Sustainable Approaches for Abnormal Situation Management

Presented by

Dr. Kazi Monzure Khoda

Department of Chemical Engineering
Qatar University

15 February 2015

Workshop on Energy & Water Security
Doha, Qatar

Process Upsets – Abnormal Situations

Is this a Normal Situation?

جامعة قطر
QATAR UNIVERSITY

Process Upsets – Abnormal Situations

Is this what we mean by Abnormal Situation?

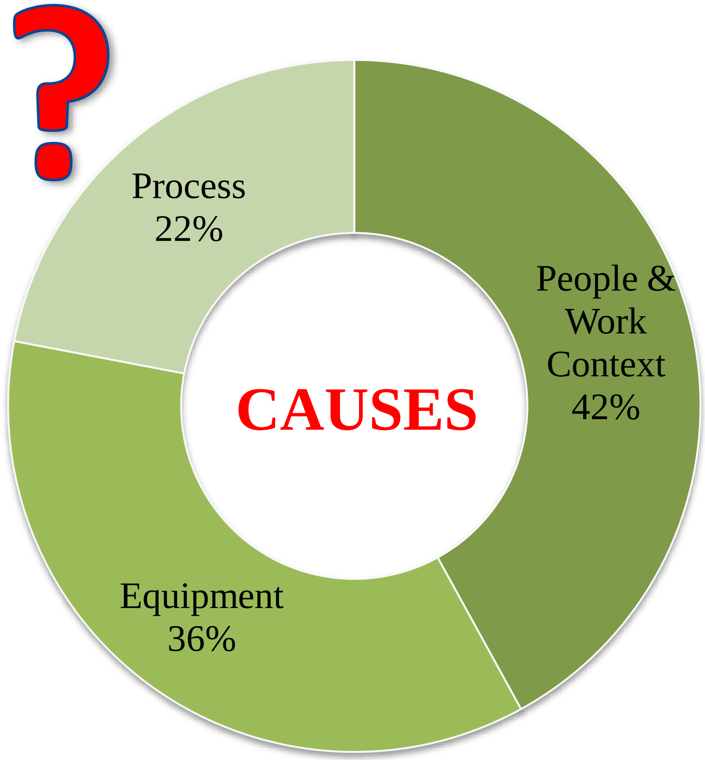
جامعة قطر
QATAR UNIVERSITY

Process Upsets – Abnormal Situations

Processes eventually deviate from normal operations; and *control system* are in place to *mitigate* such deviations.

When control system ***CAN NOT*** cope with disturbances, human intervention (DCS operators) is needed

ABNORMAL SITUATIONS



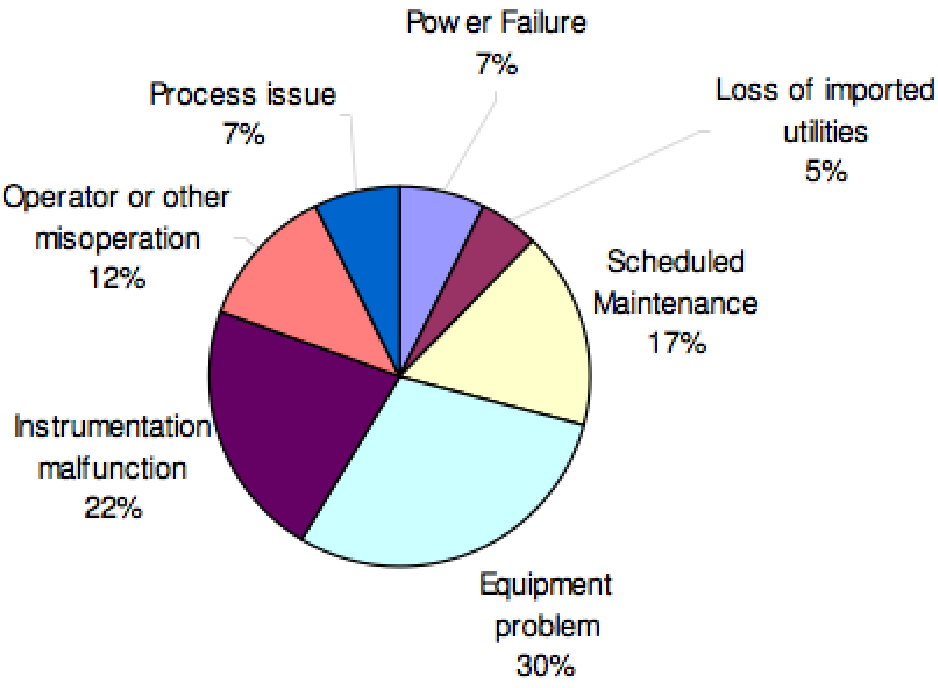
Cochran, E., Bullemer, P. (1996). "ASM: Not by New Technology Alone…", 1996 AIChE conference.

Process Upsets – Abnormal Situations

Processes eventually deviate from normal operations; and *control system* are in place to *mitigate* such deviations.

When control system ***CAN NOT*** cope with disturbances, human intervention (DCS operators) is needed

