes due to positive field-line curvature, and the ability to introduce and control particle beams for improved fueling and ash removal [?]. Additionally, Post suggests a shift towards low-Q open-ended systems for their relaxed confinement requirements and better-understood physics. This approach brings potential for more efficient, smaller, and less expensive fusion systems and opens possibilities for using alternative fusion fuels.

- In "Fifty Years of Magnetic Fusion Research (1958-2008): Brief Historical Overview and Discussion of Future Trends", 2010, by Laila A. El-Guebaly, magnetic mirror fusion is discussed as one of the original magnetic confinement concepts alongside tokamak, stellarator, and pinch [?]. Tandem Mirror (TM) research, a variation of magnetic mirror fusion, began in the 1950s. By the mid-1970s, the TM concept was proposed, offering advantages like high beta (30–70%), no driven plasma current, and the potential for direct conversion of charged particle power into electricity. The TM design consists of a long central cell with solenoidal coils terminated by end mirror cells and direct conversion systems. In the 1980s, major TM experimental facilities were built in the US, including MFTF-B and TMX-U, and conceptual power plant designs like WITAMIR, MARS, MINIMARS, and Ra were developed. However, by the late 1980s, the US Department of Energy shifted focus away from TMs to concepts with seemingly fewer challenges, like tokamaks. Despite the early promise, the TM concept has seen limited growth in recent years, with existing magnetic traps like the gas-dynamic trap and multi-plug trap at the Budker Institute of Nuclear Physics not being TMs.

- "Modern magnetic mirrors and their fusion prospects", 2010, by A.V. Burdakov et al. present advancements in magnetic mirror technology, focusing on the Gas Dynamic Trap (GDT) and the Multi-Mirror Trap from the Budker Institute of Nuclear Physics [?]. These developments represent key steps in making magnetic mirror technology viable for practical fusion applications.

- In "Concept of Fusion Reactor Based on Multiple-Mirror Trap", 2011, A.V. Burdakov and colleagues focus on advancements in multiple-mirror confinement for fusion reactors, using the GOL-3 device in Novosibirsk as a case study [?]. It reports significant improvements in plasma behavior, facilitated by new collective phenomena and enhanced plasma heating methods. These advancements, including effective heat transport control and magnetohydrodynamic stabilization, have improved the viability of multiple-mirror confinement systems for practical fusion reactor applications. The study also provides a perspective on the development of large-scale fusion devices using this technology.

- In "Gas-dynamic Trap: An Overview of the Concept and Experimental Results", 2013, A.A. Ivanov and V.V. Prikhodko explore the Gas Dynamic Trap (GDT) - a type of magnetic mirror reactor [?]. This reactor is characterized by its long distance between mirrors and high mirror ratio, enabling effective plasma confinement. The GDT's design facilitates plasma stability and offers promising applications in neutron source development for fusion materials and hybrid fusion-fission systems. The paper also reviews experimental results from GDT trials, providing insights into its potential in future fusion research.

- In "Progress in Mirror-Based Fusion Neutron Source Development", 2015, by the Budker Institute of Nuclear Physics advancements in developing a 14 MeV neutron source for fusion material studies are detailed [?]. This source, based on the Gas Dynamic Trap (GDT), a specialized magnetic mirror system, has achieved stable confinement of hot-ion plasmas with relative pressures exceeding 0.5 and elevated the electron temperature to 0.9 keV. These achievements, including the highest electron temperature reached in axisymmetric open mirror traps, position the GDT-based neutron source as a promising tool for material testing and fusion-fission hybrid systems.

