

A CONCEPTUAL DESIGN OF A MOBILE SHALE GAS PROCESSING FACILITY

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Natural gas is a key element of the UK's energy supply, comprising 35% in 2015. While consumption of natural gas has almost doubled since 1975, actual production in the UK has declined since 2000. This has led to a significant increase in gas importation.

The government is facing the trilemma of energy – (1) affordability of energy, (2) carbon reduction, and (3) energy security. It is becoming increasingly important for the UK to generate its own energy, but it will take years for renewable sources to be fully developed. Therefore, gas generation will play a vital role for many years to come and the opportunity of developing the indigenous shale gas offers the potential to assist in solving the energy trilemma. The UK is believed to have a potential of up to 1300 TCF of shale gas, of this, around 10% is believed to be recoverable. This would mean around 50 years of gas supply for the UK and offering the potential to a reduced dependence on imported natural gas.

Exploration and appraisal phases of a shale gas well production test requires flaring to collect well flow data. This increases environmental damage from greenhouse gas emissions of flared methane and CO₂ emissions, and prevents operators achieving their social license to operate. Shale gas operators therefore need to demonstrate the safe operation and minimum environmental footprint of shale gas development, to help reduce public safety and environmental concern and provide greater economic certainty for operators. The most likely approach in the near-future will be the approval of several wells for testing, followed by pilot scale facilities. To facilitate production test, a shale gas operator needs a "demand" for the gas. The most obvious UK demand is the Gas Distribution Networks (GDNs) and National Transmission System (NTS).

DNV GL has undertaken a project to develop a concept design for a self-contained and transportable gas processing facility. The purpose of the facility is to process recovered gas on a small-scale "well-to-well" development to meet gas quality requirements to deliver the gas to the NTS and/or GDNs.

If the mobile gas processing facility concept is further developed and proved, valuable natural gas resources could be recovered with minimal environmental impact.

KEYWORDS: Shale Gas, Shale Gas Development, Gas Processing, Mobile Processing, National Transmission System, Gas Distribution Network, Social License to Operate

1. Introduction

Natural gas is a key part of the UK energy supply. Total UK annual consumption of natural gas increased to 35% of all fuels consumed in 2015, while gas production has declined by 60% over the last 15 years to 2015. This has caused significant increases in gas being imported, which have more than doubled since 2005 (BEIS, 2016). Import levels are expected to increase by 70% by 2030 (Earp, 2016).

The UK has also seen a large reduction in CO₂ emissions, 32% from 1990 (BEIS, 2015), driven by the change in fuel mix for electricity generation. However, the government has set an even tighter emission reduction of 80% of the 1990 levels by 2050, which means that more challenging measures are needed to achieve the targets (Committee on Climate Change, 2017).

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1.1. Shale gas and the UK

Shale gas is a natural gas (predominantly methane) found in shale rock formations, and a process called hydraulic fracturing¹ is used to extract the gas. Estimates of UK shale gas are significant (Figure 1). There is potentially up to 1300 TCF² of shale gas in Bowland Shale alone, with around 10-20% of this believed to be recoverable (U.S. EIA/ARI, 2015).

¹ Hydraulic fracturing is a technique used to extract shale gas, which uses water, pumped at high pressure into the rock to create narrow fractures to allow the gas to flow into the well bore to be captured

² Trillion cubic feet (TCF)

Gas distribution operators are now considering the compatibility of varied sources of gas to the supply network with work ongoing with IGEM, ENA and stakeholder partners to update the Gas Safety Management Regulations following the SGN Network Innovation Contract (NIC) Oban project. National Grid has instigated the project Customer Low Cost Connections (CLoCC) (Project CLoCC, 2017). CLoCC intends to consider all types of connection to the system and to produce ‘off-the-shelf’ standardised designs for connections irrespective of the size of connection, or type of gas. Cadent Gas has also partnered with DNV GL to investigate a “proof-of-concept” for new approaches to enable entry of all compliant gases, which includes unconventional gases from shale, to the gas distribution networks (Future Billing Method, 2017).