ABNORMAL SITUATIONS

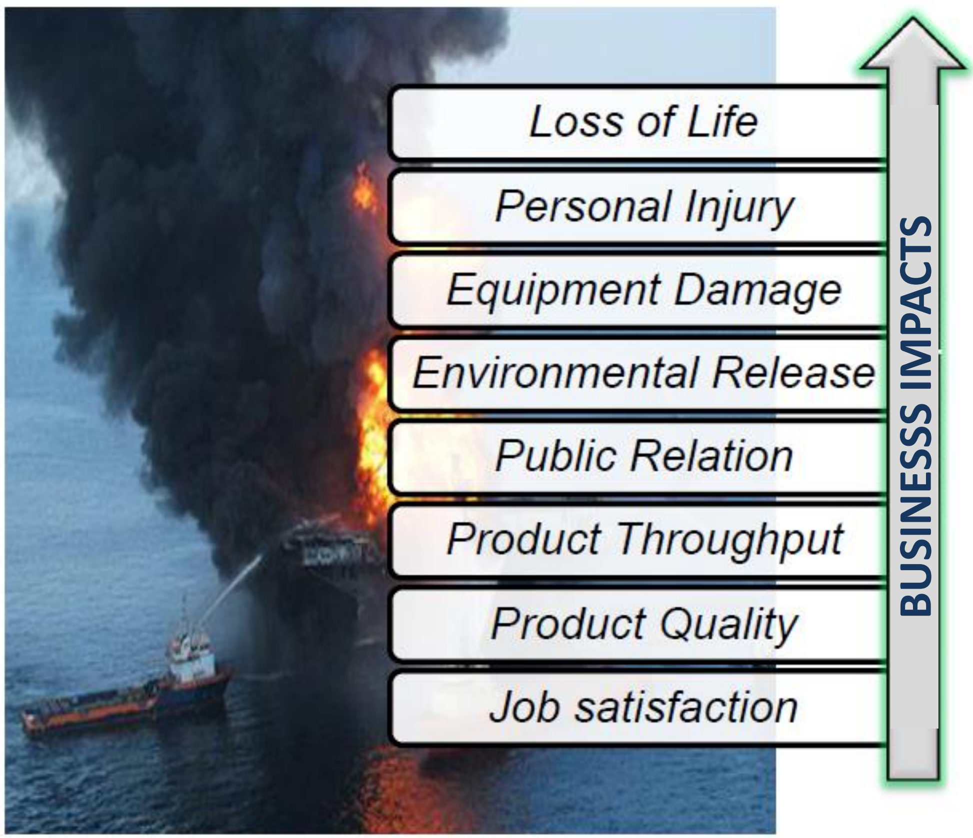


Midstream Upset Flaring and Management Options, April 2010

QATAR UNIVERSITY

Process Upsets – Abnormal Situations

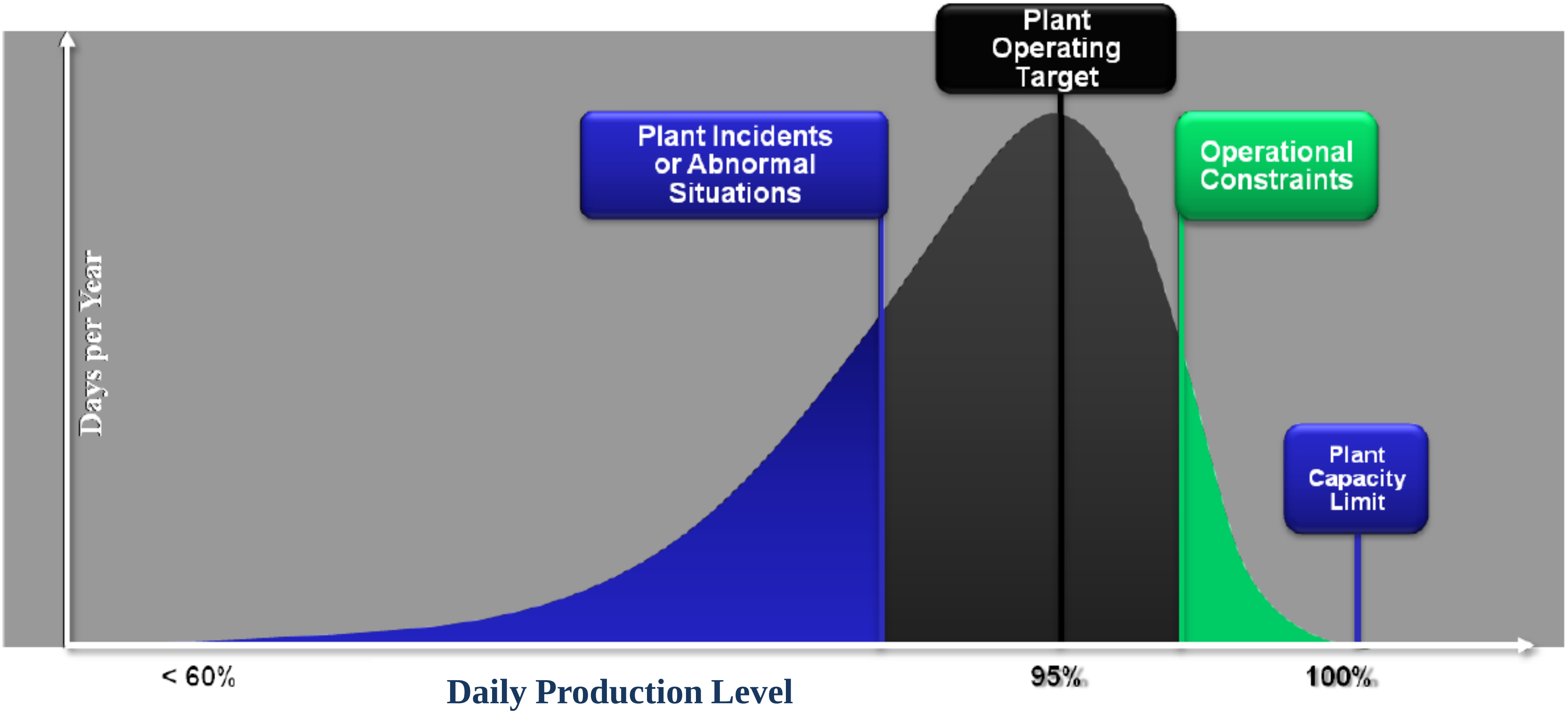
Abnormal Situations Impact Profitability



QATAR UNIVERSITY
جامعة قطر

Process Upsets – Abnormal Situations

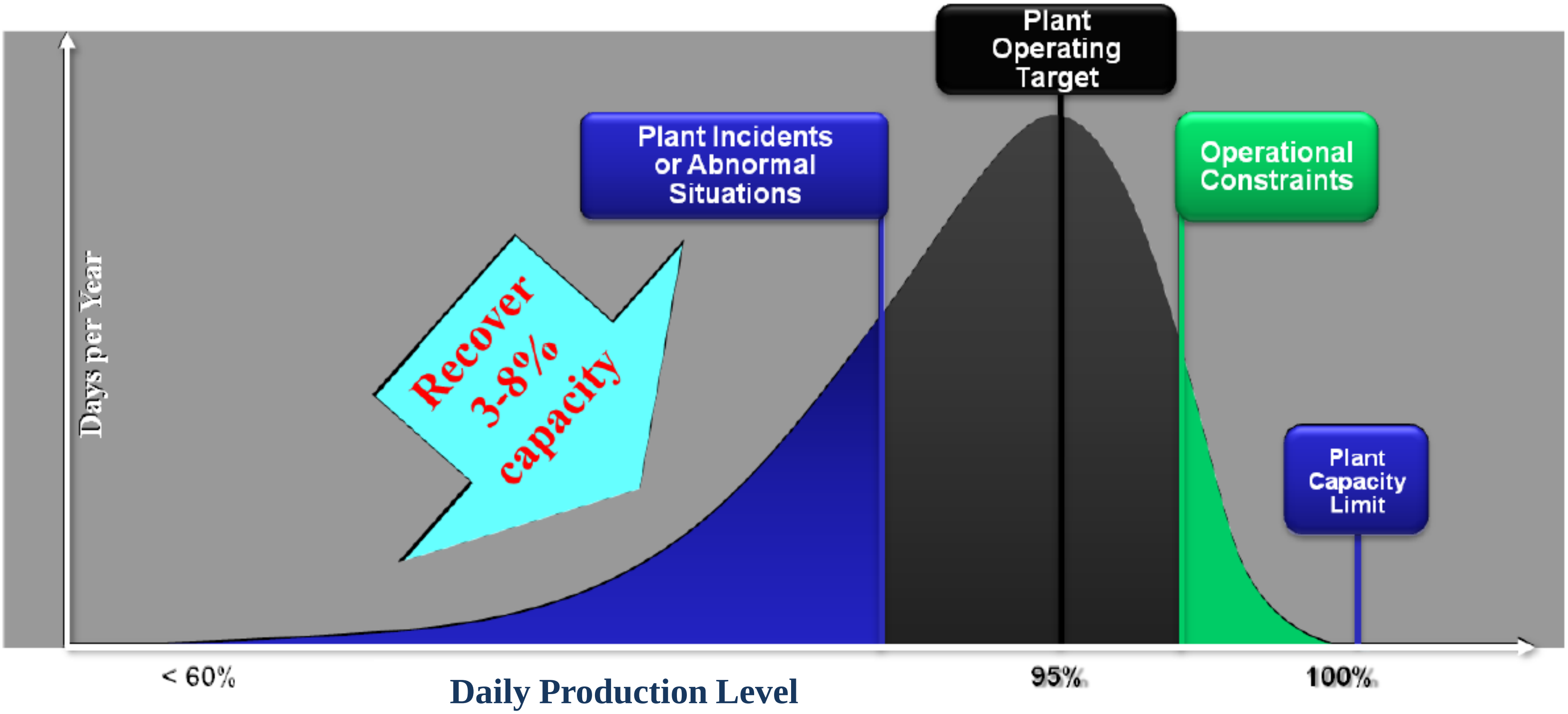
The Business Impact of Abnormal Situations



Unexpected Events can cost 3 – 8 % of Capacity

Process Upsets – Abnormal Situations

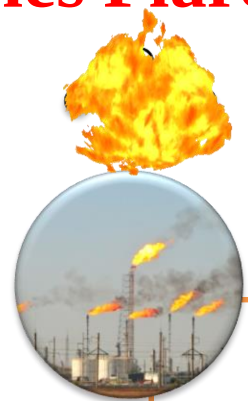
The Effects of Managing Abnormal Situations



What is 1 hour, 1 day, 1% of capacity worth?

Flaring – Abnormal Situations

Why Industries Flares?



Process Safety

- Routinely small volumes of unrecoverable gases
- Managing excess gas production

Process Upsets

- Equipment malfunction
- Off-spec production
- Depressurizing equipment
- Start-ups or Emergency shutdowns

Disposal Associated Gases

- Oil production and gas processing facilities
- Insufficient infrastructure

جامعة قطر
QATAR UNIVERSITY

Flare Reduction – Why?

Waste Valuable Resources

Negative Environmental Impacts
Unnecessary CO_2/SO_2/Nox emissions

Safety & Economics Impacts

Noise - Neighboring Communities

Visible to Surrounding Community
Visible black smoke and soot

Flare Reduction – Challenges?

- Reducing rates while production levels increase
- Cost effective alternatives
- Co-operation with neighboring/competing operators for join facilities

Global gas flaring has remained largely stable over the past fifteen years, in the range of 140 to 170 billion cubic meters (BCM)

جامعة قطر
QATAR UNIVERSITY

Flare Reduction – How?

