PCIC EUROPE
PETROLEUM & CHEMICAL INDUSTRY COMMITTEE

Monetization of associated gases from offshore oil fields by electrical power generation

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Introduction

- Every year around 150 billion cubic metres of gas are flared or vented across the global oil and gas sector.
- Equivalent to 32% of the European Union gas consumption.
- Offshore, more and more many small to medium size oil and gas fields remote from any existing commercial markets are discovered.
- Due to lack of an established gas market in these regions, the "associated gas" from these marginal fields has been flared in the past.
- But
- New technologies available to transport power on long distances
- Environmental aspects' rising concerns for project acceptance
- Funding with global solutions taking place
- Opportunity opened by the gap between gas prices and electricity market.

Gas Flaring Reduction Initiatives

- Environmental impact of the gas flaring on the agenda of international institutions.

- World Bank and European Bank for Reconstruction (EBRD) targeting flare gases reduction by 30% in 2017 (vs 2011)
- World Bank estimation : more than $50 billion flared gas every year.

- 30% less flaring equivalent to 52 million cars off the roads (CO_2 equivalent)
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- Conversion of flared gas into electrical power appears as the first stone to build economic and social development in many countries.

- World Bank and EBRD initiatives part of the United Nations' program about the "Sustainable Energy for All".

Global Gas Flaring Reduction (GGFR)

- Created by the World Bank in 2002
- To support to projects through
  - Funding,
  - Partial risks guarantees to investors in Gas-To-Power projects,
  - Technology deployment,
  - Sharing best practices,
  - Regulation and identifying
  - Natural gas monetization opportunities.

Actual Achievements and Next steps

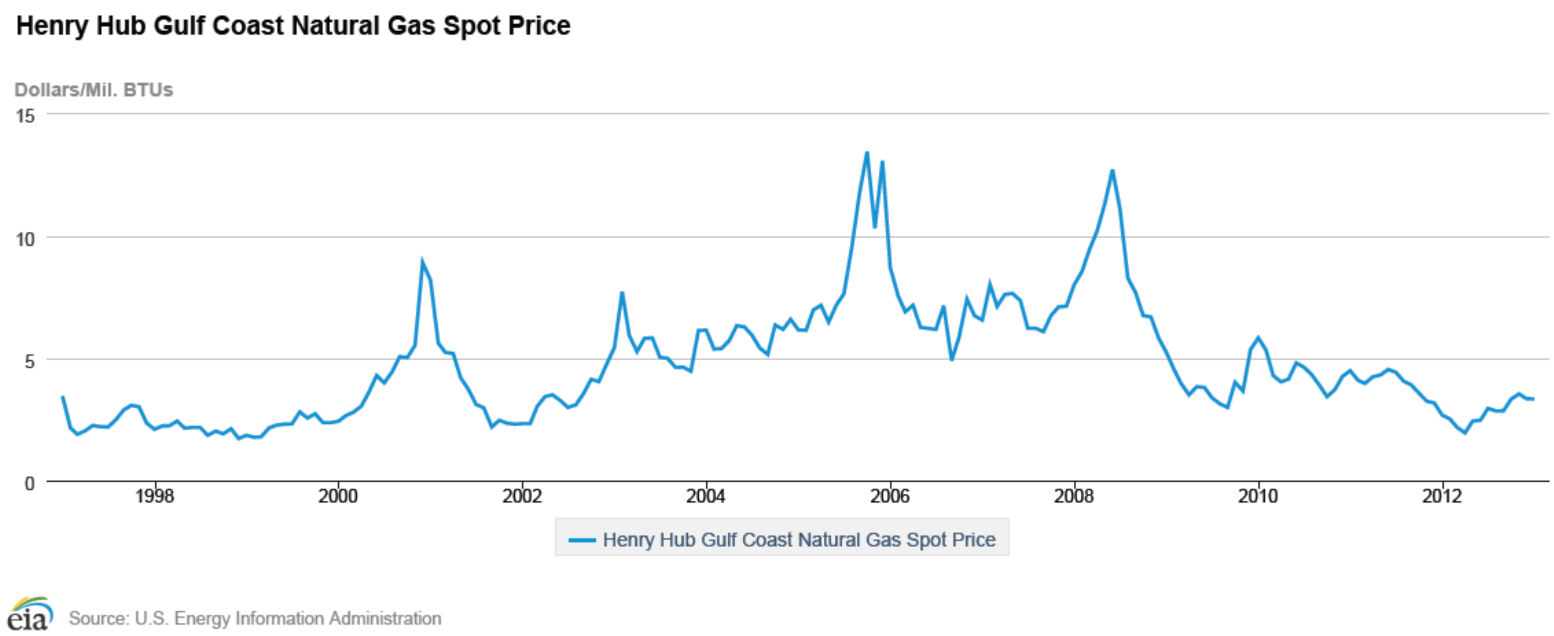
- 2005 - 2011, 20% reduction of flared gas.
  - SOCAR and BP in Azerbaijan,
  - Qatar Petroleum and Maersk in Al-Shaheen,
  - Pemex in Mexico (66% reduction,
  - Eni in Congo (with M'Bundi),
  - Kuwait targeting 1% flared gas,
  - NNPC, 4 billion cubic feet saved in Nigeria