With recent innovation projects, it is likely that shale gas can be injected to the NTS and/or GDNs, so long as it meets the gas quality requirements. The prospect of a small-scale facility to process shale gas to meet the entry requirements will therefore be highly beneficial.

1.3. Objectives

The project aim is to investigate the feasibility of a mobile gas processing facility to process recovered shale gas on a small-scale “well-to-well” development and deliver the gas to the NTS and/or local GDNs.

Key considerations for the design of the mobile processing facility are as follows:

- Process the recovered gas during the production testing on a small-scale well-to-well development.
- Deliver the processed gas to the distribution networks and meet the pipeline requirements.
- Develop a self-contained, transportable gas process facility on the back of trucks.
- Meet the road transport specification for size and weight.

1.4. Study Boundaries and Overall Assumptions

Boundaries for the study include facilities from the well flow-line up to the export gas pipeline. The produced water and condensate storage vessels are also included.

A simplified block flow diagram of processing is presented in Figure 2 with the study boundaries highlighted (dashed line).

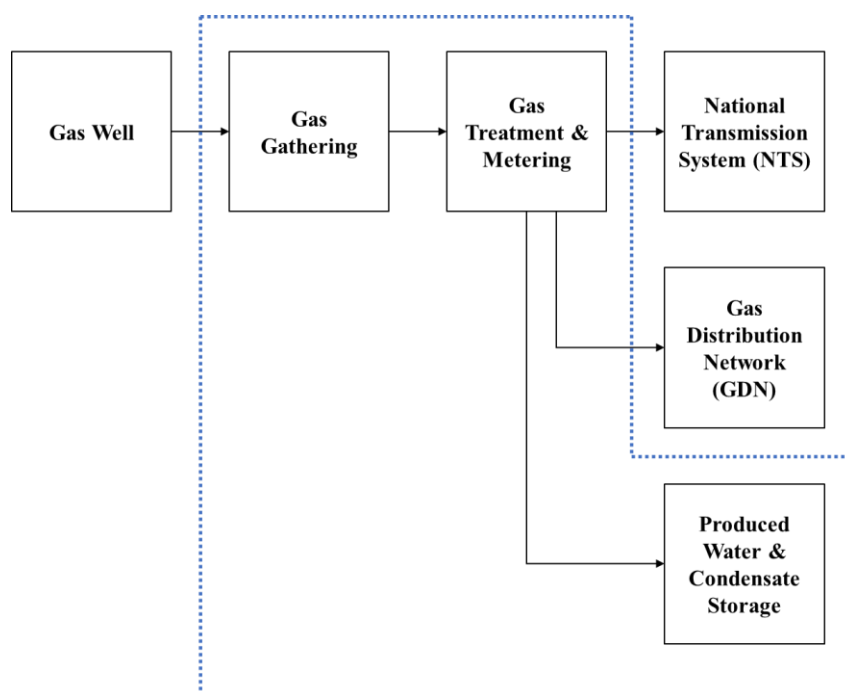


Figure 2. Simplified block flow diagram showing the study boundaries

This project only considered the period following hydraulic fracturing. It is assumed that the well has already been cleaned up before large volumes of the gas can flow to the surface. The gas recovered from the fractured wells will be directed to the mobile facility.

1.4.1. Design Capacity and Analysis Period

Early phase well production was assumed to last for 6 months, but could be extended up to a period of 24 months, with a constant well gas flow rate of 1 MMscfd³.

³ Million standard cubic feet per day

1.4.2. Network Entry Requirements

Different natural gas grids have their own set of gas quality specifications, but before gas can be injected, it needs to be processed to be suitable for grid injection. The specifications are summarised below for the NTS and GDN (see Table 1).