Legislation | **Flare Recovery** | **Flare Utilization** | **Incentives**

Qatar's Proactive Legislative Acts

- '02 Establishing Supreme Council for the Environment
- '05 Kyoto Protocol & '07 AlShaheen CDM Project
- '09 World Bank Global Gas Flaring Reduction (GGFR)
- '12 COP Meeting

UNFCCC

GGFR
Global Gas Flaring Reduction
A Public-Private Partnership

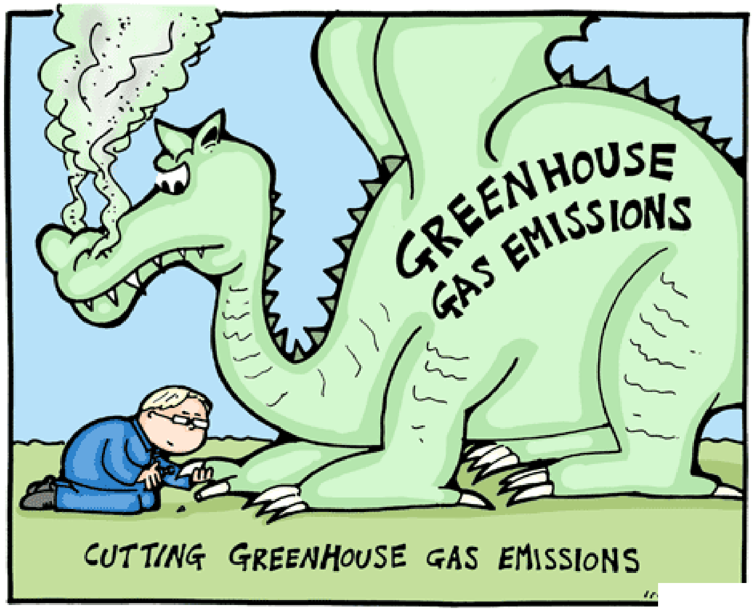
Flare Reduction – How?

Legislation

Flare Recovery

Flare Utilization

Incentives



جامعة قطر
QATAR UNIVERSITY

Flare Management – Generic Approach

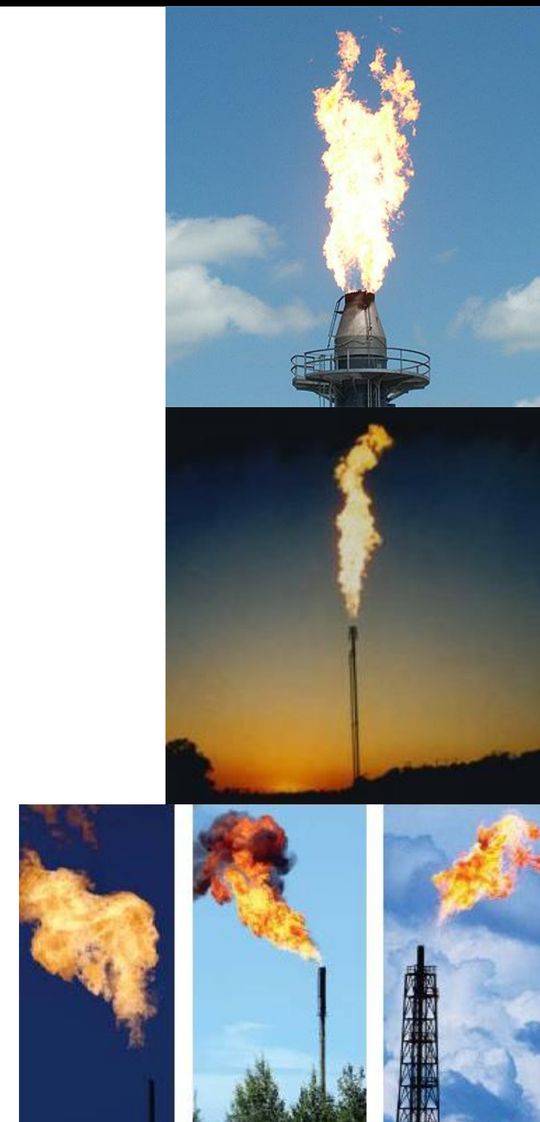
Identify key flaring sources due to upsets

↓

Identify causes & consequences of process upsets

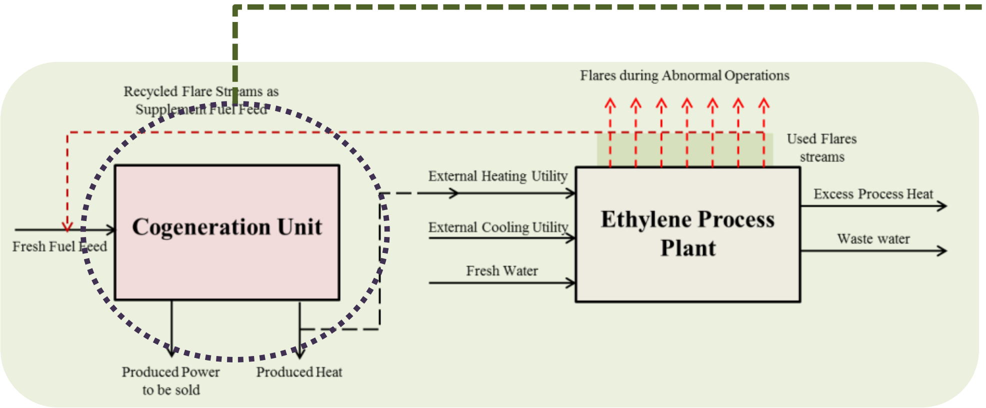
↓

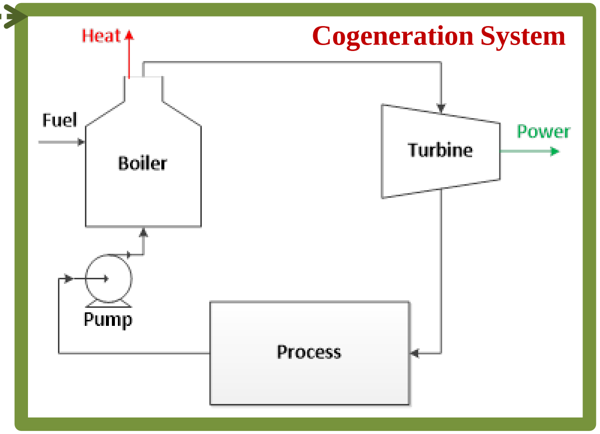
Apply recent process design/control and optimization methods

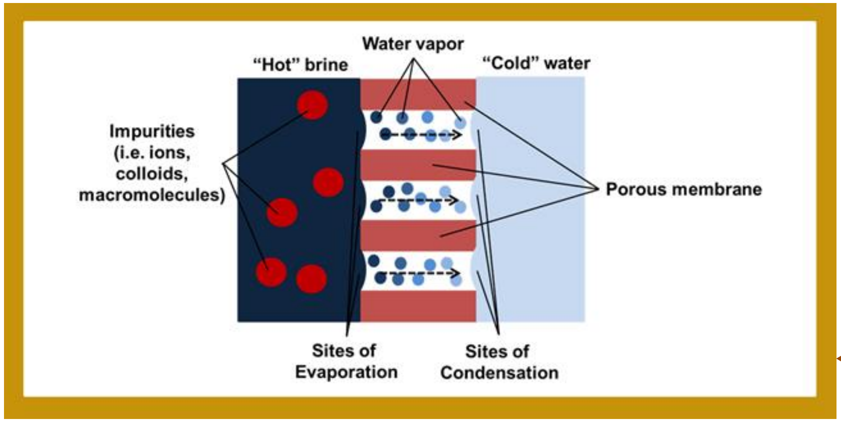


Energy Integration Alternatives

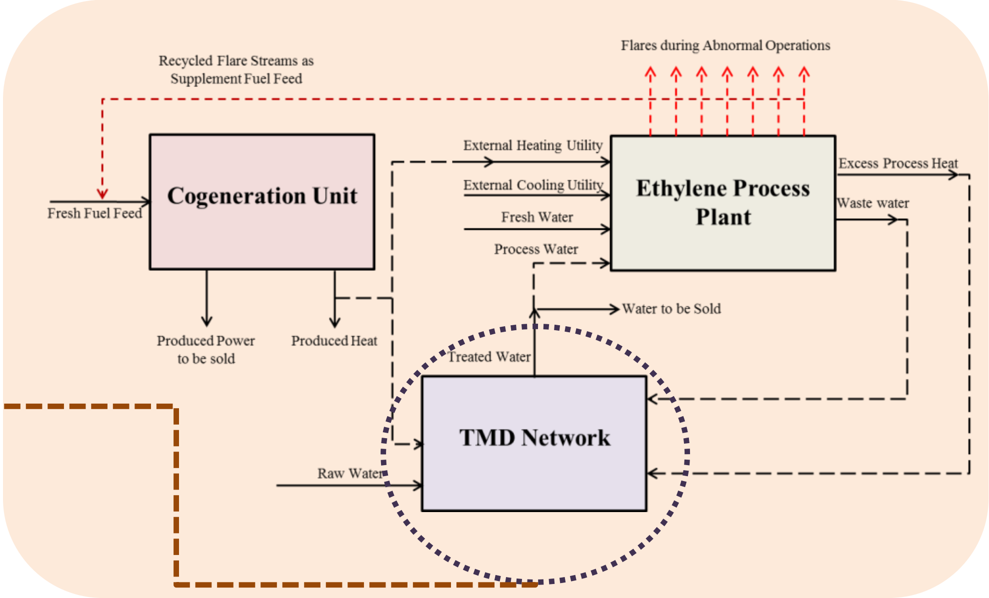
Proposed Alternatives for Managing Flare Streams





