Leading Industrial Scale Clean Energy Transition

December 24, 2021

DASTUR ENERGY

About the Dastur Group of Companies

1. 65 years of experience in engineering, technology and consulting
2. Assisted clients with over $100B of new investment decisions and turnarounds
3. Assisted clients with over $20B of stressed asset restructuring
4. Over 1000 clients in more than 20 countries
5. 60% of our major clients have been with us for over 20 years
6. 650 engineers with 10,000+ years of cumulative experience

Austin, TX based Dastur Energy is the clean energy arm of the Dastur group of companies, which has 65^{+} years legacy of designing and engineering large scale capital projects worldwide

Dastur Energy Leadership & Key Experts

Atanu Mukherjee
President & CEO

An energy thought leader, an entrepreneur and a business and technology leader Atanu works at the highest levels of enterprises, investors and governments. Earlier he was in senior business and technology leadership at Microsoft Corp. and Digital Equipment Corp.

Atanu has a graduate degree in Engineering and Management from MIT School of Engineering and MIT Sloan School of Management and was a Research Fellow at CSAIL.

Abhijit Sarkar
Vice President

As a business leader, and investment and commercial manager Abhijit works with the C-Suite of energy and industrial companies. Earlier, he led program and business management at Microsoft Corp. He was an investment manager at Janus Capital where he invested in emerging markets, the commodity and the energy sectors.

Abhijit is a graduate in Computer Science & Economics from MIT and holds an MBA from the Wharton School.

Dastur Energy Leadership & Key Experts

Steven Winberg
Strategic Advisor

Steven Winberg has 39 years of experience in the energy industry. He served as Assistant Secretary for Fossil Energy, US Department of Energy.

Mr. Winberg received a bachelor's degree in nuclear science from the State University of New York Maritime College and an MBA from the University of Pittsburgh.

Phil Amick
Gasification Expert

Phil has previously worked for Brown & Root, Power Systems Engineering Inc. (PSE), Destec, Dynegy, Global Energy Inc., ConocoPhillips, Phillips 66 Company and CB&I. He was the Chairman of Gasification Technologies Councill and served on its Executive Committee .

Phil holds a bachelor's degree in mechanical engineering from the Rose-Hulman Institute of Technology, Terre Haute, Indiana, USA.

Ken Medlock
Energy Economics Expert

Kenneth B. Medlock III, Ph.D., is the James A. Baker, III, and Susan G. Baker Fellow in Energy and Resource Economics at the Baker Institute and the senior director of the Center for Energy Studies.
Medlock received his Ph.D. in economics from Rice University.

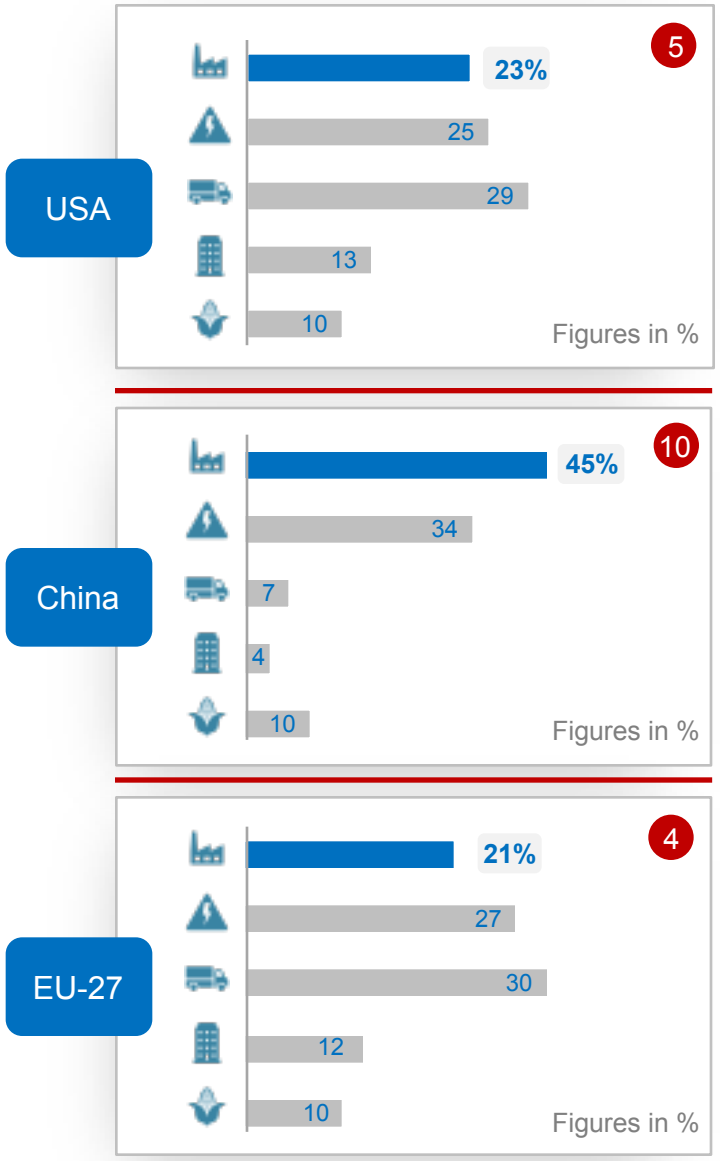
Jerry Hausman
Policy and Industrial Economics Expert

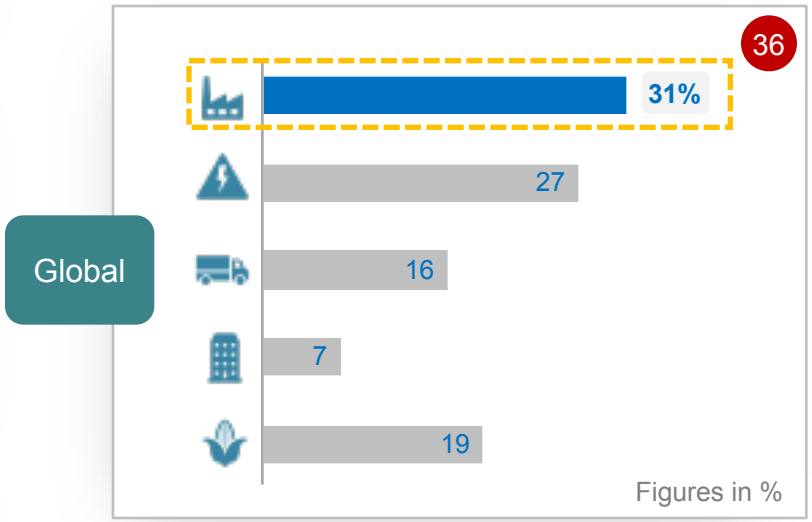
Jerry A. Hausman is the John and Jennie S. MacDonald Professor of Economics at MIT in Cambridge, Massachusetts, USA. He is the Director of the MIT Telecommunications Economics Research Program

Susan Hovorka
Geologic Sequestration & EOR Expert

Susan D. Hovorka is a Senior Research Scientist at the Bureau of Economic Geology, Jackson School of Geosciences, at The University of Texas at Austin.
Hovorka has earned her BA in geology from Earlham College and an MA and Ph.D. from the University of Texas

What Problem does Dastur Energy Address - The 70% Emissions Challenge





Renewables target only 30% of the total CO_2, emitted from power generation

Difficult to decarbonize industrial sector accounts for the majority of the challenge

