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Putting relevant science and engineering back into every decision made!

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Flare Volumes by Country

Gas flaring data 2013-17 (billion cubic meters)

		2013 bcm	2014 bcm	2015 bcm	2016 bcm	2017 bcm	2016-17 change bcm	2013-17 change bcm
1	Russia	19.9	18.3	19.6	22.4	19.9	-2.5	0.0
2	Iraq	13.3	14.0	16.2	17.7	17.8	0.1	4.6
3	Iran	11.1	12.2	12.1	16.4	17.7	1.3	6.6
4	United States	9.2	11.3	11.9	8.9	9.5	0.6	0.3
5	Algeria	8.2	8.7	9.1	9.1	8.8	-0.3	0.6
6	Nigeria	9.3	8.4	7.7	7.3	7.6	0.3	-1.7
7	Venezuela	9.3	10.0	9.3	9.3	7.0	-2.4	-2.3
8	Libya	4.1	2.9	2.6	2.4	3.9	1.6	-0.2
9	Angola	3.2	3.5	4.2	4.5	3.8	-0.7	0.6
10	Mexico	4.3	4.9	5.0	4.8	3.8	-1.0	-0.5
11	Malaysia	2.8	3.4	3.7	3.2	2.8	-0.3	0.0
12	Oman	2.4	2.6	2.4	2.8	2.6	-0.2	0.2
13	Kazakhstan	3.8	3.9	3.7	2.7	2.4	-0.2	-1.3
14	Egypt	2.4	2.8	2.8	2.8	2.3	-0.5	0.0
15	Indonesia	3.1	3.1	2.9	2.8	2.3	-0.4	-0.8
16	Saudi Arabia	2.0	1.9	2.2	2.4	2.3	-0.1	0.3
17	Turkmenistan	2.3	2.0	1.8	1.8	1.7	-0.2	-0.6
18	China	1.9	2.1	2.1	2.0	1.6	-0.4	-0.4
19	Gabon	1.4	1.5	1.6	1.6	1.5	-0.1	0.1
20	India	1.7	1.9	2.2	2.1	1.5	-0.6	-0.2
21	United Kingdom	1.4	1.3	1.3	1.3	1.4	0.0	0.0
22	Canada	1.5	2.1	1.8	1.3	1.3	0.0	-0.2
23	Syria	0.4	0.4	0.5	0.6	1.2	0.6	0.8
24	Rep. of the Congo	1.4	1.3	1.2	1.1	1.1	0.0	-0.3
25	Brazil	1.3	1.5	1.3	1.4	1.1	-0.3	-0.2
26	Ecuador	0.8	1.0	1.1	1.2	1.1	-0.1	0.3
27	Cameroon	0.8	0.9	1.1	1.1	1.0	-0.1	0.2
28	Qatar	1.4	1.3	1.1	1.1	1.0	0.0	-0.4
29	Vietnam	1.1	1.1	1.0	0.9	1.0	0.1	-0.1
30	UAE	1.2	0.9	1.0	0.8	1.0	0.1	-0.3
	Rest of world	12.5	12.8	11.1	10.0	8.4	-1.6	-4.0
	Global total	139.6	143.9	145.6	147.6	140.6	-7.1	1.0

Source: NOAA, GGFR. Rounded numbers.