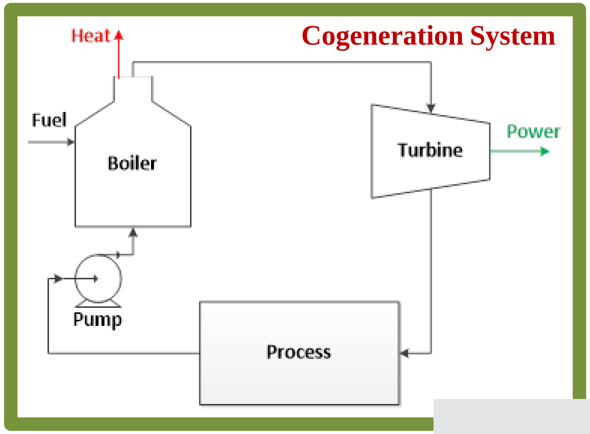


Thermal Membrane Distillation



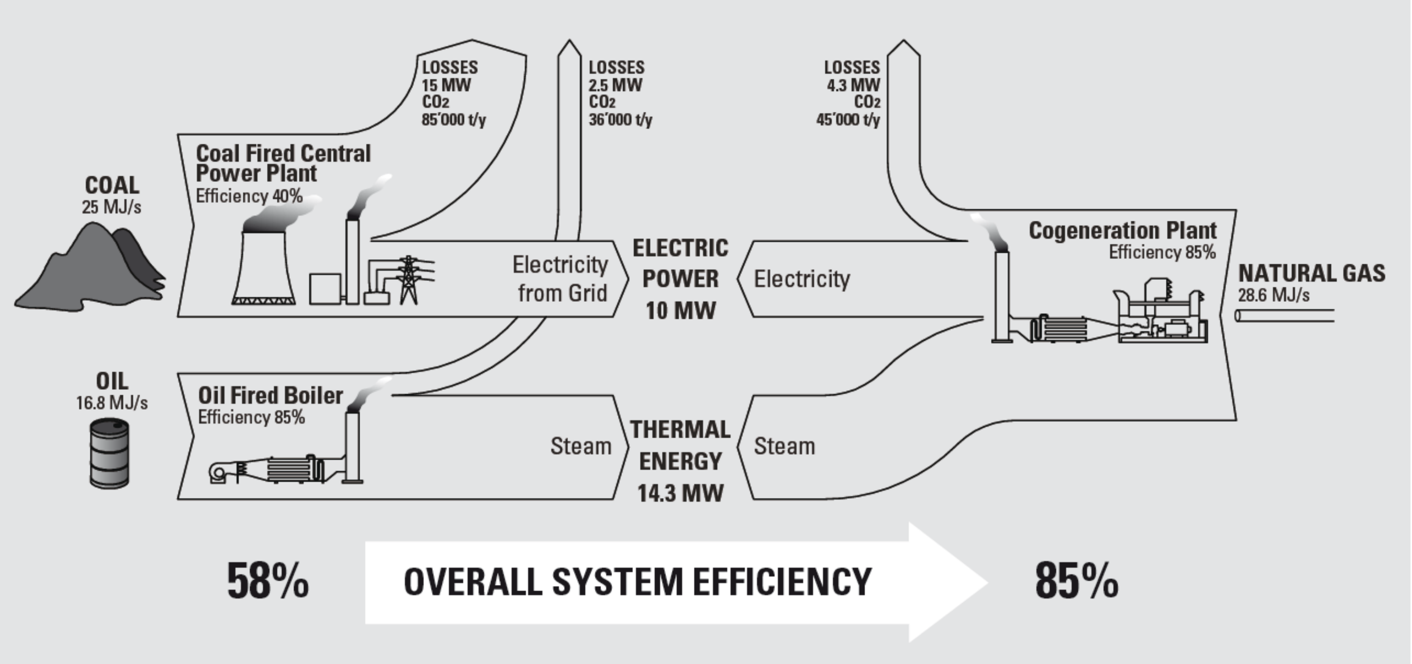
COGEN Approach

What is Cogeneration (COGEN)?



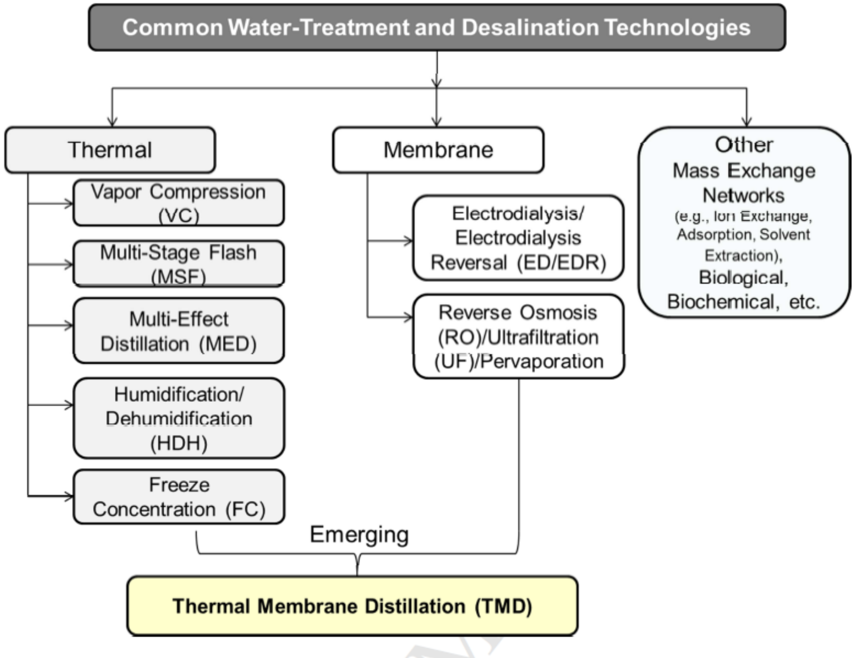
Advantages of COGEN

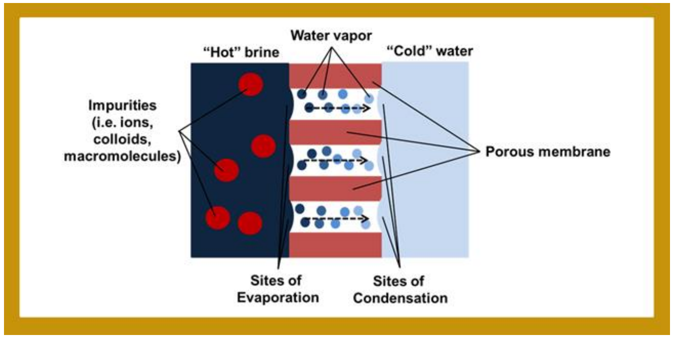
- Simultaneous generation of heat and power
- Reusing waste flare streams
- Carbon tax savings



TMD Approach

What is Thermal Membrane Distillation (TMD)?