- **All current projects are onshore**

- **Offshore, more complex and more costly**

Gas market situation

- Gas prices show all signs to stand at low levels
- Pressure of the unconventional fields
- (around $3 per MBTU at US Henry hub)
- Export of NG becomes a challenge.

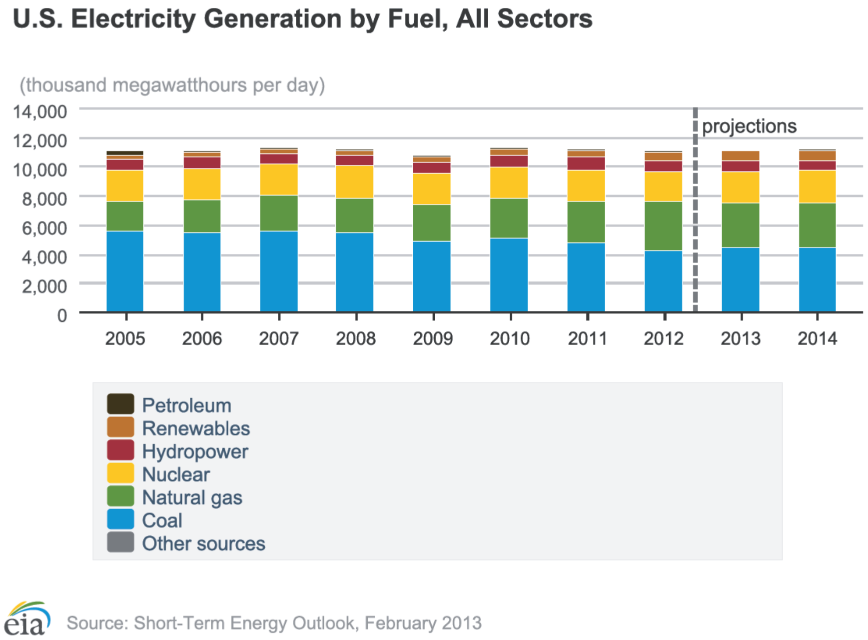


Electricity market situation

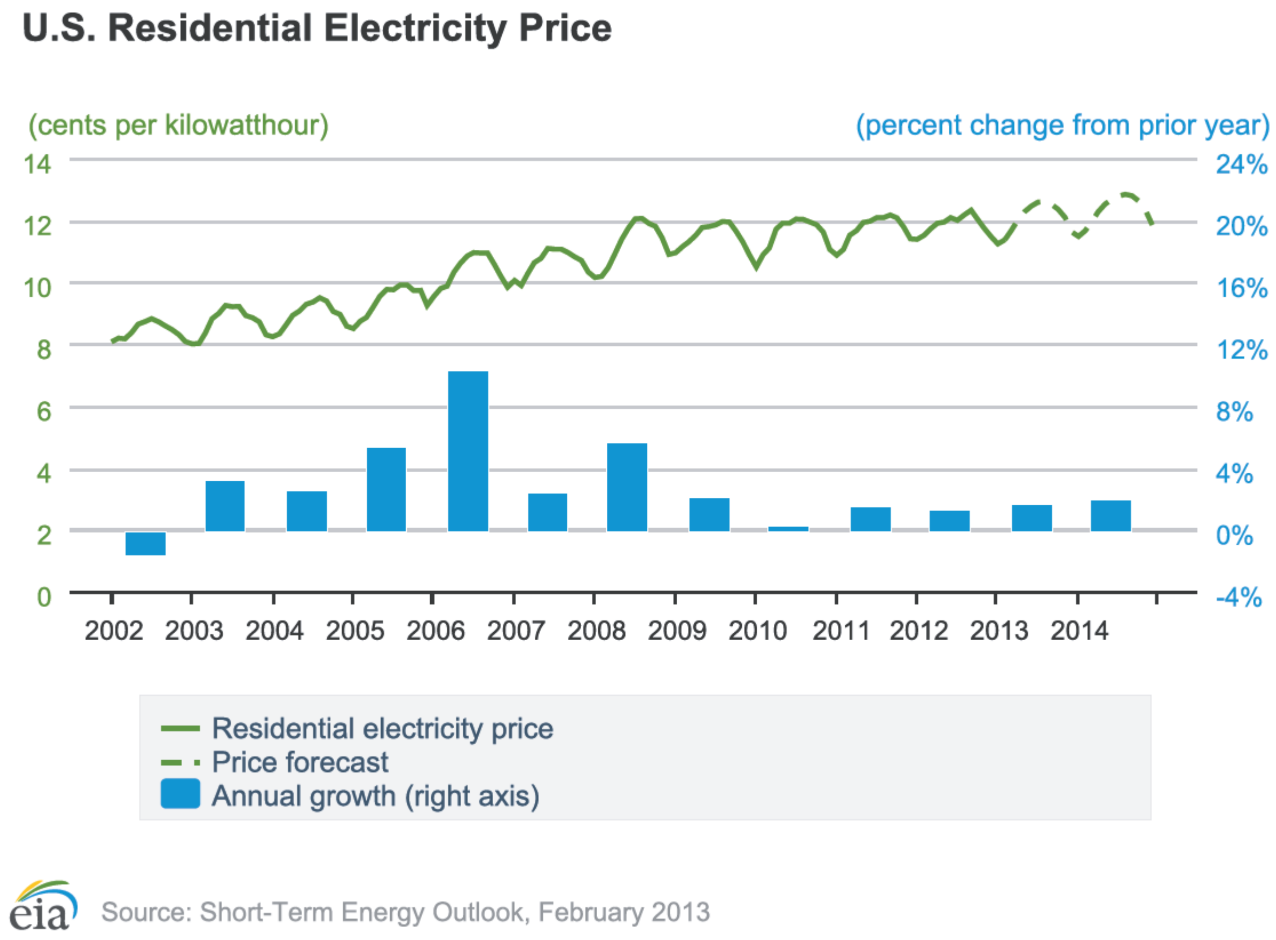
- Secondary energies (such as electricity) driven by local market prices
- Remain steady or increasing
- Needs in all countries increase faster than the power supply

Electricity market situation

- US example: share of NG doubled in energy mix to produce electricity over the last ten years.
- Gas consumption increase in generation, so reduction electricity price expected as gas prices did.