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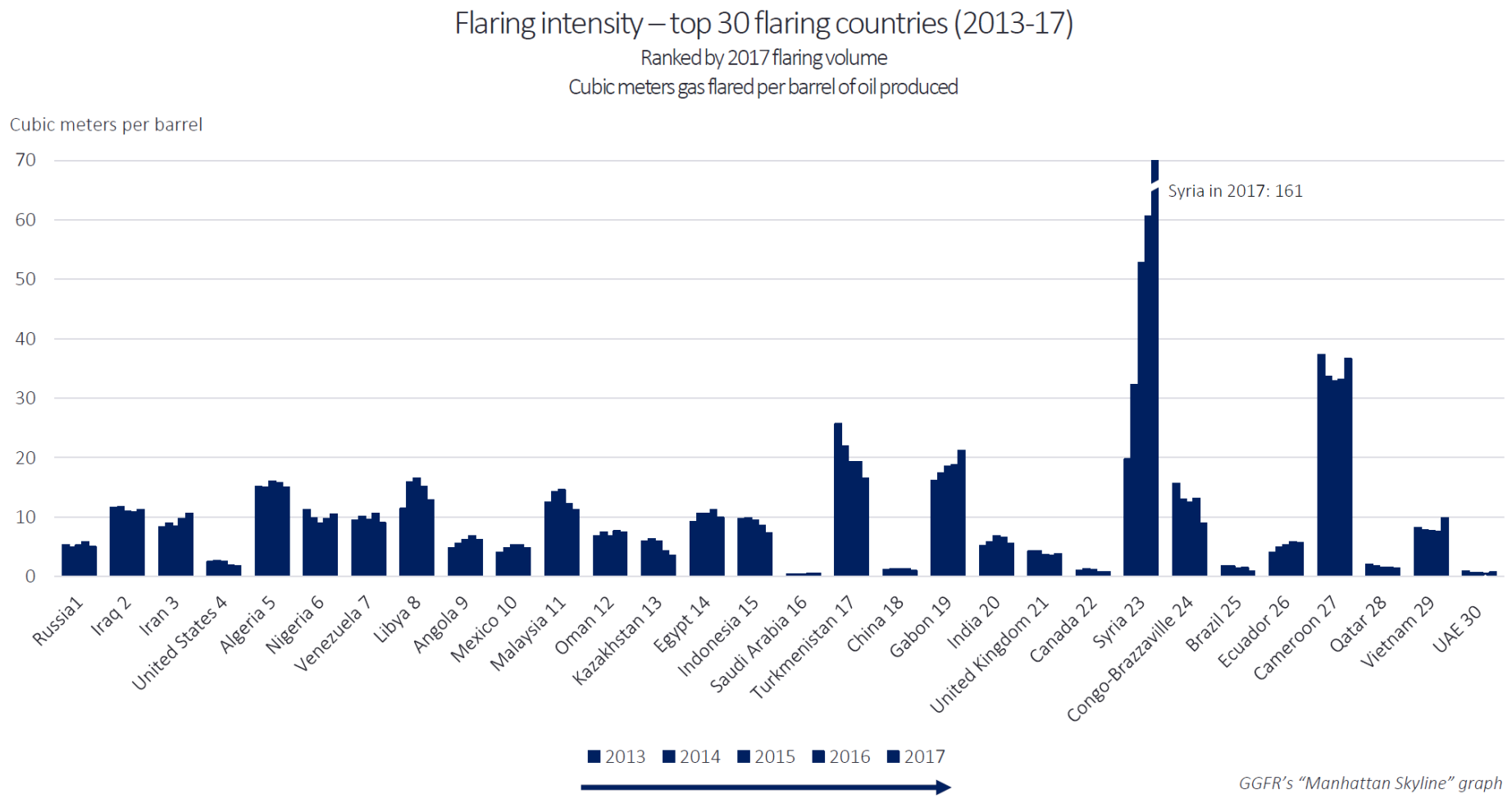
Flaring by Country



GGFR's "Manhattan Skyline" graph

Source: GGFR, based on NOAA/GGFR/BP/EIA data

Global average intensity (2017): 4.8 m^3/bbl

The Impact of Flaring Gas

- Environmental Implications
  - Climate change, greenhouse gas, global warming, acid rain, agriculture
- Health Implications
  - Adverse Effects, Haematological effects
- Economic Loss
  - Wasting an Economic commodity, legal restrictions

Key to Alternate Solutions

- Revisit Operations - changes in market conditions, infrastructure, service, regulations, production characteristics change with time.
- Innovation and flexibility in approach - Understand the challenges and solutions.
- Capitalize on previous experience and emerging technologies.
- Create Partnerships with other Operators and Suppliers resulting in synergy and focus in finding cost effective alternatives.
- Complete buy-in from all Stakeholders - communities, regulators, venture partners and executive and their boards.

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Factors to Consider in Gas Flaring

- Production
  - Reservoir Characteristics
  - Reserves
  - Timing
- Local and Global Market
  - Demand and future potential
  - Infrastructure
  - Pricing structure
- Commercial
  - Asset costs and return on investment
  - Approvals, regulations and permitting
  - Tax relief, social programmes and environmental considerations

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A Few Alternatives to Gas Flaring Based on Existing Technologies

1) Tertiary Recovery of Hydrocarbons
2) Gas Storage
3) Process Heat/Power Generation- Local and Commercial
4) Liquefied Natural Gas
5) Gas Treatment and Liquids recovery
6) Gas To Liquids