Thermal Membrane Distillation

Several Configurations of TMD

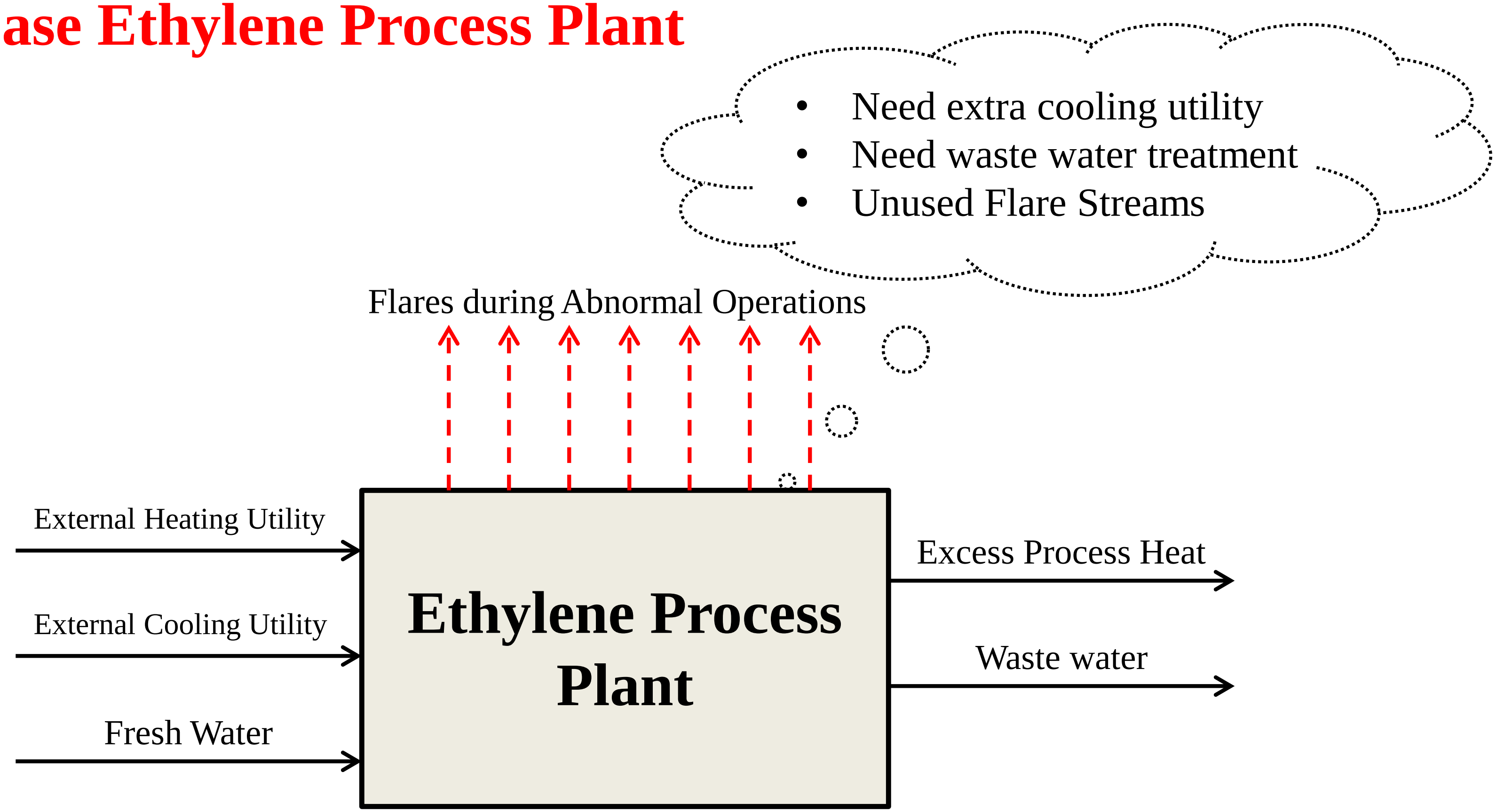
- Direct contact membrane distillation (DCMD)
- Vacuum membrane distillation
- Air gap membrane distillation (AGMD)
- Sweep gas membrane distillation (SGMD)

Advantages of TMD

- Low level heating
- Moderate operating temperature and pressure
- Ability to treat highly concentrated feeds
- High –purity permeate products
- Compact size
- Modular nature