- In "Magnetic-confinement Fusion", 2016, by J. Ongena et al., the concept and history of magnetic mirrors in fusion research is presented [?]. The paper describes magnetic mirrors as working by increasing the magnetic field strength at both ends of a confinement region, using additional coils to create a 'magnetic bottle'. This design repels plasma particles with an identical pole to the strong end magnetic fields, trapping them within the bottle. Despite this innovative approach, achieving effective confinement in mirror machines proved challenging, primarily due to instabilities caused by end losses. Particles with velocities mainly along the magnetic field line would not be stopped by the end mirrors and escape, leading to a non-Maxwellian velocity distribution and instabilities. This issue ultimately led to the abandonment of the magnetic-mirror approach in 1986 when the U.S. decided not to operate the Mirror Fusion Test Facility B (MFTF-B).

- In "Encouraging Results and New Ideas for Fusion in Linear Traps", 2018, by P.A. Bagryansky and colleagues reviews recent advancements in linear trap technologies [?]. This study highlights the efficiency of multiple-mirror confinement with gas-dynamic traps and introduces the helical-mirror variant for improved confinement of rotating plasmas, laying a foundation for future fusion energy exploration and development.
- In "Fusion by beam ions in a low collisionality, high mirror ratio magnetic mirror", 2022, Egedal et al.'s study introduces the Fast Beam Ion Solver (FBIS) model to improve the understanding of ion behavior in magnetic mirror geometries, contributing to the design of WHAM++, a cost-effective magnetic mirror device [?].

1.2 Novatron concept

The Novatron Fusion Group, a start-up based in Stockholm, is working on an innovative approach to magnetic fusion energy. Their concept, an evolution from conventional mirror confinement methods, aims to solve the poor confinement issues that have hindered traditional designs. The design is characterized by an axisymmetric, high mirror-ratio plasma that strategically aims to suppress interchange instabilities through its unique curvature.

A key aspect of Novatron's design is the integration of a mirror-cusp magnet topology, which marries the features of a classic magnetic mirror with those of a biconic cusp. This design ensures a normal magnetic field akin to that of a traditional magnetic mirror, while also adopting the favorable curvature features of a biconic cusp. The axisymmetric design is crucial in minimizing mid-plane leakage and neoclassical transport, common problems in classical cusp configurations.

Addressing the technical challenges in plasma containment, such as interchange instabilities and axial losses, Novatron has developed specific strategies. These include vortex stabilization, which involves rotating the plasma around a central axis, and anchor cells that create regions of favorable curvature to counteract the central cell's unfavorable curvature. The design also incorporates line tying, using conducting plates to facilitate electron flow from regions of unfavorable to favorable curvature.

The design further tackles axial losses, particularly those stemming from drift cyclotron loss-cone (DCLC) modes. Techniques such as filling ambipolar poles and employing centrifugal potentials for ion trapping are key components of Novatron's strategy against these instabilities. The design's approach to managing DCLC modes involves a nuanced understanding of plasma dynamics and magnetic field manipulation.

In terms of magnet design evolution, Novatron emphasizes high magnetic field symmetry. This is achieved through a three-coil system that shapes the magnetic field to enhance confinement and stability. This system marks a significant improvement over previous models by addressing the issue of unfavorable pressure gradient plasma, a challenge observed in earlier experiments like the RFC-XX-M.

As Novatron prepares for its proof-of-principle experimental facility, with initial experiments scheduled for late 2023, the fusion community observes with interest. The goal is to progress towards a 1.5 GWe reactor, Novatron 4, by the end of the 2020s. While some details, such as fuel choice and energy conversion methods, remain unspecified, Novatron's fusion concept represents a thoughtful and technically sound step towards realizing efficient and sustainable fusion power.

2 Cost Category 10: Pre-construction costs

Cost Category 10, which encompasses Capitalized Pre-Construction Costs, is an essential aspect of project budgeting in plant construction. This category includes a range of preliminary expenses incurred before the actual construction begins. These costs cover the acquisition of land and associated rights, obtaining necessary permits and licenses for the site and plant, and conducting essential studies and reports to ensure compliance and feasibility. Additional elements include various other pre-construction expenditures and a contingency allocation to account for unforeseen costs in these areas. This category is fundamental in laying the groundwork for a successful construction project, ensuring that all legal, environmental, and logistical bases are covered in preparation for the actual building phase. Total costs for for Cost Category 10 are $ C100000 M.