Low carbon energy carriers, waste gas transformation and CCUS is key

Total Emissions (GT)
Industry
Electricity
Transport
Building
Agriculture

Source: Breakthrough Energy, Euro Stat, DE Research

Dastur's Philosophy and Approach to Industrial Scale Clean Energy Transition

01 Recognizing that CO_2 is the Enemy, NOT Gas, Wind, Coal, Oil, Solar or Nuclear

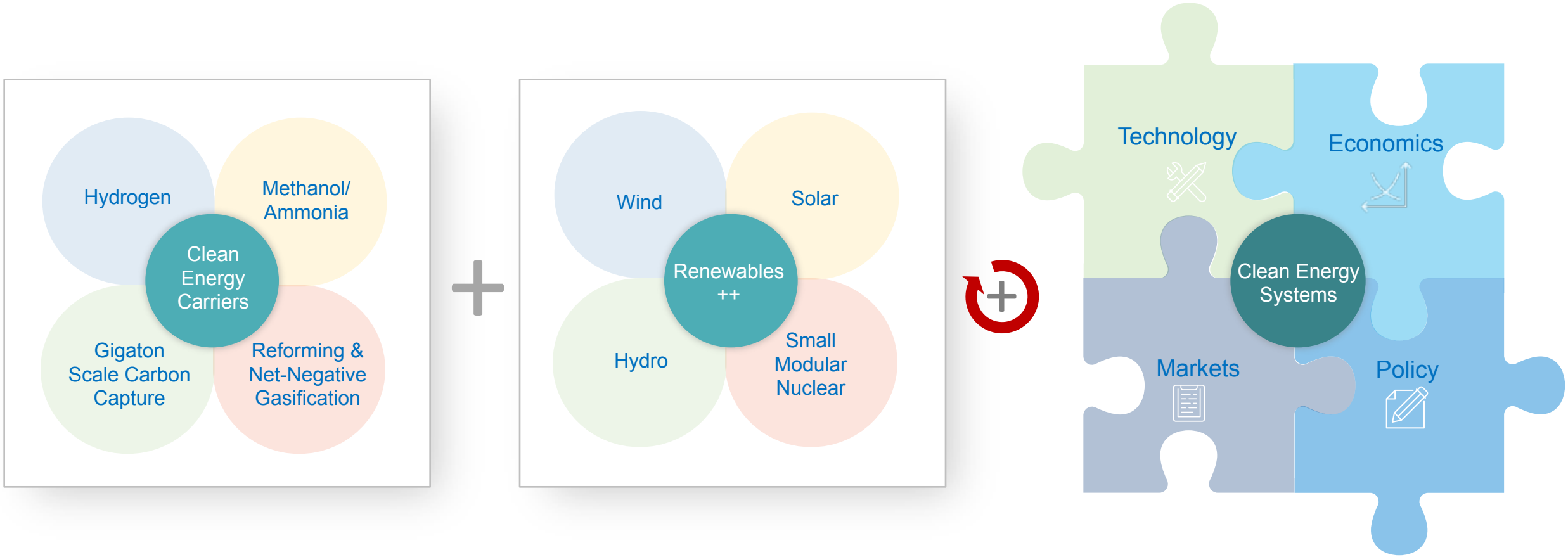
02 Decarbonizing Industrial Activity is Key to a Net Zero World

03 Hydrogen and Other Low Carbon Carriers Key to Industrial Decarbonization

04 Giga Ton (GT) Scale CO_2 Management Infrastructure Essential for Deep Decarbonization

05 Without Economic Viability, Energy Transition cannot be Accelerated

Our Vision - A Systems Approach to Deep Decarbonization with a Portfolio of Options



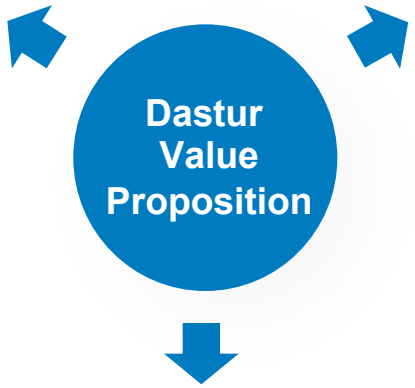
Dastur Energy Value Proposition

Design & Solutions

(Concept, Market Model, Policy, Feasibility, System Design)

Technology & Engineering

(Technology Licensing, IP & Knowhow, Basic Engineering / PDP)



Economics & Finance

(Techno-Economics, Business & Operating Models)

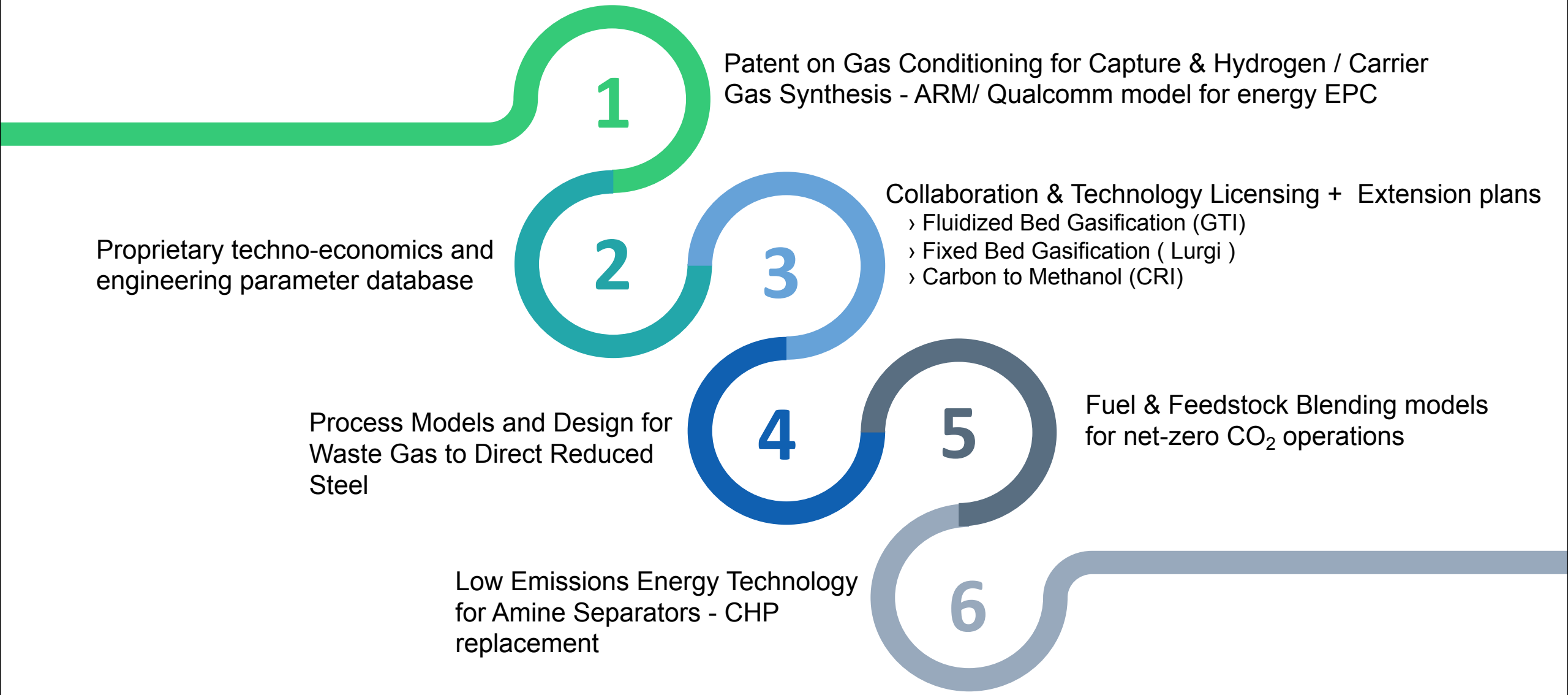
Clean Energy

- Gasification
- Methanol and derivatives
- H_2, Ammonia, Derivatives, Fuel blends
- H_2 Turbines, Clean Power Systems