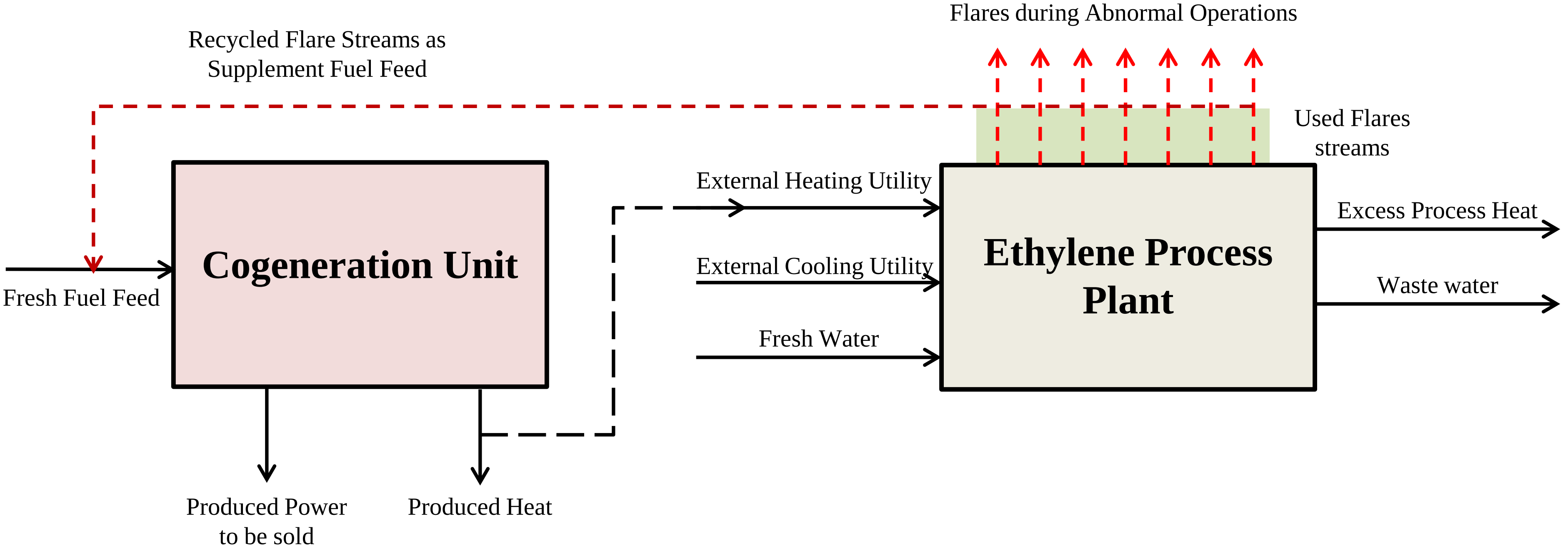
Case Study

Base Case Ethylene Process Plant

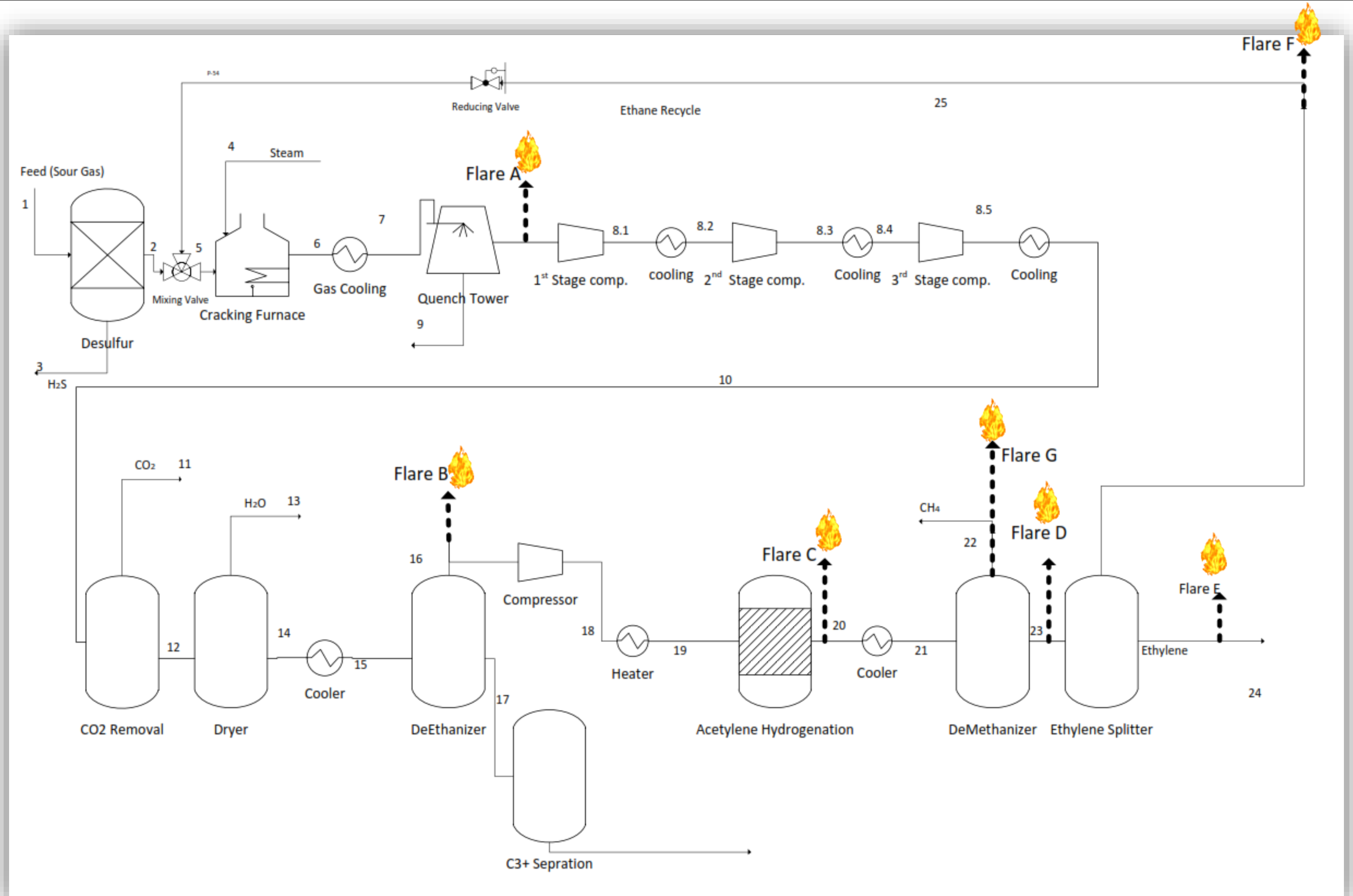


COGEN Approach

Flare Mitigation Approach using Cogeneration Unit



Possible Flare Locations

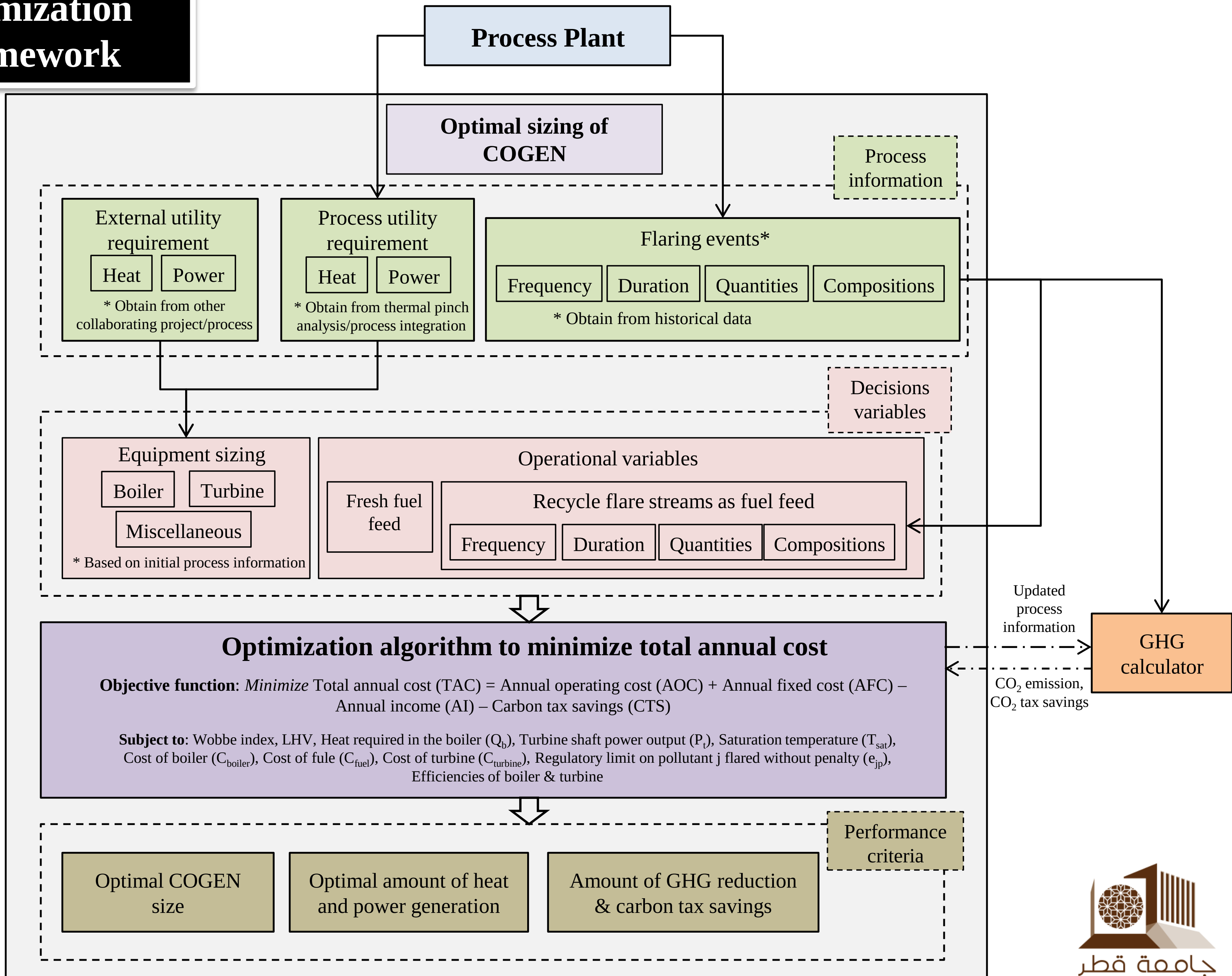


Flare Name	Location
Flare A	Top of quench tower
Flare B	De-ethanizer overhead
Flare C	Acetylene hydrogenation outlet
Flare D	De-methanizer bottom product
Flare E	Off-spec Ethylene
Flare F	Ethylene splitter overhead/ Ethane Recycle
Flare G	De-methanizer overhead