Table 1. Gas quality requirement for NTS and GDNs

		National Transmission System (NTS)	Gas Distribution Networks (GDN)
Pressure ⁴	Max	70-94 barg (depending on location)	34-70 barg (depending on location)
Temperature	Min	1 °C	1 °C
	Max	38 °C	38 °C
Hydrocarbon dewpoint	Max	-2°C at any pressure up to 85 barg	-2°C at any pressure up to 85 barg
Water dewpoint	Max	-10 °C at 85 barg	-10 °C at 85 barg
Wobbe Index	Min	47.2 MJ m ⁻³	47.2 MJ m ⁻³
	Max	51.41 MJ m ⁻³	51.41 MJ m ⁻³
Calorific Value (CV) ⁵	Min	36.9 MJ m ⁻³	36.9 MJ m ⁻³
	Max	42.3 MJ m ⁻³	42.3 MJ m ⁻³
Total Sulphur	Max	50 mg m ⁻³	50 mg m ⁻³
Hydrogen Sulphide	Max	5 mg m ⁻³	5 mg m ⁻³
Carbon Dioxide	Max	2.5 % mol	2.5 % mol
Oxygen	Max	0.001 % mol	0.001% mol
Hydrogen	Max	0.1% mol	0.1% mol
Inerts	Max	7 % mol	7 % mol
Organo-halides	Max	1.5 mg m ⁻³	1.5 % mol
Incomplete combustion factor (ICF)	Max	0.48	0.48
Soot Index (SI)	Max	0.6	0.6

2. Concept Development

This section describes the various stages of the mobile gas processing facility.

2.1. Process Boundaries

The raw gas may not meet the NTS pipeline specifications. Gas condensates, impurities and inerts, such as nitrogen, mercury, or hydrogen sulphide need to be removed by the gas processing facility.

The main gas processing requirements is summarised in the block flow diagram shown in Figure 3.

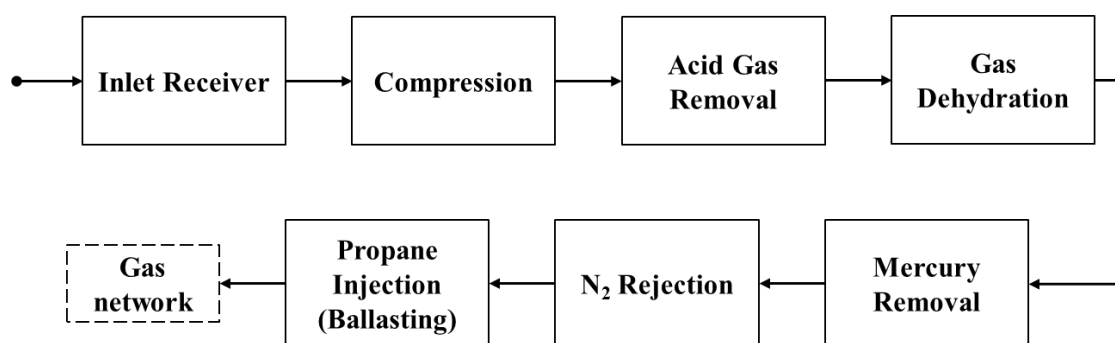


Figure 3. Gas treatment facility diagram

2.1.1. Gas Gathering and Treatment

During the hook-up phase, reusable flowlines (flexible pipe) will be connected to the well flow-line to deliver gas from the well to the mobile processing facility.

⁴ Pressure depends on back pressure and delivery point in the entry facility

⁵ This is subject to gas entry location and volumes; a target for the CV may be set within this range.

Gas is then treated to meet the entry specifications. Gas treatment design concepts used for the mobile processing facility were identified and evaluated for the use of each system, described below.

Inlet Receiver

An inlet vessel will receive multiphase flow from the well to separate the liquid from the gas stream and other particulate matter. Initial volumes of liquid should be removed to reduce sizing of equipment downstream. A vertical pressure vessel will be used to reduce space occupied on the back of the truck.

Compression

It is assumed that fluid coming from a single wellhead has low pressure, and therefore, needs compression to achieve grid entry pressures of 34 and 74 barg. Processed gas can either be subjected to:

- Full compression in the inlet to the gas treatment (after inlet receiver) using multi-stage compression with inter-stage cooling; or
- An initial intermediate compression of gas through to the gas treatment units, and compression to transmission pipeline pressure (after gas treatment).