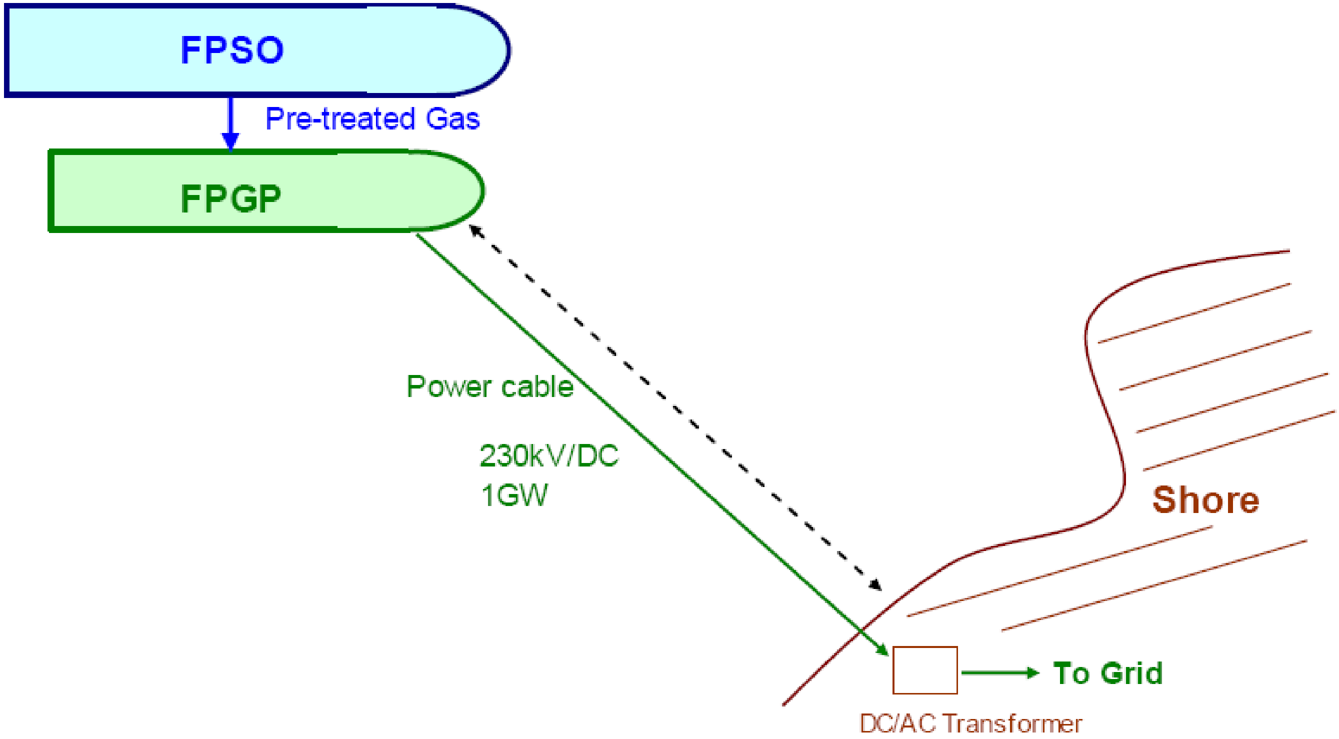


• Instead, electricity price steadily increasing.



An option for OAG use

- Floating Power Generation Plant (FPGP) can be considered as an option to take advantage of those energy reserves.



Design basis

- Gas supplied from an FPSO « cleaning » the gas

- Maximise electricity production and thus revenues
- So Combined Cycle option retained

- Based on production capability of 1 GW.

- Distance to shore : 250 to 300 km
- Water depth : 2500 m

Gas to Wire concept

- GTW is a mean of transmitting gas energy under the form of electrical power.
- Development of HVDC links makes long distance transport easier.

- GTW represents a possible solution to monetise gas where gas markets are not close to a field.
- Electrical power could be produced and exported either as Alternative or Direct Current, depending on the distance to shore.

GTW – Applicable range

- Marginal gas fields or associated gas with a production lower than about 200 mmscfd with a transportation requirement less than 2000 km could be exploited for electrical power generation.

- Beyond, conventional techniques of transportation using pipelines for higher production rates or LNG carriers for longer distances offer better potential.

- Final configuration will always depend on local marketability, economic context, technical feasibility, and contract terms that will always be project specific.

HVDC basics

- AC vs DC starts with Electricity market
- Thomas Edison supported DC
- Georges Westinghouse supported AC .
- And the winner was …Georges
- Transformers of Nicolas Tesla was the key .
- But came back in the 1950’s with first transmission between Sweden and Gotland Island.
- Overcome limitation due to huge capacitance of submarine cables