Cost Category - 11 Land and Land Rights

This Cost Category includes the purchase of new land for the reactor site and land needed for any co-located facilities such as dedicated fuel cycle facilities. Costs for acquisition of land rights should be included.

2020 update *Scope:* Purchase of new land *Previous values:* Different acreage estimates across the four fusion plant concepts based on their fusion power rating. Cost of $10,900/acre. Prior example: 462 acres × $10,900/acre = $4.9 million / 150 MW plant capacity = $33/kW. Min $14/kW, Average $20/kW, Max $33/kW *Reduction strategies:* Use of existing power plant site (potentially streamlined siting process if an existing nuclear fission plant site, perhaps after the fission plant has retired, but could also be a coal plant for repowering with fusion); minimum plant site acreage (much less need for buffer area than fission plant because fusion plants ; minimum price acre (marginal land far from cities (although it could also be argued that low radiation source terms will allow siting closer to cities)). Representative plant acreage and cost per acre for greenfield plant site: 400 acres × $10,000/acre = $4 million / 150 MW plant capacity = $27/kW, giving 23.8 M $.

2022 update A fusion power core will have a footprint as discussed in Cost Category 21, consisting of buildings that contain the fusion power core, turbine hall and hotcell. For most concepts, the site will also house switchyards and heat rejection (cooling towers). The site size will be set by the regulating authority, which will prescribe a site size proportional to the tritium inventory. The cost basis here is to determine the costs of the site beyond the boundary of the buildings scale in linear proportion to neutron power, with aneutronic fuels requiring the smallest boundary. Note also that these costs will not be required for retrofitting an existing power plant, or for heat sources that are brought onto an existing site. Greenfield site costs will vary by location. The costs are C110000 M for a system comprising of Nmod modules. The expression used to calculate the cost is given below:

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C_20 = sqrt(N_mod) * (P_NEUTRON /239 * 0.9 + P_FUSION/239*0.9)
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Cost Category 12 – Site Permits

This Cost Category includes costs associated with obtaining all site related permits for subsequent construction of the permanent plant. The total for this element is $ C120000 M.

Cost Category 13 – Plant Licensing

This Cost Category includes costs associated with obtaining plant licenses for construction and operation of the plant, typically $1 M to $10 M. This range accounts for the technical and engineering studies, safety analyses, and environmental impact assessments required. The total for this element is $ C130000 M.

Cost Category 14 – Plant Permits

This Cost Category includes costs associated with obtaining all permits for construction and operation of the plant, typically $ 500,000 to $ 5M. This cost can escalate if the licensing process is prolonged or if there are unique legal challenges. The total for this element is $ C140000 M.

Cost Category 15 – Plant Studies

This Cost Category includes costs associated with plant studies performed for the site or plant in support of construction and operation of the plant. For new designs, this can range from \$ 10 M to over \$ 100 M, especially if new safety features or innovative technologies are being developed. The total for this element is \$ C150000 M.

Cost Category 16 – Plant Reports

This Cost Category includes costs associated with production of major reports such as an environmental impact statement or the safety analysis report, usually in the range of \$ 500,000 to \$ 5 M. Comprehensive site evaluations, especially in environmentally sensitive areas, can be expensive. The total for this element is \$ C160000 M.

Cost Category 17 – Other Pre-Construction Costs

This Cost Category includes other costs that are incurred by Owner prior to start of construction and may include public awareness programs, site remediation work for plant licensing, etc. Typically, \$ 100,000 to \$1 M. Costs depend on the extent of the consultation process and the public's level of interest and concern. The total for this element is \$ C170000 M.

Cost Category 19 – Contingency on Pre-Construction Costs

This Cost Category includes an assessment of additional cost necessary to achieve the desired confidence level for the pre-construction costs not to be exceeded. We have set the basis as 10 % of the total costs in this major category. The total for this element is therefore \$ C190000 M.