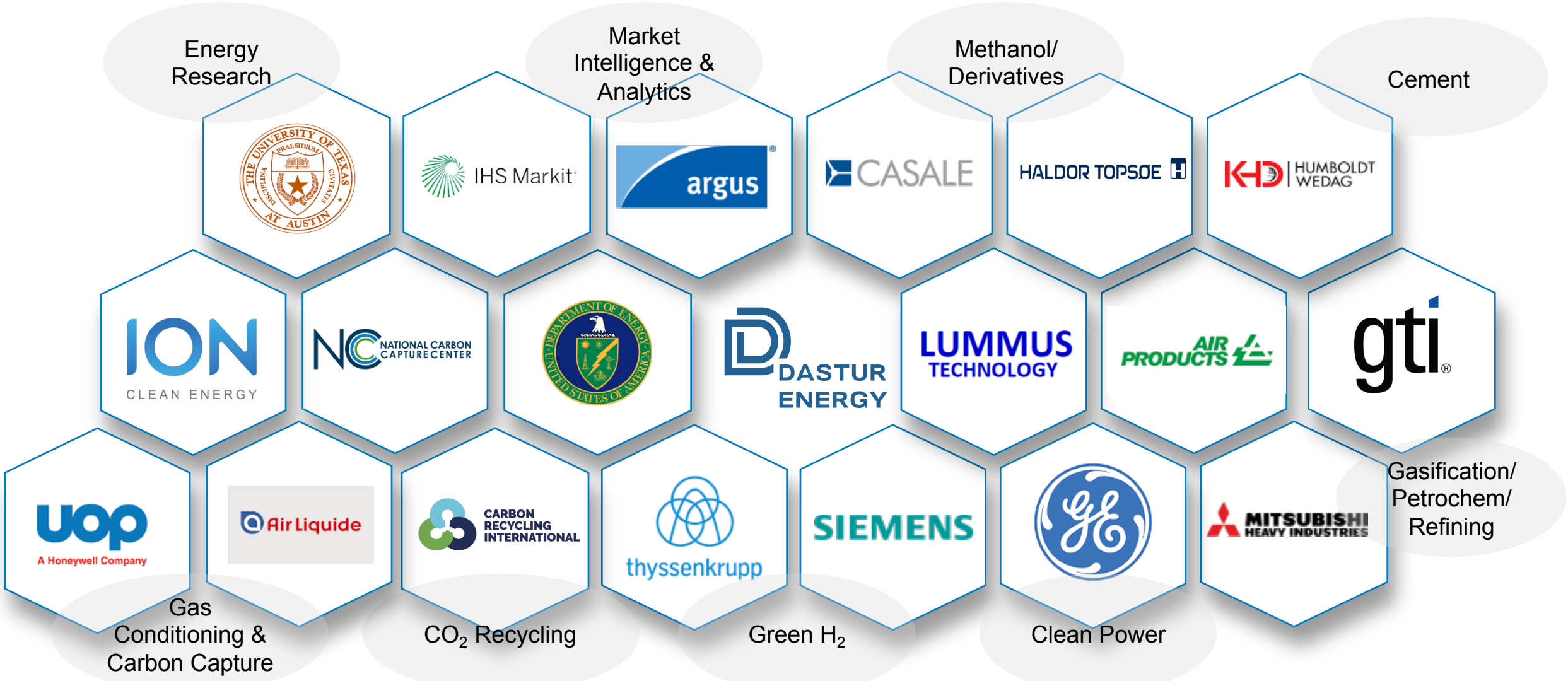
Carbon Engg

- Gas Conditioning & Conversion
- Carbon Capture and Utilization
- Carbon Transport – Tanker and Pipeline
- EOR & Sequestration - Storage and CO_2 EOR

Dastur Energy IP and Knowhow – Optimal Gas Conditioning is Key to Decarbonization