Ethylene process base case with all possible flare locations

جامعة قطر
QATAR UNIVERSITY

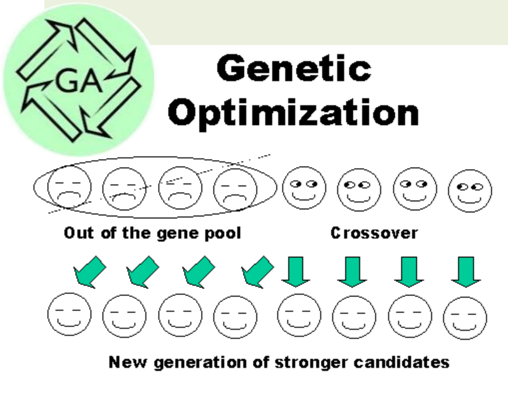
Optimization Framework



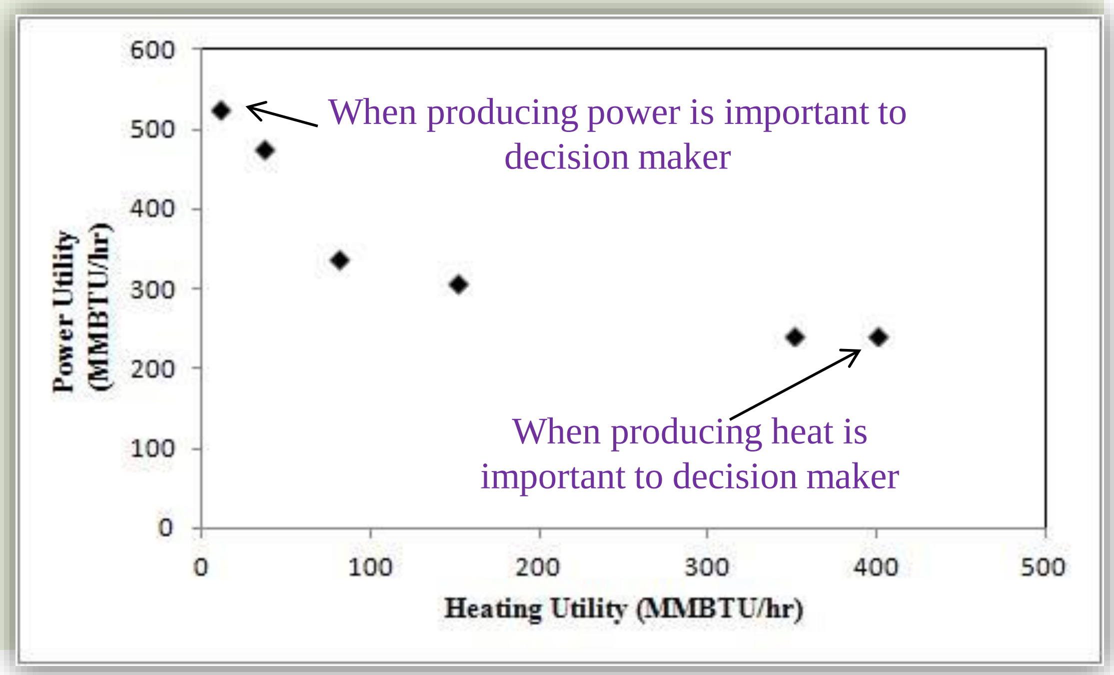
جامعة قطر
QATAR UNIVERSITY

Optimal Sizing of COGEN

- Platform: MATLAB
- Optimization toolbox: Genetic algorithm toolbox
- Advantage of optimization formulation: Generic and flexible

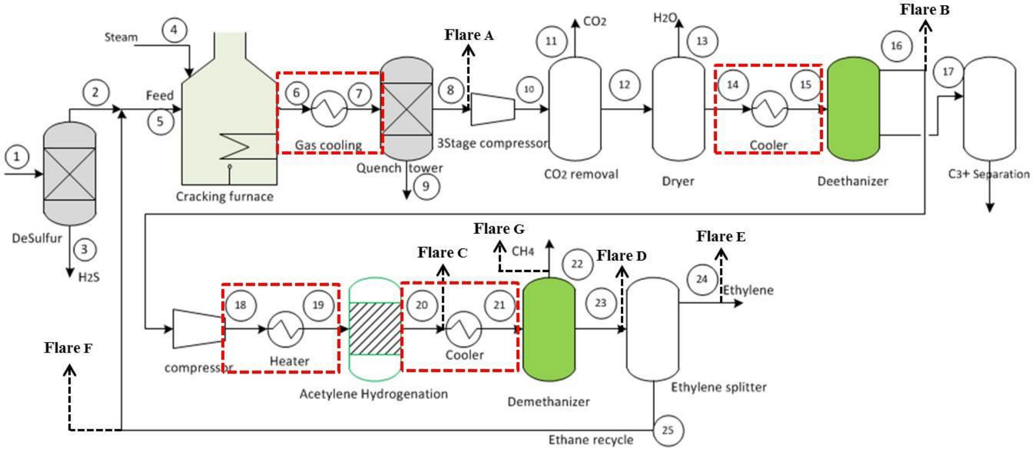


Pareto Fronts

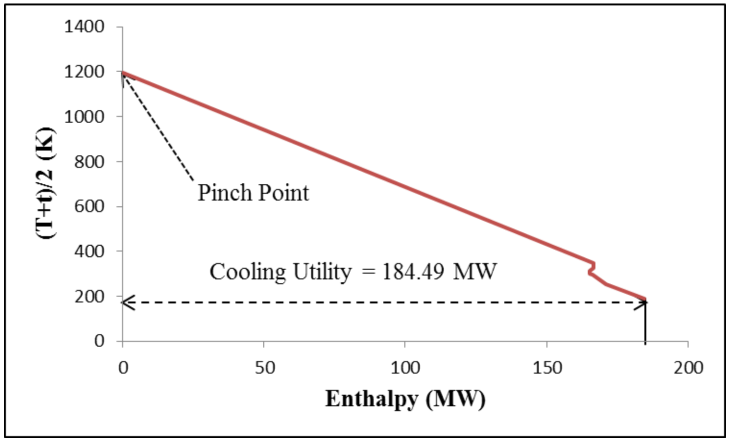


TMD Approach

Why……?



Grand Composite Curve



Minimum cooling utility for our base case ethylene plant is :

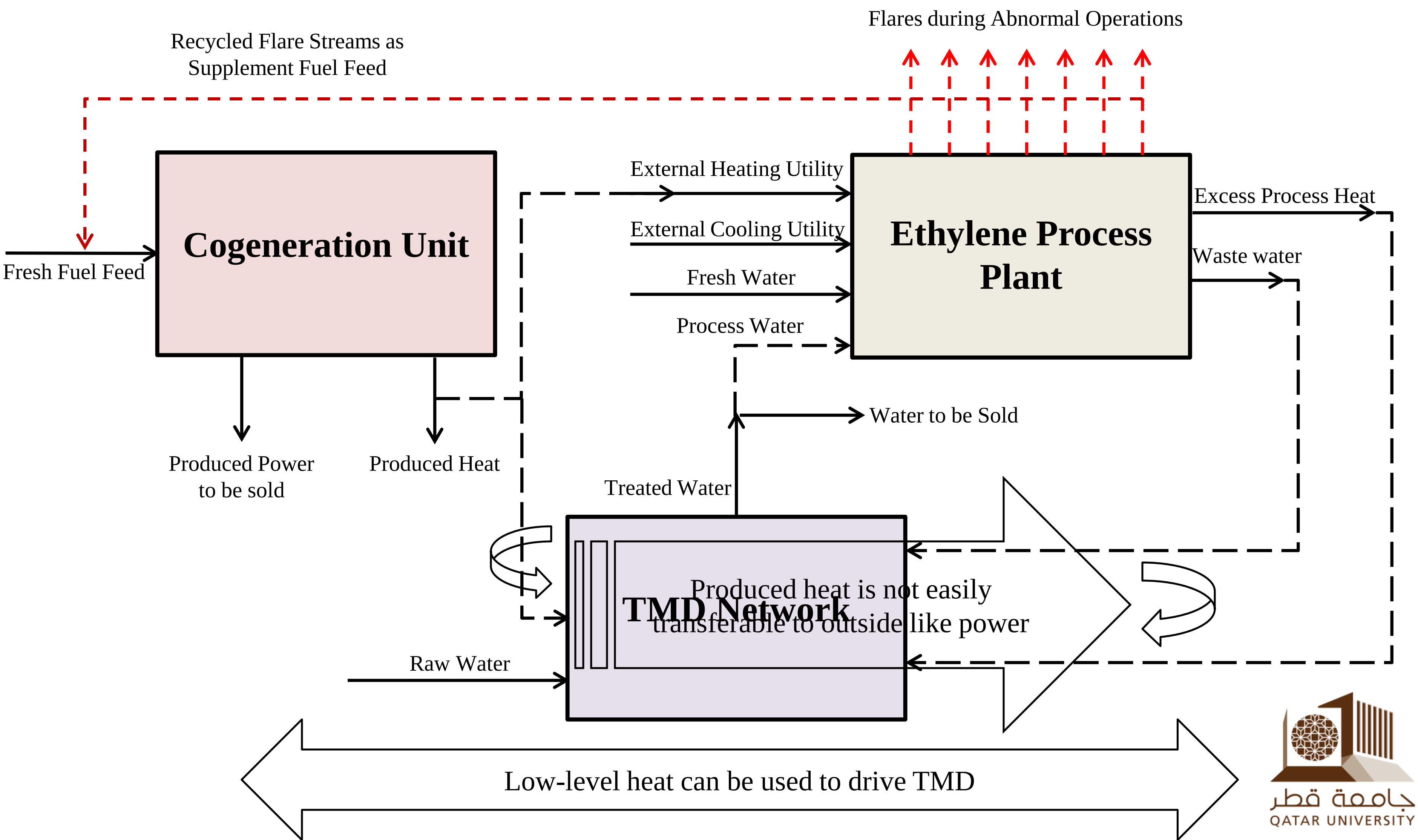
184.49 MW = 629.50 MMBtu/hr

Before Heat Integration	After Heat Integration
• Heating utility cost: $1.53 MM/yr • Cooling utility cost: $24 MM/yr • Total utility cost: $25.53 MM/yr	• Heating utility cost: $0 MM/yr • Cooling utility cost: $23 MM/yr • Total utility cost: $23 MM/yr

Still the cooling utility cost is significant

TMD Approach

Flare Mitigation Approach using COGEN Unit and Thermal Membrane Distillation Network