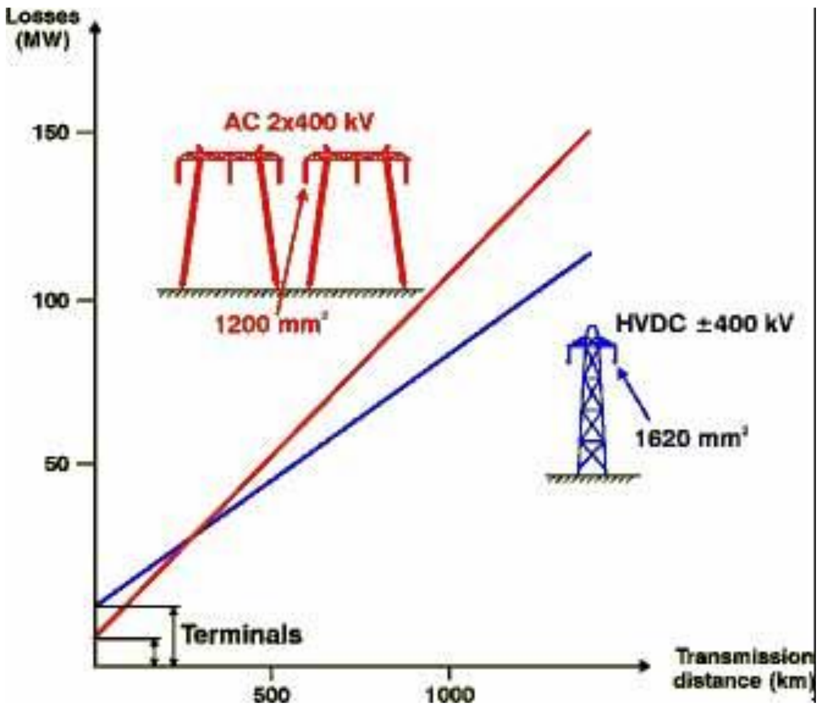
HVDC examples

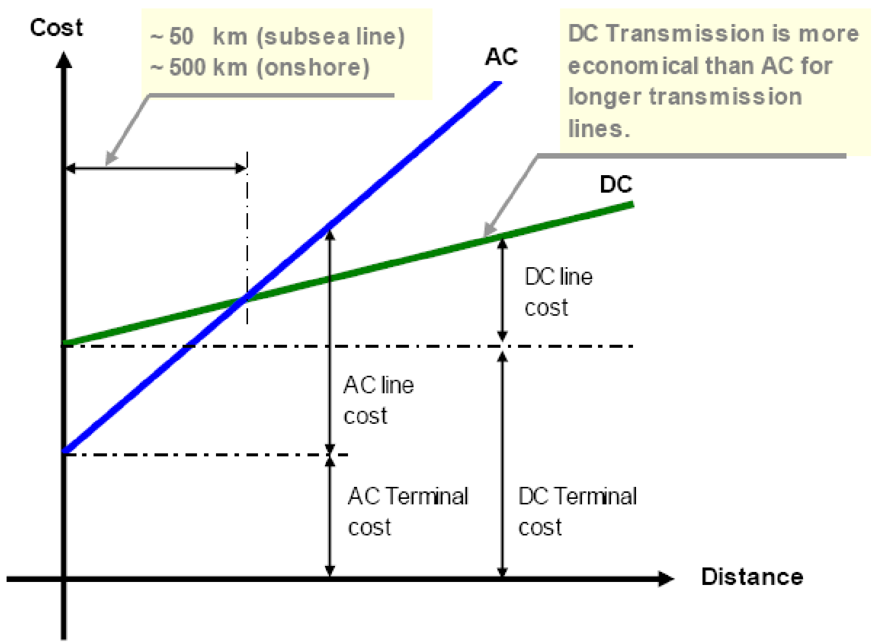
- Development of power semiconductors (from thyristors to IGBT) permit development of the technology both onshore and subsea.

- Transfer of 6500 MW @ 800 kV over 2 500 km.
- Connection of offshore windfarms : 800 MW @ 320kV over 130 km