Broad Network of Partnerships across the Clean Energy Value Chain



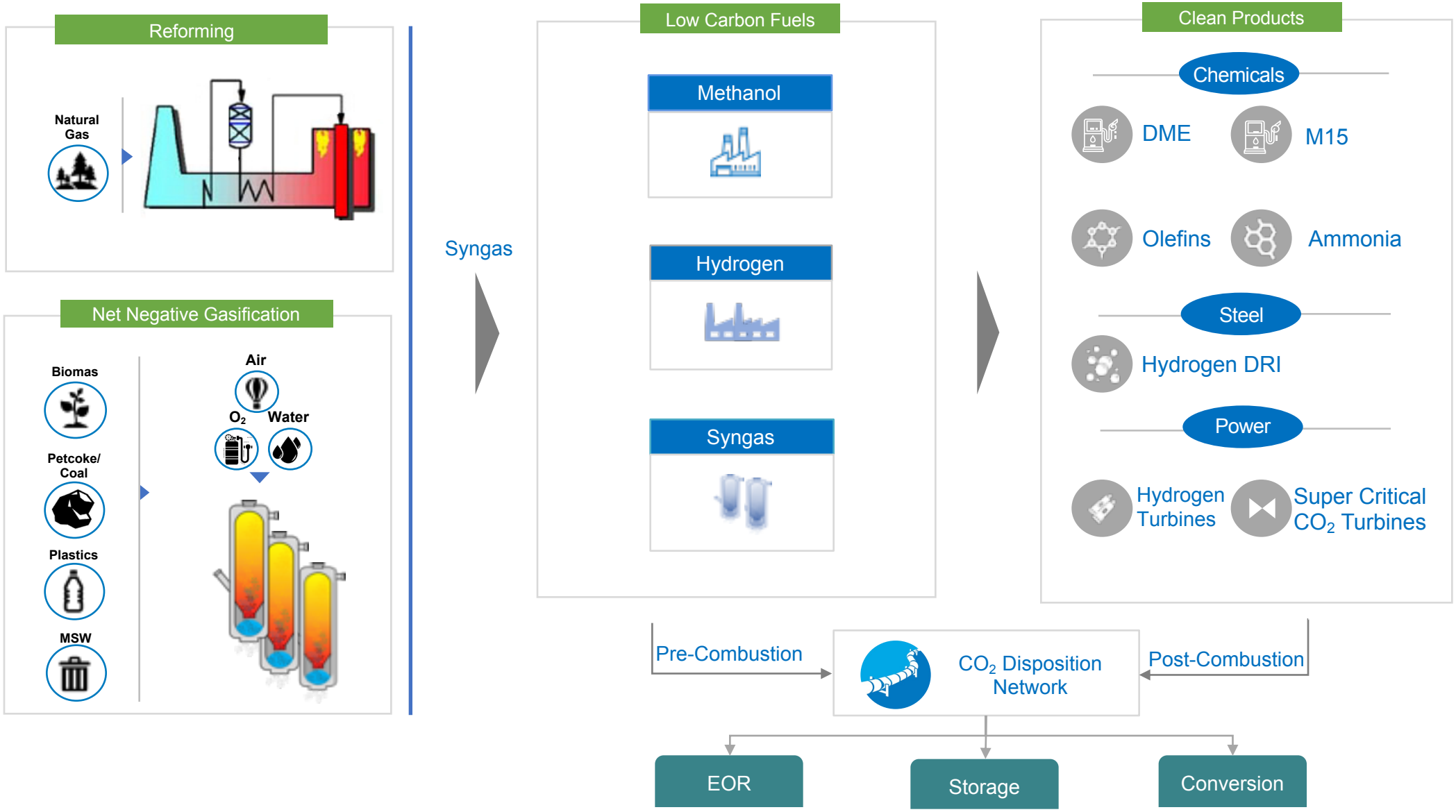
Dastur Energy – Recent Projects

US DOE & Cleveland-Cliffs	USTDA & BPCL	USTDA & IOCL	USTDA & Greenko	Abu Dhabi National Oil Company	CSIR – CIMFR	NITI Aayog, Govt. of India
Industrial Scale Carbon Capture from Blast Furnaces of Burns Harbor works, Indiana, USA	Clean Fuels & Products through Gasification of Petcoke from BPCL Refinery, Kochi, India	Industrial Scale Carbon Capture from Hydrogen Units of IOCL Refinery for EOR, Koyali, India	Clean energy carriers through gasification of biomass and MSW – **Proposal stage**	Hyper-Scale Blended Fuel Gasification for Large Scale EOR, Hydrogen and Chemicals in UAE	Coal based syngas to Methanol unit	Carbon Capture Policy Framework and Deployment Mechanism for India
Carbon Capture | Gas Conditioning | H_2 rich fuel usage | Sequestration	H2, Methanol, MEG, Acetic Acid, Clean Power | Refinery to Petrochemicals | Carbon Capture	Carbon Capture | EOR | Refinery Operations | Food & Beverage	Biomass + MSW gasification | Bio-methanol & green hydrogen | Feasibility & Pre-FEED	Petcoke + Coal Gasification | IGCC Power | H2 | Chemicals | Carbon Capture | EOR	Engineering | Project Management | Erection | Commissioning	Carbon Capture | Policy Framework | CCUS Financing| Sustainable Development

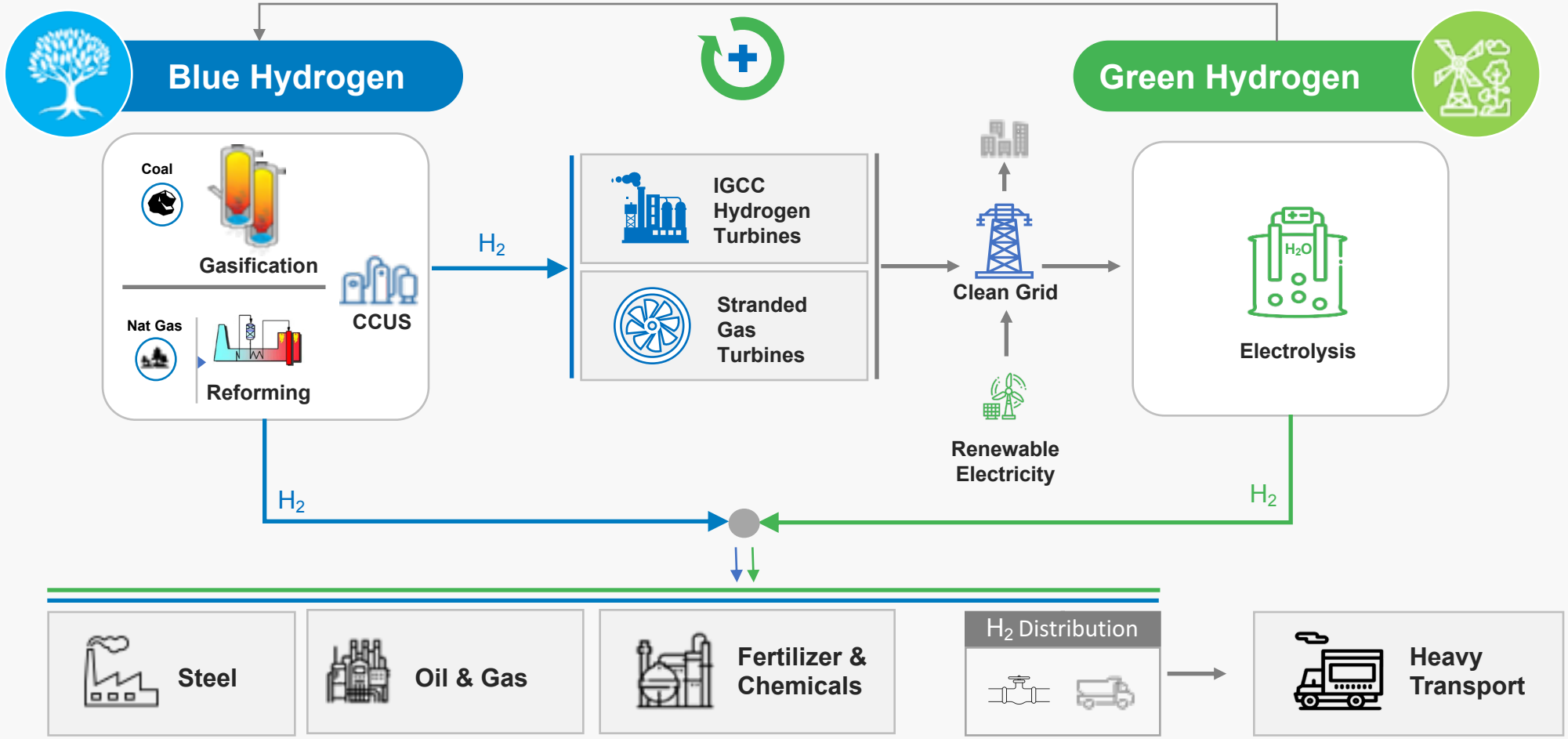
We are pioneering some of the leading industrial scale clean energy projects around the world

Dastur Energy's Systems Model Framework for New Energy Carriers, Gasification and Giga Ton Scale Carbon Capture Management that will be the Building Blocks for Enabling the Low Carbon Industry