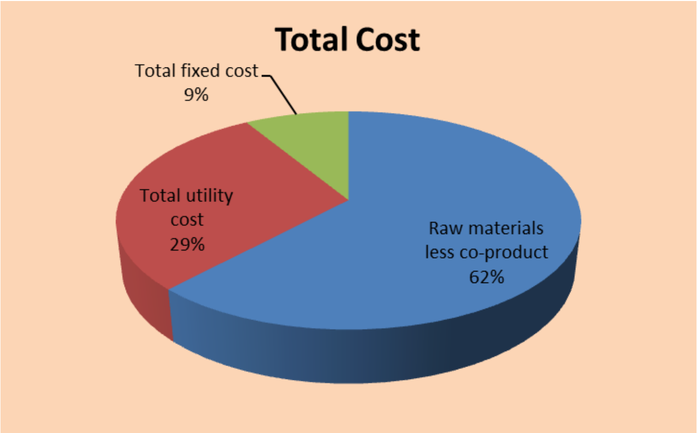


جامعة قطر
QATAR UNIVERSITY

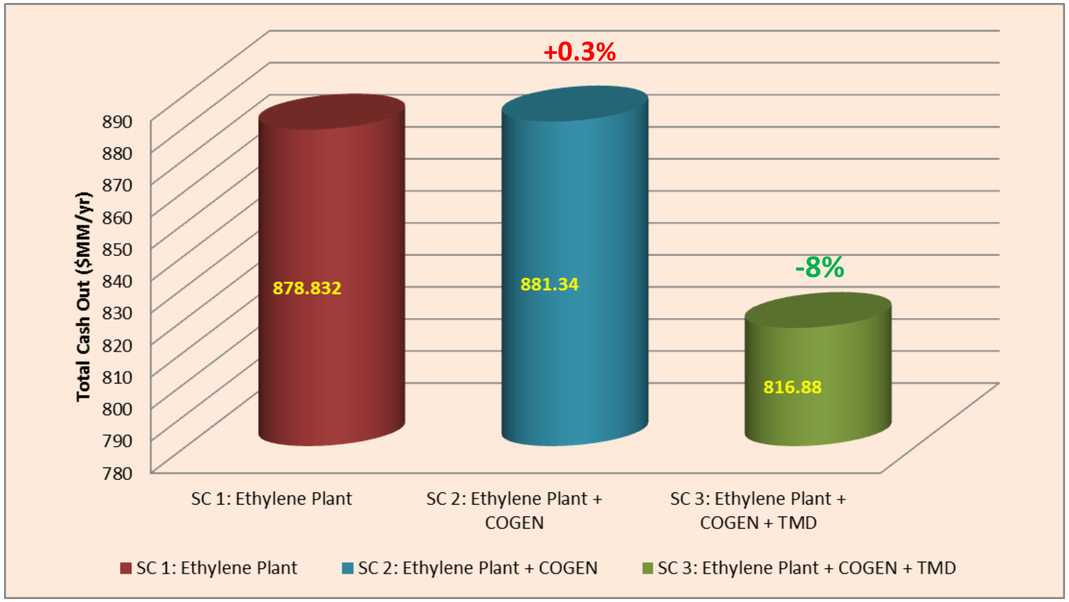
Ethylene Production Cost

Comparison between the Results for the Two Proposed Flare Mitigation Approaches for Existing Ethylene Plant

Basis:	
Ethtylene production (ton/yr)	900000
Crude oil price ($/bbl)	100
NG price ($/MMBtu)	4
COGEN heating utility (MMBtu/hr)	400
COGEN power utility (MMBtu/hr)	245
Price of cooling water at 293K per 10^9J ($)	4
Cost of heating fluid at 593K per 10^9 J ($)	6



Total cast out = Total raw materials cost + Total utility cost + Total fixed cost – Total income



Multi-objective Optimization

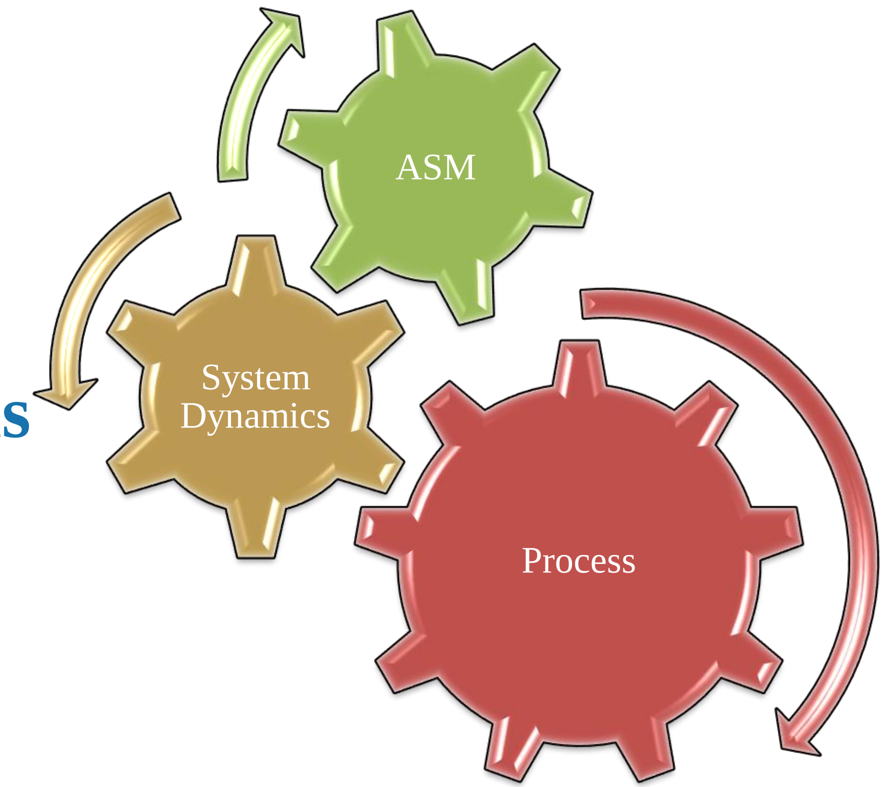
Cost → Production → Mass utilization → Energy efficiency → Safety → Environmental Impact

Methodology *must*

- Comprehensive
- Systematic
- Generally applicable

Provide decision makers tools (e.g. Pareto curves)

- Determine optimal flaring strategies/policies



Outcomes

So Far…….

- ❑ Historical database of flaring scenarios
  - Ahmed Mhd Nabil AlNouss, Monzure-Khoda Kazi, and Fadwa Eljack. Importance of Process and Flaring Data and its Analysis for the Management of Abnormal Situations - An Ethylene Process Case Study (In preparation).
- ❑ Green house gas calculator
  - Fahd M. Mohammed, Monzure-Khoda Kazi, and Fadwa T. Eljack. Tracking of GHG Emissions and Tax Implication During Normal/Abnormal Situations – Ethylene Process Base Case Industrial Application
- ❑ COGEN – as flare mitigation approach
  - Kamrava, S., Gabriel, K. J., El-Halwagi, M. M., & Eljack, F. T. (2015). Managing abnormal operation through process integration and cogeneration systems. Clean Technologies and Environmental Policy, 1-10.
- ❑ Multi-objective optimization framework
- ❑ Optimal sizing of COGEN
  - Monzure-Khoda Kazi, Fahd Mohammed, Ahmed Mhd Nabil AlNouss and Fadwa Eljack. Multi-objective optimization methodology to size cogeneration systems for managing flares from uncertain sources during abnormal process operation (Submitted in Computers and Chemical Engineering).
- ❑ Potentiality of TMD
  - R.Gonzalez-Bravo, N.A. Elsayed, J.M. Ponce-Ortega, F. Napoles-Rivera, M.M. El-Halwagi, Applied Thermal Engineering (2014)
- ❑ Economic comparison

جامعة قطر
QATAR UNIVERSITY

Ongoing Works

- Multi-time period method for discrete flare sources
- Impact of fuel quality, energy pricing policy, equipment performance and other external factors related with proposed methodology.
- Optimal design of TMD systems

Environment vs Economy

Acknowledgements

Research Group:

Dr. Fadwa Eljack

Engr. Fahd Mohammad

Engr. Ahmed AlNouss

Collaborators:

Dr. Mahmoud El-Halwagi

Serveh Kamrava

Kerron Gabriel

Dr. Qiang Xu

Ha Dinh

Industry Advisory Board:

QChem

Funding:

Qatar National Research Fund

NPRP 5-351-2-136

Thank You