HVDC economics

- Over 250 km, losses in AC are higher than in DC



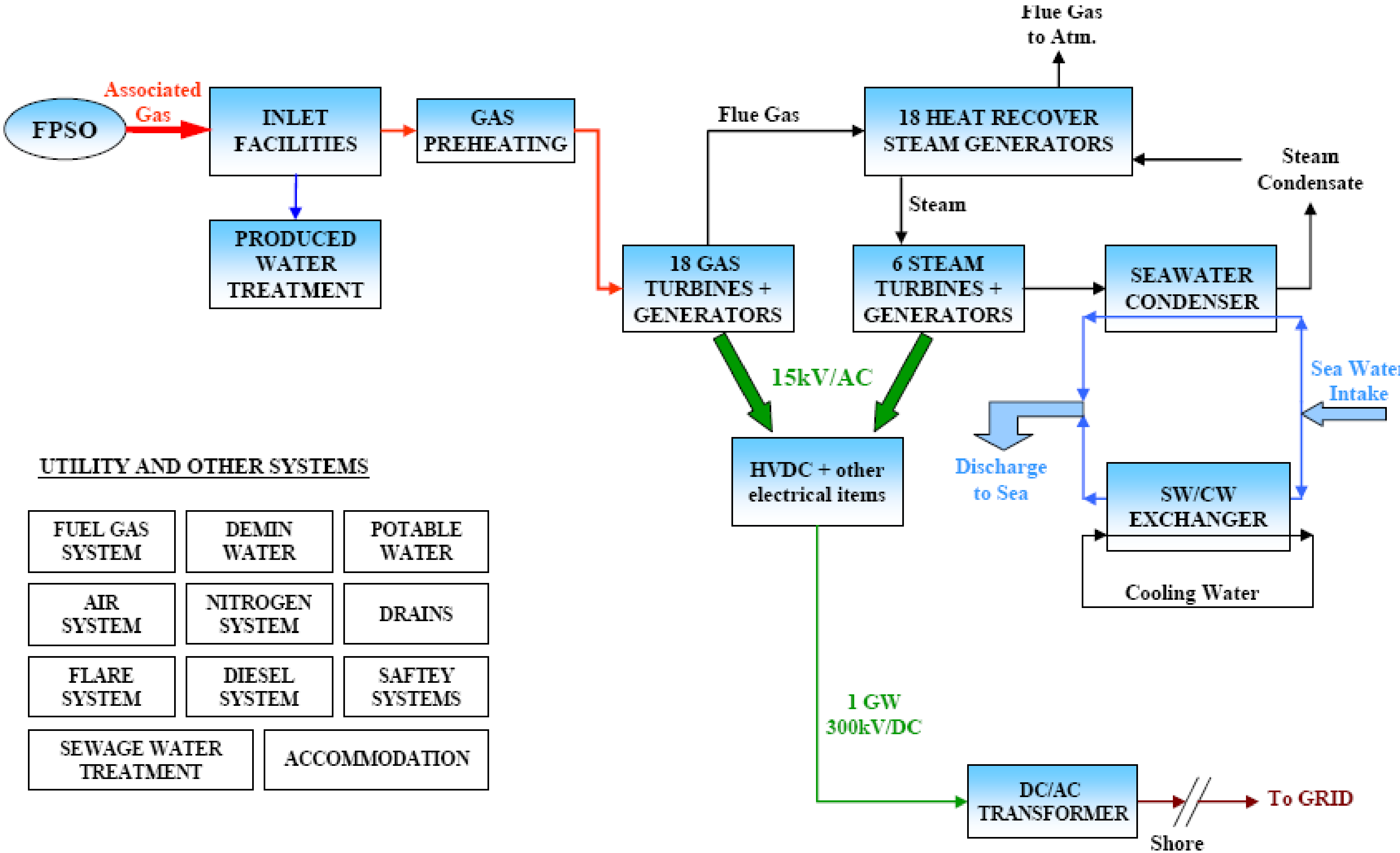


Design basis

Inlet Pressure	~ 60 to 70 Bara
Inlet Temperature	~ 40 to 45 °C
Standard Gas Flow	~ 150 MMSCFD
Lower Heating value	~ 41 MJ/m3

- Potential energy capability around 2 000 MW LHV.
- Combined cycle gas turbine (CCGT) offers efficiency from 50% to 65 % ,
- Electrical production potential of 1 to 1.3 GW