Dastur Energy - Commercial Scale Deep Decarbonization Model for the Industry

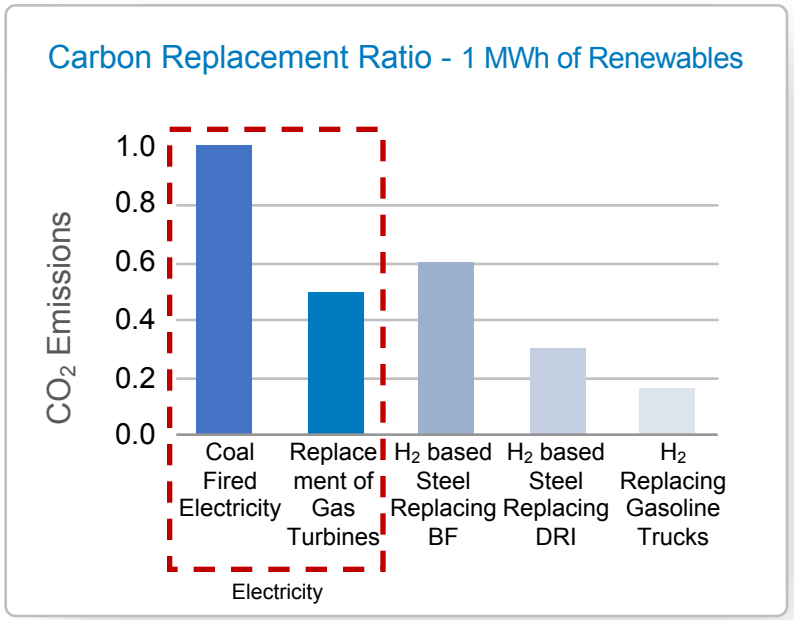


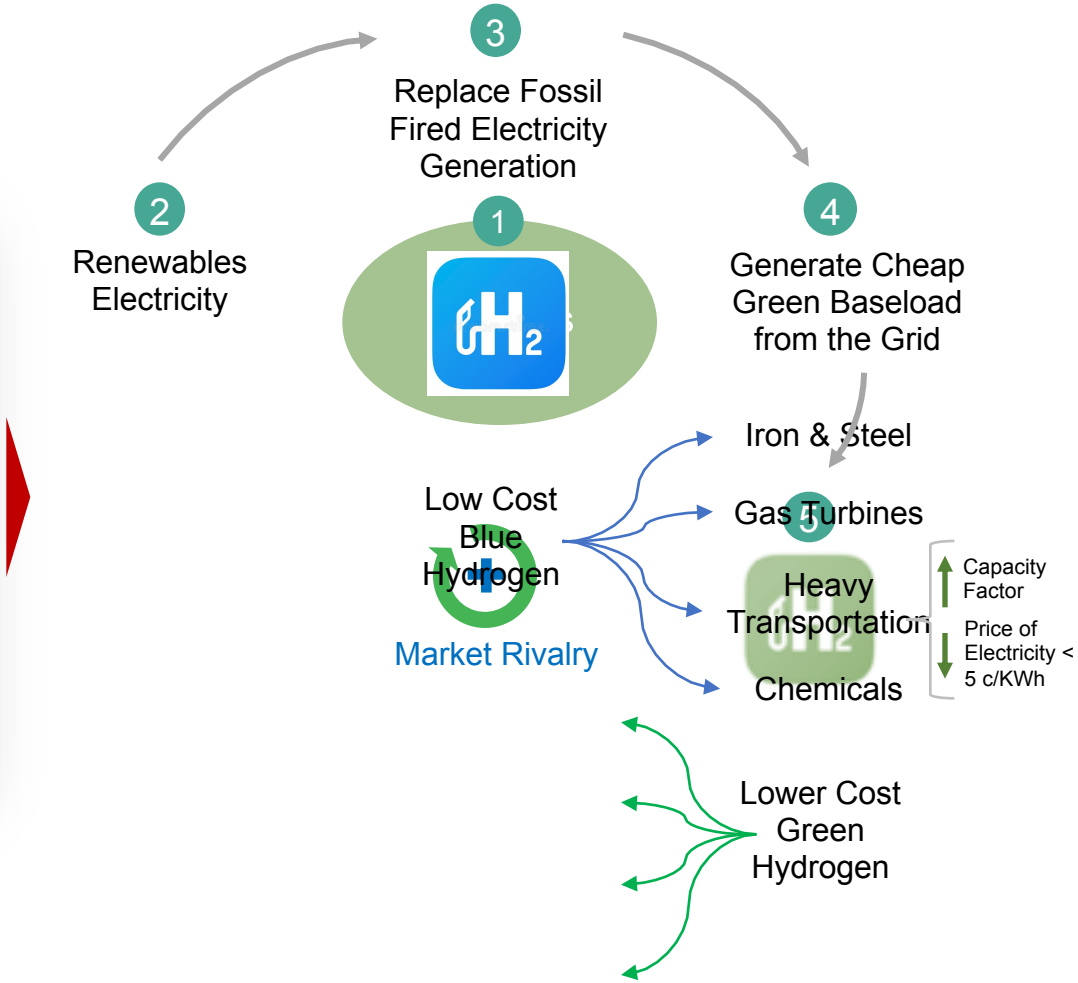
Dastur Energy - Model for Hydrogen Economy Evolution