3 Cost Category 20: Capitalized Direct Costs (CDC)

We borrow all of the two-digit cost accounts from the GENIV EMWG Guidelines, which depart slightly from the IAEA 2001 guidelines. Each subcategory is broken out separately. In the EMWG Guidelines document, cost category 20 is designated as "Capitalized Direct Costs" (CDC). This category is a key component of the overall cost structure for energy plant projects and includes various essential expenditures directly related to the construction and commissioning of a plant. Typically, such costs encompass all direct expenses incurred in the physical construction of the plant, including materials, labor, and any other resources directly associated with the construction activities.

3.1 Cost Category 21: Structures and Improvements

This account covers all direct costs associated with the construction and provision of physical plant buildings and structures. Key elements include the reactor, turbine, electrical equipment, and cooling system structures, along with site improvements, facilities, and miscellaneous building work. The costs for these structures, especially the heat island and turbine buildings, represent a significant portion of the total cost of the facility. For instance, the Heat Island Building is noted for its compact design, thick radiation shielding walls, and inclusion of access corridors and hot cell, leading to its estimated cost. The Turbine Building, housing turbines and auxiliary equipment, is also a major cost component, with its size and cost dependent on the size of turbines and equipment. Additional facilities like the Hot Cell, Service Water, and Fuel Handling Buildings, Control Room, On-Site AC Power, and other administrative and service buildings are also included, each having distinct scaling factors and cost estimates based on their specific functions and requirements within the power plant. We provide a detailed cost estimation approach for each of these buildings, reflecting their critical role in the overall construction and operation of the energy plant.

2020 Update *Scope:* Site preparation and yard work, reactor building, turbine building, security building and gatehouse, control and administrative buildings, maintenance shop, any other site structures

StandardFigures/siteplan2023-eps-converted-to.pdf

Figure 1: Site plan with labels according to the cost accounts described in the text. Cooling towers and Switchyards are costed elsewhere.

and facilities. *Previous values:* CAD calculations for building volumes and concrete volumes multiplied by materials costs. Min \$373/kW, Average \$606/kW, Max \$1,142/kW. *Reduction strategies:* Minimal reactor building size and wall/ceiling thickness (while fully preserving safety); minimal volumes for concrete and other materials (expensive concrete vs. inexpensive soil or sand, perhaps as inner fill material within metal or concrete walls); avoidance of unnecessary buildings in plant design; reuse of buildings if an existing power plant site; modular construction, as in Wartsila Modular Block. *Updated value:* Average of previous value reduced by 25 % with implementation of feasible strategies listed above. \$606/kW $\times$ - 0.25 = \$470/kW, giving a total for CAS21 of C210000 M \$.