Process description



Main systems

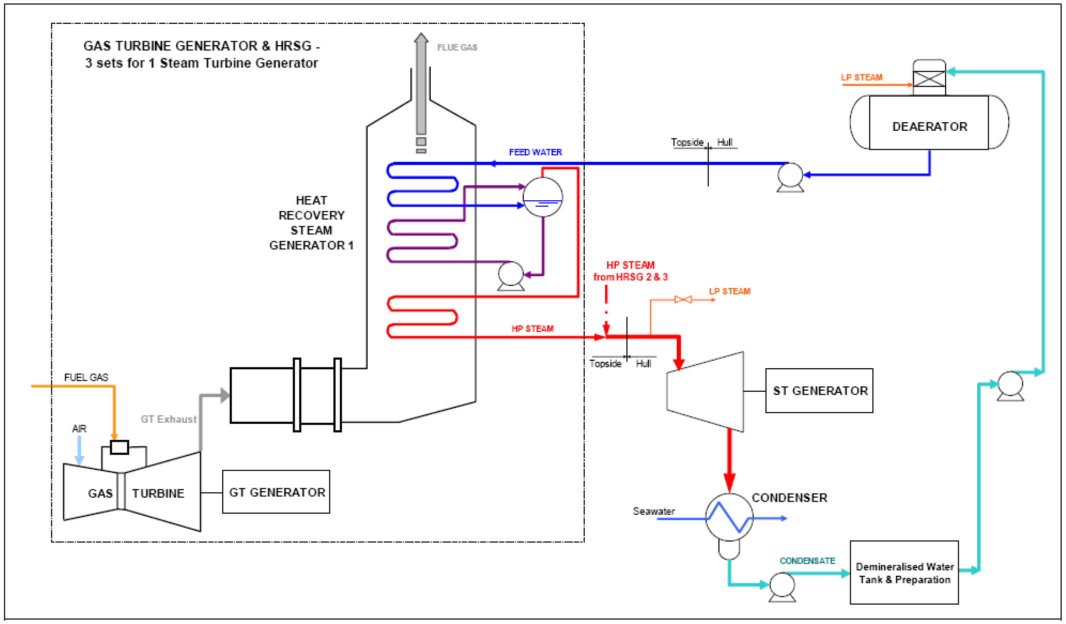
- An inlet system:
  - Inlet Separation / Gas Pre-heater / Fuel Gas System
- A CHP generation system:
  - Gas Turbines + Generators
  - Heat Recovery Steam Generators
  - Steam Turbine + Generators
- A transmission system:
  - HVDC converters and main electrical distribution
- A utility system:
  - Seawater Direct Cooling System, Water Treatment, Common Utilities (Accommodations, ICSS, Cranes,…)

Pros and cons for main turbine choice

	IGT(*)	AGT (*)	Comments
Power Output	+	-	
Weight	+	-	
Footprint	+	-	
Cost	+	-	
Efficiency	-	+	
Marine Adaptation	--	++	Lot of experience for AGT, none IGT
Maintenance	--	++	Maintenance to be adapted in offshore context for IGT

Chosen configuration

- 6 combined cycles of 3 GTG for 1 STG
- Each GTG coupled with a dedicated WHRU.
- Three WHRU feed a 40 MW steam turbine.
- Steam turbine condenser cooled by sea water.