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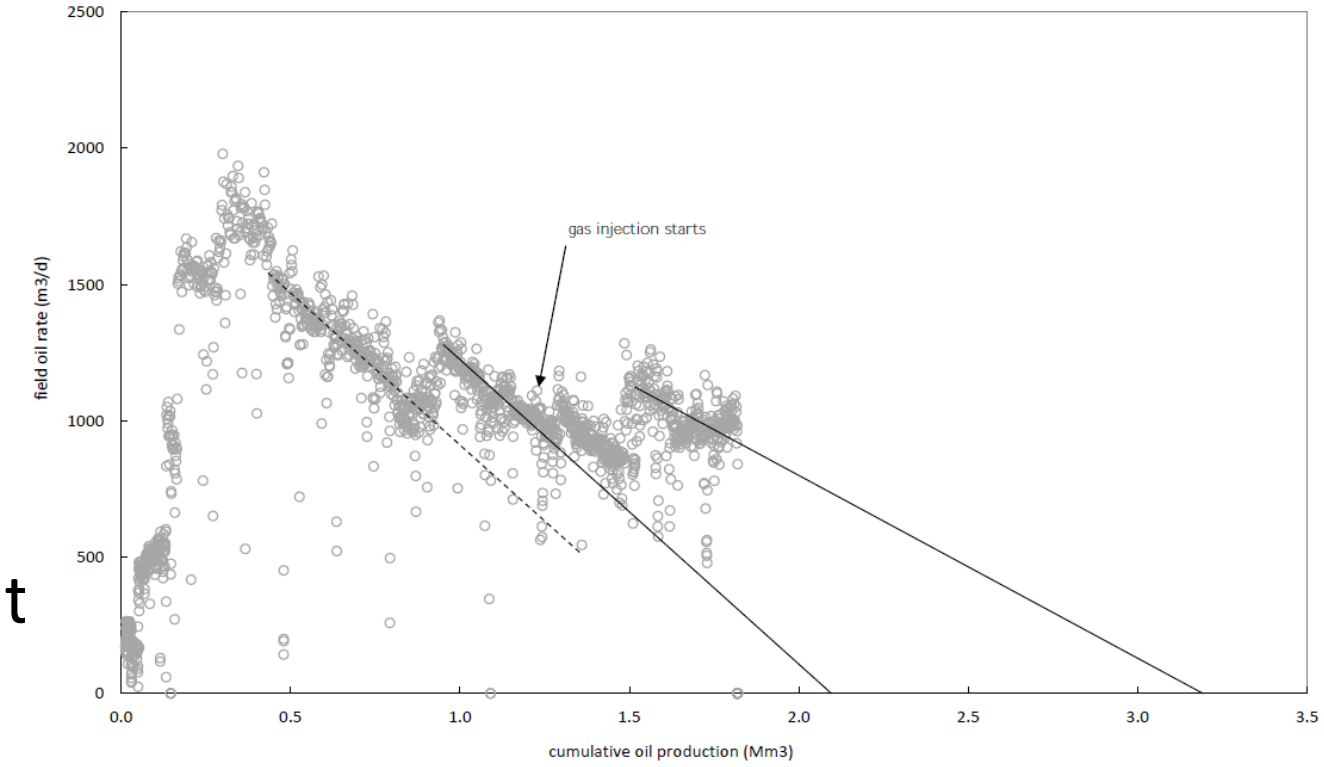
Gas Storage

- Arbitrage – Gas can be bought cheaply when there is low demand.
- Adjustment of supply and transmission/process capacity.
- Short-term flexibility.
- Can provide an emergency supply of gas.
- Potentially high capital costs due to the need for cushion gas.
- Reservoirs need to have specific characteristics.