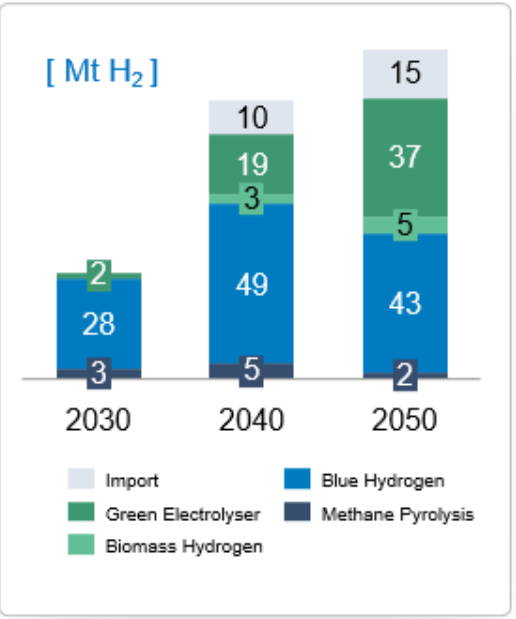


Energy Security, Economic Prosperity

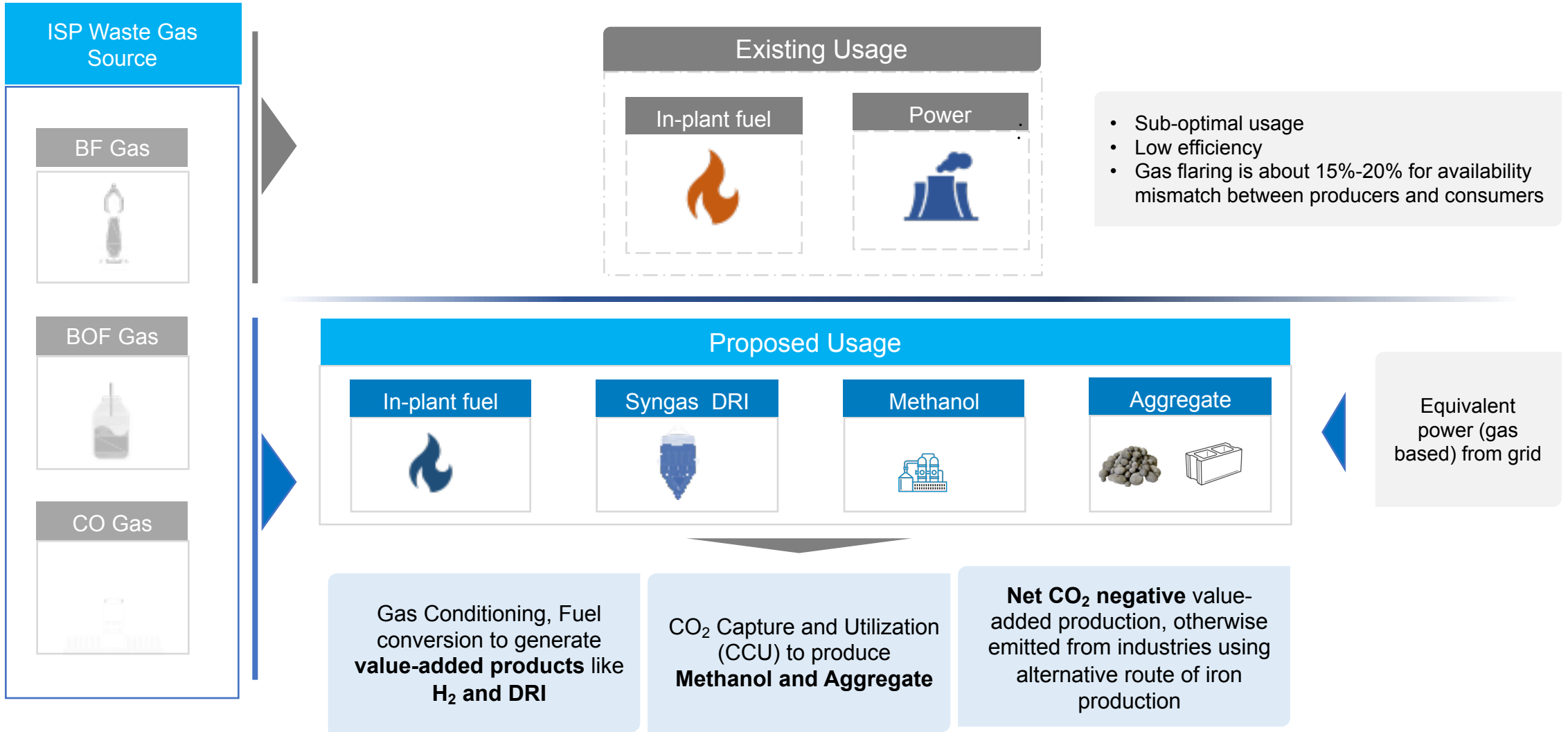
The Market Evolution Model for the Hydrogen Economy





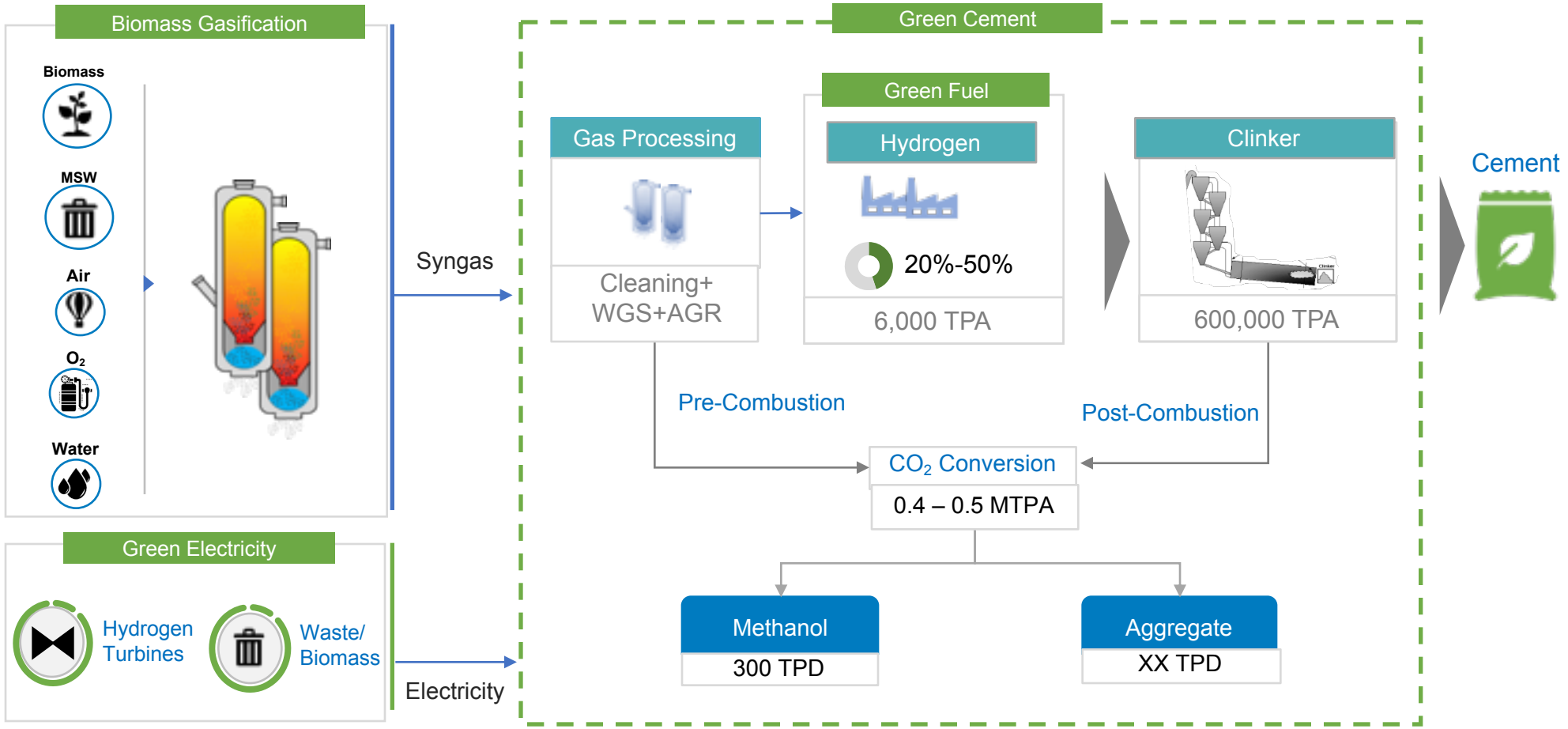


Dastur Energy – Iron & Steel Industry Transformation and Decarbonization Model



Dastur Energy – Hydrogen Based Cement Plant Decarbonization Model

1. Biomass Gasification
2. Green Hydrogen & Electricity
3. Carbon Capture
4. Carbon Conversion for Value Added Products



1. Considering clinker factor of around 0.6, clinker production for 3 mtpa cement is estimated to 1.8 mtpa
2. Hydrogen consumption calculated as 20 kg per tonne of clinker based on equivalent energy consumption
3. Energy consumption has been calculated at benchmark parameter (BAT) of 2.7 MMBtu per tonne of clinker

Source: Dastur Research, IEA

Dastur Energy - Model for Large Scale CO_2 Capture and Management – '**GT Scale CO_2 Grid**'

Industrial emitters

Refineries

Power

Gasification / H_2 production

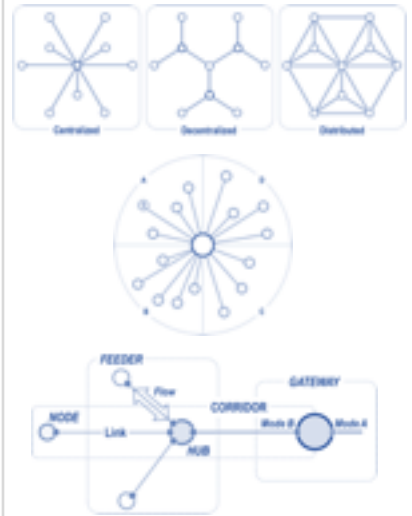
Iron & Steel

Chemicals / e-chemicals

0.5 GTPA of CO_2

CO_2 Collection & Processing Hub

CO_2 Transportation



Storage

- Gulf Coast
- Texas off-shore

25 - 30 GT#

#Over 50 yrs.