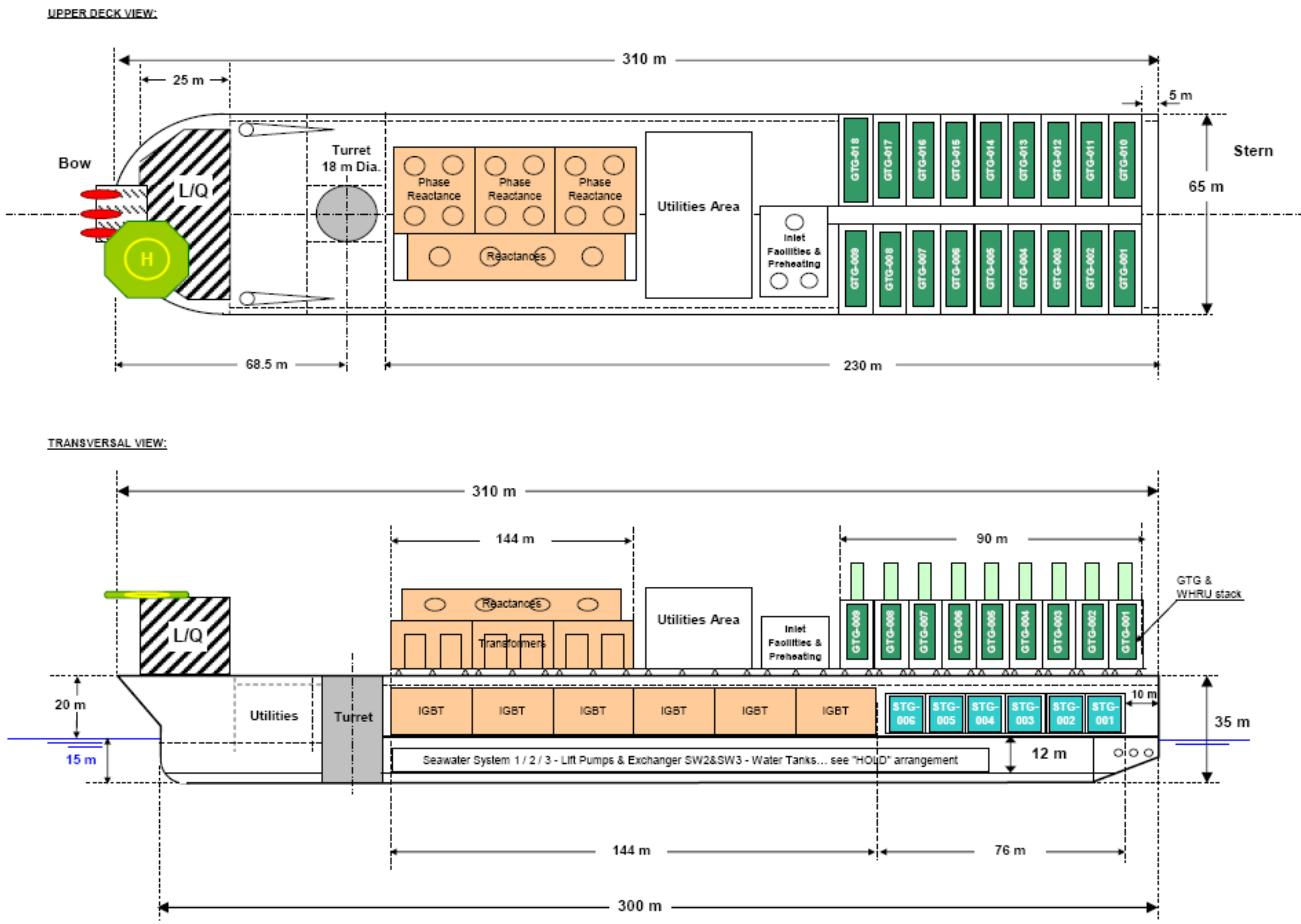
Space and weight main figure

- Space requirements :
  - HVDC System 15 000 m^2 in the hull
  - GTG + WHRU 7 000 m^2
  - STG 2 600 m^2, in the hull
  - Steam Systems
  - Seawater System
- Weight figures :
  - Power Generation + Steam System 13 000 T
  - Sea water System 6 000 T
  - HVDC System 3 600 T

Arrangement

FLOATING POWER GENERATION PLANT CONCEPTUAL STUDY : FLOATER GENERAL ARRANGEMENT

LoA	310,0 m	Draft	15,0 m
Lpp	300,0 m	Scantling Draft	N/A
Beam	65,0 m	Hull Weight	60 000 t
Depth	35,0 m	Hull Cost	330 M$



Economical summarize

- Revenues

– Production capability	1 GW
– Annual production (97 % availability)	8 497 G Wh.
– Selling average cost	US$ 50 / MWh
– **Annual income (MUS$)**	**$425 million /year**

- CAPEX breakdown (MUS$)

– Power generation	$750 million
– Power distrib (inc HVDC)	$1 000 million
– Topsides and utility	$1 200 million
– Hull	$330 million
– **Total CAPEX**	**$3 300 million**

Operations Expenditure (OPEX)

• Operation costs	$30 million
• Maintenance costs	$42.5 million/year
• Fuel	0
• OPEX/year	$93.75 million/year

Return On Capital Employed and Breakeven

- Thanks to the “free” fuel, with revenue of $500 million a year and operation costs of $94 million
  - Gross margin $406 million
- For $3.3 billion investment
  - ROCE 12%
  - Breakeven in 8 years

GTW profitability aligned with usual ratio in utilities industry.

Conclusions

- Target was optimized efficiency and increased electricity generation.
- Number of potential improvements
  1. Aero-derivative gas turbine replaced by industrial type
  2. Simple cycle option evaluated as alternative
  3. Topsides and Utilities design optimised
  4. Footprint improved with more powerful GTG
  5. Constructability improved to optimize installation in the hull
  6. Mooring systems and HVDC interference to be avoided
  7. HVDC system adapted to the space requirement

- Technology offers a valuable option to GTW for fields where
  1. The amount of associated gas is very high
  2. Region needs more electrical power (everywhere)

Conclusions

- In a world where energy is becoming more and more expensive (as outlined during the 14th session of the UNO on sustainable development) can we still waste 150 billion cubic meter of gas (equivalent to 25 % of the US consumption)?
- The business model of converting flared gas into electricity is very similar to the Gas-To-Liquid (GTL) solution.
- Value is extracted from the widening gap between gas prices and electricity price.

QUESTIONS ?