Cost Category	Building	Wall materials	\$/kW gross	L	W	H	Vol	Esc year	Esc	\$/kW gross
21.01.00	Site improve. & facs		20.7					2019	1.19	24.6
21.02.00	Heat Island Building	Concrete & Steel	131.6	48.3	48.3	60	140000	2009	1.42	186.8
21.03.00	Turbine building	Steel	45.3	48.3	48.3	30	70000	2019	1.19	54.0
21.04.00	Heat rejection	Concrete & Steel	31.7	48.3	48.3	15	35000	2019	1.19	37.8
21.05.00	Power supplies	Concrete & Steel	9.1	9.7	9.7	6.0	560	2019	1.19	10.8
21.06.00	Plant aux.	Concrete & Steel	4.5	4.8	4.8	3.0	70	2019	1.19	5.4
21.07.00	Hot cell	Concrete & Steel	65.8	24.2	24.2	60	35000	2013	1.42	93.4
21.08.00	Heat Island Services	Steel frame	13.2	4.8	4.8	10	233	2013	1.42	18.7
21.09.00	Service water	Steel frame	0.2	1.3	4.0	4.0	21	2019	1.19	0.3
21.10.00	Fuel storage	Steel frame	0.9	5.0	15.0	2.5	188	2019	1.19	1.1
21.11.00	Control room	Steel frame	0.7	4.0	12.0	2	96	2019	1.19	0.9
21.12.00	Onsite AC power	Steel frame	0.7	3.6	10.8	1.8	70	2019	1.19	0.8
21.13.00	Administration	Steel frame	3.7	20.0	60.0	10	12000	2019	1.19	4.4
21.14.00	Site services	Steel frame	1.3	7.3	22.0	3.7	593	2019	1.19	1.6
21.15.00	Cryogenics	Steel frame	2.0	11.0	33.0	5.5	2003	2019	1.19	2.4
21.16.00	Security	Steel frame	0.7	4.0	12.0	2	96	2019	1.19	0.9
21.17.00	Ventilation stack	Steel & concrete	22.7			120		2019	1.19	27.0
21.98.00	Spare parts allowance									0.0
21.99.00	Contingency allowance		0.0							0.0
21.00.00	Structures and site facs		354.9							470.7

Table 1: Cost categories for buildings, and their cost estimation

Cost Category 21.1 Site Preparation/Yard Work

Includes clearing, grubbing, scraping, geo-technical work, site cut, fill and compact, drainage, fences, landscaping, etc. Cost is \$ C210100 M using NETL Reference case B12A, account 13, bare erected costs for 13.1 site preparation and 13.2 site improvements, for a 686MW gross power plant in 2019 \$, applying escalation per table 1.

Cost Category 21.2 Heat Island Building

Includes installation, labor, and materials for concrete and metalwork for the building surrounding and supporting the heat island, including the containment structure. Also includes the biological shielding, structural excavation and backfill, foundations, walls, slabs, siding, roof, architectural finishes, elevators, lighting, HVAC (general building service), fire protection, plumbing, and drainage. Cost is \$ C210200 M using Waganer cost reference for ARIES-ST.

Cost Category 21.3 Turbine Generator Building

Includes installation, labor, and materials for concrete and structural metalwork for the building surrounding and supporting the turbine generator(s). (For concepts that do not produce electricity, this account can be replaced with appropriate energy product buildings.) Also includes structural excavation and backfill, foundations, walls, slabs, siding, roof, architectural finishes, elevators, lighting, HVAC, fire protection, plumbing, and drainage. This building contains the turbines and heat exchangers. Cost is \$ C210300 M using NETL

Reference case B12A, account 14.3, turbine building bare erected costs for a 686MW gross power plant in 2019 $, apply escalation per table 1.

The rest of the 21 series accounts are for other support buildings on the site. Modular concepts might have a separate building to house centralized functions for all modules, such as an external control room. Here, the building costs are for the complete civil structure, including structural excavation and backfill, foundations, finishes, and building services such as elevators, lighting, HVAC, fire protection, or domestic water and drainage, but do not include the specialized equipment within.