EOR

- Permian Basin (West TX)
- East Texas
- Central Texas

10 - 50 MTPA

Ref : EIA, 2018

CO_2 Grid Operator's Boundary

Large scale CO_2 collection, aggregation, transport and disposition infrastructure that is economically attractive and operationally seamless for emitters

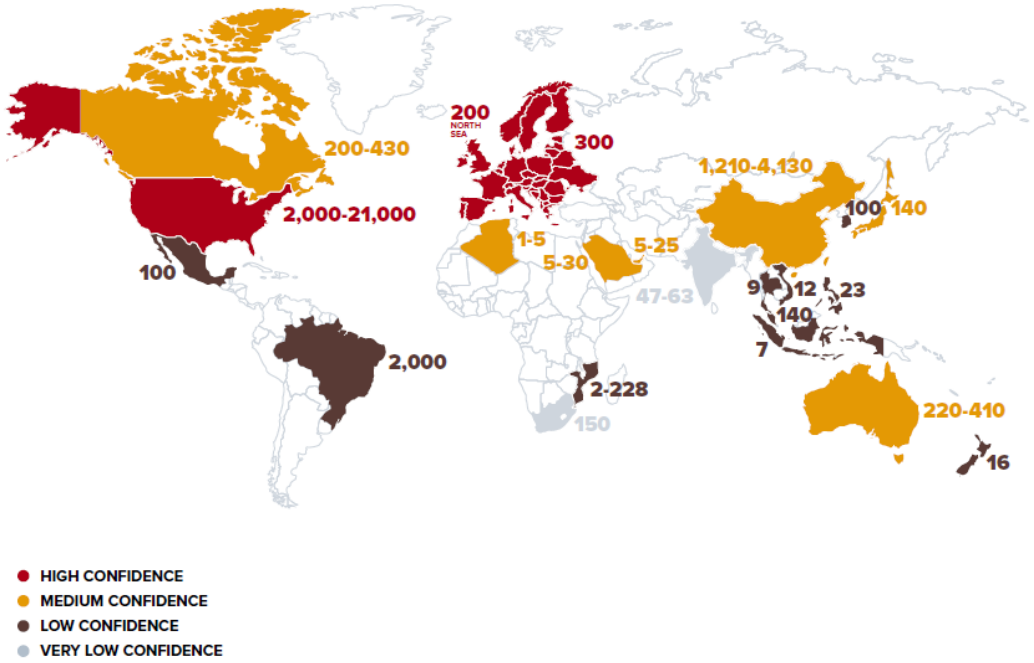
Operating Principles of the GT Scale CO_2 Grid

1. Grid contains access points and hubs, federated pipeline, very large-scale sinks (sequestration)
2. Grid transfers to EOR disposition on a spot and contractual basis like other commodity markets
3. Grid carries out Monitoring Verification and Accounting (MVA) to enable emitter to collect credits
4. Grid offers ‘Take or Pay’ contracts for minimum volume of CO_2 to emitters
5. Grid prices in or transfers the operating risks of transport & sequestration away from emitters

Example: A GT Scale CO_2 Grid Architecture for Inter-Region CO_2 Sequestration and Transport

CO_2 Sequestration Landscape

Estimate of Global CO_2 Geological Storage Capacity in Billions of Tonnes.
Confidence is a measure of the maturity of storage resource appraisal



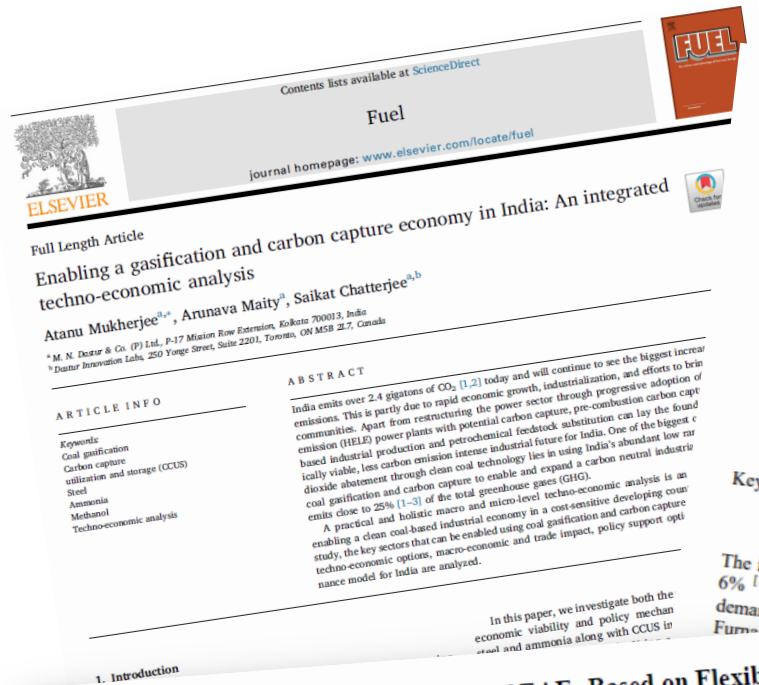
Source: *Medlock & Miller*, 2021

- Optimized Automated Switched Transport across Source-Sinks based on QoS
- Federated CO_2 Transport Grid Design
- Risk & Liability Hedge Model for Sequestration
- Investment, Financing & Policy Requirement
- Anchor GT Scale H_2 Projects

Competitive Positioning of Dastur Energy

Company \ Parameters	Partnership	Competitive Cost Structure	IP & Knowhow	Systems Approach
DASTUR ENERGY / DASTUR	✓	✓	✓	✓
Worley	✓	?	?	?
FLUOR	✓	?	✓	?
BECHTEL	✓	?	?	?
Technology Licensors	✓	?	✓	?
Management Consultants	✓	?	?	?

Dastur Energy's Ongoing Research in Energy Transition for the Industry



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Full Length Article

Enabling a gasification and carbon capture economy in India: An integrated techno-economic analysis

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ARTICLE INFO

Keywords:
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Carbon capture utilization and storage (CCUS)
Steel
Ammonia
Methanol
Techno-economic analysis