Tertiary Recovery of Hydrocarbons

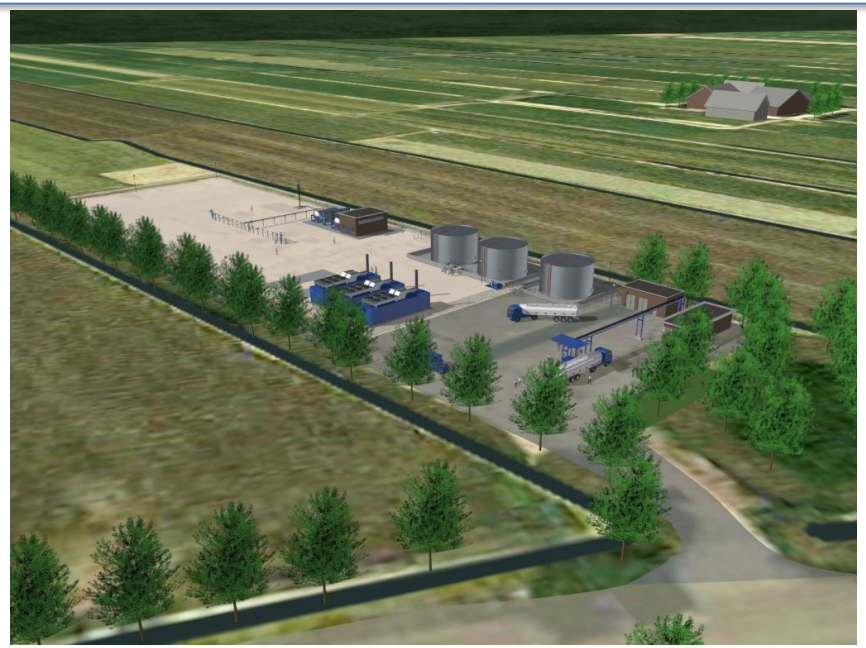
- Clean, relatively low cost.
- Improves efficiency of oil recoveries.
- Can be sold solely for this purpose.
- Possible monetisation of gas in late life of field.
- Some arbitrage opportunities.
- Reservoirs have to have the right characteristics.



Process Heat & Power Generation

- Can be viable even for every small volumes of gas.
- Can onsite power equipment and for process heat.
  - Provides reliability
  - Reduces operating costs
  - Reduced transportation costs
- Can provide electricity or CHP to remote locations.
  - Economic benefits as revenues from electrical sales and liquids recovery
  - Community/local engagement benefit.
- Requires only limited infrastructure.

Case Study in the Netherlands



- Provide Peak Power on 15 minute notice Resulting in premium sales prices for less production.
- Electricity into local grid in high area demand resulting on less load at peak hours and reliable supply.
- Minimum impact on sound and visual with locals.
- Good support from neighbours and community.

- Three 2 MW Units.
- Total gas requirement at full load 2.3 MMSCFD.
- Producing approximately 60 barrels of condensate per day based on average utilization.
- Less than a year to install and commission.

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Liquified Natural Gas (LNG)

- Simple, safe technology.
- Clean energy source with low impact on the environment.
- Global market
  - Domestic
  - Industrial
  - Power Generation