- **21.04 - Heat Rejection Building**: This account covers the costs associated with the systems needed for rejecting heat from the power plant, scaled to the rejected thermal power. Cost is $ C210400 M using NETL Reference case B12A, account 14.2, boiler building bare erected costs for a 686MW gross power plant in 2019 $, apply escalation per table 1.
- **21.05 - Electrical Equipment & Power Systems Building**: It includes the costs for all electrical equipment and power systems, scaling with the net electrical power output of the plant. Cost is $ C210500 M, using a smaller version of the turbine building - multiple floors, concrete, per table 1.
- **21.06 - Plant Auxiliary Systems Building**: This account addresses the costs of auxiliary systems in the plant, such as compressed air, inert gas storage, and distribution systems, scaling with the gross electrical power. Cost is $ C210600 M as smaller version of the turbine building - multiple floors, concrete, per table 1.
- **21.07 - Hot Cell Building**: The cost for the Hot Cell Building, designed for handling large and hazardous components, is scaled in relation to the Reactor Building. Cost is $ C210700 M as a smaller version of the Heat Island Building by 50%, per table 1.
- **21.08 - Heat Island Service Building**: This includes the costs for a service building specific to the reactor, similar in cost to structures in projects. Cost is $ C210800 M as smaller version of the Heat Island Building by 10%, per table 1.
- **21.09 - Service Water Building**: The Service Water Building, essential for the plant's water supply needs, has its costs modeled after similar structures in other power plant projects. Cost is $ C210900 M following NETL Reference case B12A, account 14.5, circulation water pumphouse and 14.6 water treatment building bare erected costs for a 686MW gross power plant in 2019 $, applying escalation per table 1.
- **21.10 - Fuel Handling and Storage Building**: This account covers the costs for buildings related to handling and storing fuel, scaled according to tritium usage or fusion power. Cost is $ C211000 M, scaled relative to the administration building per table 1.
- **21.11 - Control Room Building**: It encompasses the expenses for the control room building, essential for plant operations, with costs similar to those in previous plant designs. Cost is $ C211100 M scaled relative to the administration building per table 1.
- **21.12 - On-Site AC Power Building**: This account includes the costs for buildings housing on-site alternating current (AC) power systems, comparable to similar structures in other projects. Cost is $ C211200 M scaled relative to the administration building per table 1.
- **21.13 - Administrative Building**: It covers the costs associated with the construction of the plant's administrative building, with cost estimates based on previous similar projects. Cost is $ C211300 M as NETL Reference case B12A, account 14.4, administration building building bare erected costs for a 686MW gross power plant in 2019 $, apply escalation per table 1.
- **21.14 - Site Service Building**: This account entails the costs for a building providing various site services, with costs aligned with those in comparable plant designs. Cost is $ C211400 M as NETL Reference case B12A, account 14.7, machine shop building bare erected costs for a 686MW gross power plant in 2019 $, apply escalation per table 1.

- **21.15 - Cryogenic and Inert Gas Storage Building**: It includes the costs for buildings that store cryogenic and inert gases, essential for plant operations. Cost is $ C211500 M Like site services, per table 1.
- **21.16 - Security Building**: The Security Building account covers the costs for structures dedicated to the plant's security and surveillance. Cost is $ C211600 M like administration, see table 1.
- **21.17 - Ventilation Stack**: This account addresses the costs of the ventilation stack, a crucial component for plant ventilation and safety. Cost is $ C211700 M as NETL Reference case B12A, account 7, ventilation stack bare erected costs for a 686MW gross power plant in 2019$, apply escalation per table 1.

A Glossary of terms

ALPHA Accelerating Low-Cost Plasma Heating and Assembly

ARIES Advanced Reactor Innovation and Evaluation Study

ARPA-E Advanced Research Projects Agency - Energy

BOP Balance of plant

CAD Computer-aided design

CBS Cost breakdown structure

DOE U.S. Department of Energy

D-D Deuterium-deuterium

D-T Deuterium-tritium

ETS Energy transfer and storage

FCR Fixed charge rate

FPC Fusion power core

FPP Fusion power plant

FRC Field reversed configuration

HP High pressure

HVAC Heating, ventilation, and air conditioning

I&C Instrumentation and control

IOU Investor Owned Utility

IFE Inertial fusion energy

kWh Kilowatt Hour

LCOE Levelized cost of electricity

LOCA Loss of coolant accident

LP Low pressure

MFE Magnetic fusion energy

MIF Magneto-inertial fusion

MTF Magnetized target fusion

MW Megawatt

MWe Megawatt electric

MWth Megawatt thermal

NEA Nuclear Energy Agency

NIF National Ignition Facility

NRL Naval Research Laboratory

SLC Stabilized liner compressor

SMR Small modular reactor

TAE TAE Technologies

USD U.S. dollars

B Bibliography