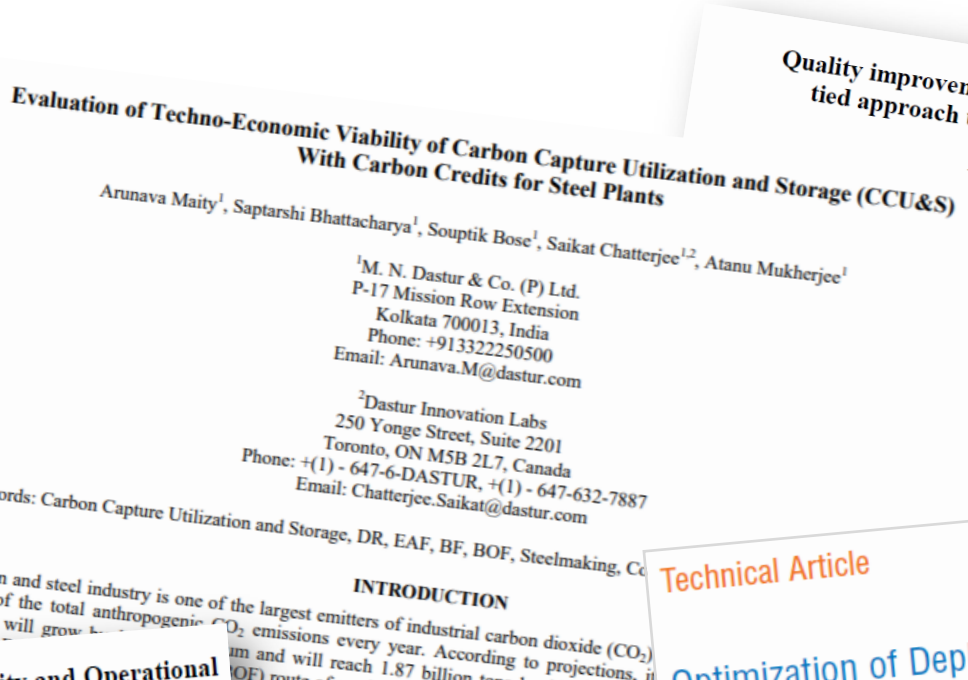
ABSTRACT

India emits over 2.4 gigatons of CO_2 [1,2] today and will continue to see the biggest increase in emissions. This is partly due to rapid economic growth, industrialization, and efforts to bring communities. Apart from restructuring the power sector through progressive adoption of emission (HELE) power plants with potential carbon capture, pre-combustion carbon capture based industrial production and petrochemical feedstock substitution can lay the foundation dioxide abatement through clean coal technology lies in using India's abundant low rank coal gasification and carbon capture to enable and expand a carbon neutral industrial emits close to 25% [1–3] of the total greenhouse gases (GHG).

A practical and holistic macro and micro-level techno-economic analysis is an enabling a clean coal-based industrial economy in a cost-sensitive developing country study, the key sectors that can be enabled using coal gasification and carbon capture techno-economic options, macro-economic and trade impact, policy support options nance model for India are analyzed.

1. Introduction

In this paper, we investigate both the economic viability and policy mechanisms steel and ammonia along with CCUS in



Evaluation of Techno-Economic Viability of Carbon Capture Utilization and Storage (CCU&S) With Carbon Credits for Steel Plants

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Keywords: Carbon Capture Utilization and Storage, DR, EAF, BF, BOF, Steelmaking, Co

INTRODUCTION

The iron and steel industry is one of the largest emitters of industrial carbon dioxide (CO_2) 6% [1] of the total anthropogenic CO_2 emissions every year. According to projections, it demand will grow [illegible] and will reach 1.87 billion tons by 2035[2]. Inclu Furnace (BOF) route of production, the average CO_2 emission for Thus, the steel industry is set to produce around 3.9 billi ssia, Ukraine, and the USA account for more than 90

process of capturing CO_2 from emissions produced fi The captured CO2 is compressed and converted into l mercial activities. Along with storage/sequestration, the hanced Gas Recovery (EGR) [4] allows recovery of r the chemical and fertilizer industries to produce metha loyment of Carbon Capture Utilization and Storage (atives. Although CCU&S presents great prospect, majo wer and cement sectors [5], while the steel industry h

opment and adoption of carbon-lean technologies, amon issions in the iron and steel sector are very site-specific [illegible] on the

Quality improvements in a multistrand billet caster tundish: Triangle tied approach using simulation, plant trials and economics

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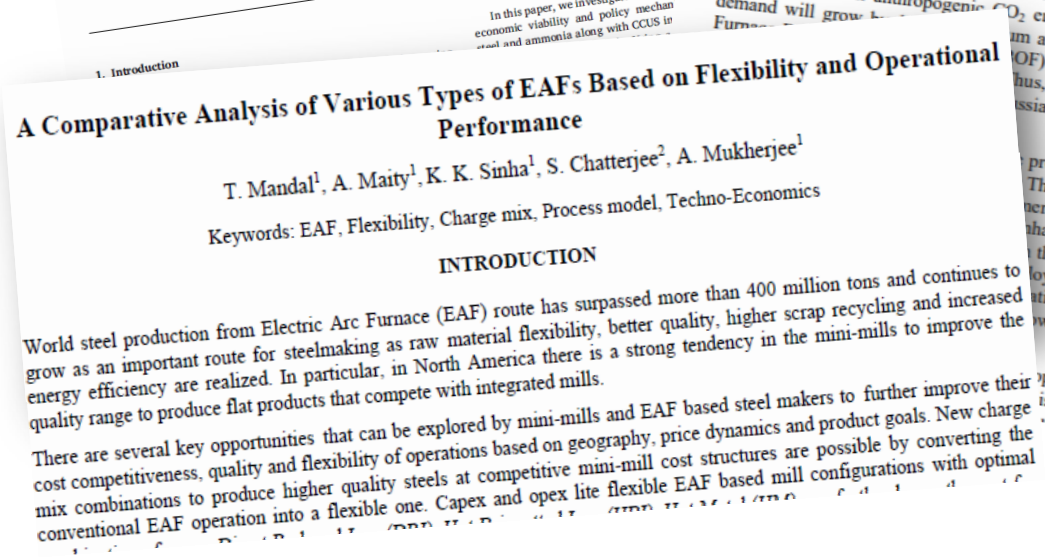
c approach, including computational fluid dynamic has been taken up to quantify quality SBQ and OCTG grades. The effect ontrol devices (ECD related

Technical Article

Optimization of Dephosphorization Practice in BOF Shops Using Advanced Analytics

High phosphorus levels in steel result in products with poor mechanical properties, erode profit margins, lower flexibility in downstream processing and disrupt delivery schedules. A robust advanced analytics model was developed for finding optimum process parameters resulting in low end blow phosphorus and high phosphorus partitioning in an LD shop. Best patterns were determined for oxygen blowing, material charging sequence and bottom stirring. This model, along with a machine learning approach, can suggest real-time operating recipes to the operators resulting in a massive 13% increase in the current success rate of the heats complying with the aim phosphorus level.

Precise control over phosphorus levels in finished steel products ensures high profit margins, flexi- due to increased phosphorus levels in iron ores. Additionally, basic oxygen furnace (BOF) slag, which



A Comparative Analysis of Various Types of EAFs Based on Flexibility and Operational Performance

T. Mandal[1], A. Maity[1], K. K. Sinha[1], S. Chatterjee[2], A. Mukherjee[1]

Keywords: EAF, Flexibility, Charge mix, Process model, Techno-Economics

INTRODUCTION

World steel production from Electric Arc Furnace (EAF) route has surpassed more than 400 million tons and continues to grow as an important route for steelmaking as raw material flexibility, better quality, higher scrap recycling and increased energy efficiency are realized. In particular, in North America there is a strong tendency in the mini-mills to improve the quality range to produce flat products that compete with integrated mills.

There are several key opportunities that can be explored by mini-mills and EAF based steel makers to further improve their cost competitiveness, quality and flexibility of operations based on geography, price dynamics and product goals. New charge mix combinations to produce higher quality steels at competitive mini-mill cost structures are possible by converting the conventional EAF operation into a flexible one. Capex and opex lite flexible EAF based mill configurations with optimal

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