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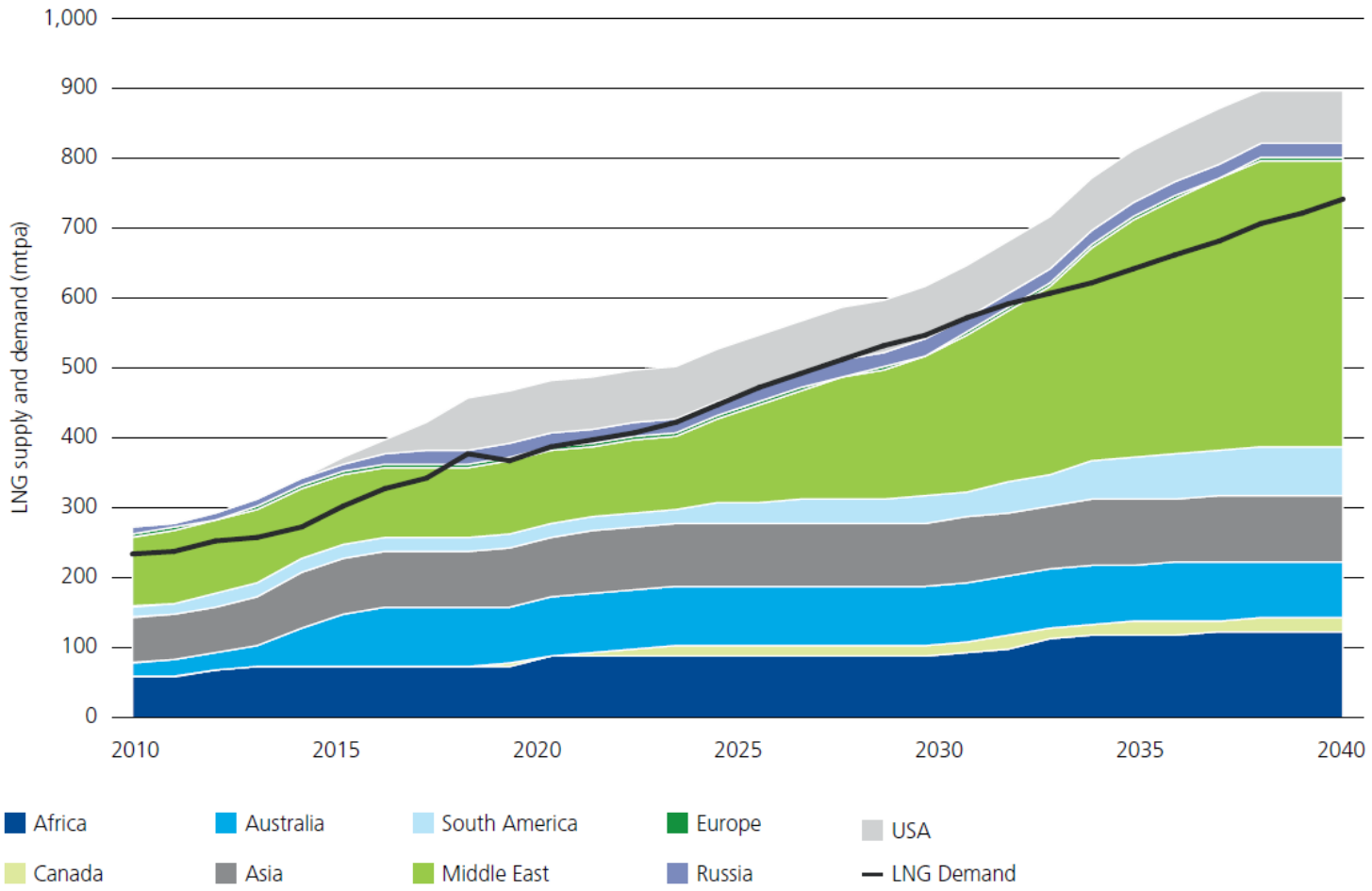
LNG Market Growth

Figure 1. Both LNG supply and demand is expected to grow steadily despite headwinds



Source: Deloitte MarketPoint analysis

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Gas Treatment, NGL's & Liquids Recovery

- Economic – Generate additional income from hydrocarbon liquid sale.
- Proven technologies like mechanical refrigeration.
- "Deep cut" providing product to local markets (condensate, LPG's and Pentanes, etc).
- Treatment of gas to meet hydrocarbon and water dewpoints – Then used for fuel, process heat, power generation, petrochemical, sales, etc.

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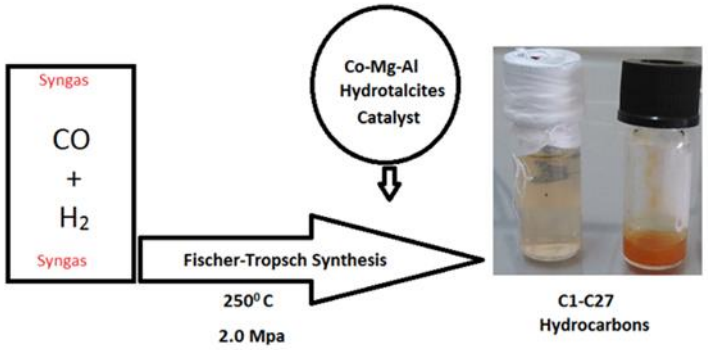
NGLs and Deep Cut Example

- “Deep cut” Gas processing Facility
- Economic benefits
  - Produces 156 m³/day of stabilized condensate
  - 66 m³/day of LPG for market
  - 85,000 m³/day of overhead gas for power generation
  - Increase fuel quality for power, reduced diesel usage
- Positive social impact; increase reliability of heat and power.

New “Old” Technology
Gas To Liquids



- Fischer–Tropsch exothermic process.
- Catalyst-based process converts natural gas to longer hydrocarbon chain – Creating synthetic fuels.
- Typical conversion rates of 1 MMCFD to 100 barrels of oil
- Products are easy to transport, usable as feed stock.
- Considerable progress in development in last 30 years creating the way for smaller plants to be economically feasible.
- Gas be applied to offshore gas as well.

Conclusions

- Many different proven options and solutions.
- Changes in technology mean proven designs are more economic than previously.
- These techniques remove liability and monetise an otherwise wasteful by-product.

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Putting relevant science and engineering back into every decision made!

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