Full compression of gas prior to entering the gas treatment units was selected for the study. It is beneficial to the dehydration unit downstream to perform compression and cooling upstream, as this will reduce water content in the gas stream and hence reduce the water removal requirement of the dehydration equipment. The inlet pressure to the dehydration unit should be above 34 barg for the efficient removal of water.

Full compression will be achieved using multistage centrifugal compressors, while inter-stage cooling will be achieved using air coolers.

Acid Gas Removal

Zinc oxide fixed bed has been selected for the acid gas removal unit (AGRU). It has various advantages over the other identified processes (e.g. low temperature/cryogenic, membrane, and scavengers). It does not require the use of liquid desiccant to perform H₂S removal, which eliminates the requirement of additional equipment for liquid inventory. It is also a widely-used technology especially with its high selectivity for H₂S and its applicability to treat gas streams with low levels of H₂S. The process is also advantageous as it can be used with a wet or dry gas stream.

The system will consist of an adsorbent bed on a 1 x 100% configuration. To increase the robustness of the process and to increase the level of saturation prior to bed change-out, which occurs every 6-12 months, space for a second vessel will be included. **Water Removal / Gas Dehydration**

ADAPT[®] technology, which is based on solid-bed adsorption technology using silica gel as the adsorbent media, will be used for hydrocarbon dewpointing whilst removing the remaining water content in the gas stream. The main advantage of this solid-bed dehydration process over glycol dehydration is the use of solid, instead of liquid desiccant which also eliminates space requirement of additional liquid storage and eliminates entrainment and foaming issues. ADAPT also does not require the use of rotating machinery and has low pressure drop across the bed eliminating the need for recompression and making it easier to maintain.

A minimum of two towers, one for adsorption and another for regeneration, will be required. The towers will have internal insulation on them to avoid heating and cooling of vessel wall.

Bed regeneration will be achieved by passing feed gas, which is normally 10% of the total feed flow, through the regeneration heater (maximum outlet temperature of 275°C), the bed to be regenerated, the regeneration cooler (outlet temperature of 35°C) and the condensate knockout pot.

Mercury Removal

Metallic sulphide bed process has been selected for the mercury removal unit (MRU). It offers a number of advantages over the other solid bed processes (e.g. sulphur impregnated activated carbon, solid-supported ionic liquids and silver impregnated molecular sieves) such as - (1) it can be placed at upstream locations as it is more resistant to liquid carryover, (2) it is a widely-used technology which can treat both wet and dry gas streams, and (3) although it is non-regenerable it can still be handled in an environmentally-friendly way by selling it to specialist smelters to be re-used.

Typically, 2 x 100% mercury trains is recommended, but in this instance only a 1 x 100% mercury train will be used; a mercury train on standby is not included since the plant will only be operating for a short period of time.

The use of metallic sulphide bed process ensures safety of personnel during handling of spent absorbent material as the mercury will not desorb even when the absorbent is fully saturated.

Nitrogen Rejection

Molecular Gate technology, which makes use of pressure swing adsorption technique, has been selected for the study as it removes nitrogen from the gas stream and at the same time reduces CO₂ to less than 2.5 mol % in a cost-effective manner, especially for streams with small gas feed rates. The technology can handle process flowrates which range from 0.5 MMscfd up to 50 MMscfd or even greater. It also does not require any liquid desiccants, making it preferable over absorption and cryogenic separation.

The unit will be placed upstream of the Propane Injection unit as heavier hydrocarbons, such as propane and C₄+, have high affinity to the adsorbent material and will be removed along with the nitrogen and carbon dioxide into the tail gas. The system will consist of two vessels with the molecular sieve (fixed bed) adsorbent (titanium silicate) to create a continuous process and rapid cycles between adsorption and regeneration. The tail gas (N₂, CO₂, some methane and other hydrocarbons) will be directed to a single gas-engine drive generator set (genset) to burn the tail gas.

The process operates by “swinging” the pressure from the high feed pressure where the N₂ and CO₂ are adsorbed on fixed adsorbent beds to a lower regeneration pressure. At this lower pressure, the affinity between the adsorbent and the N₂ and CO₂ is lower causing them to become free from the adsorbent and removed as tail gas; a small methane stream (typically 20% of the of the feed flowrate) is then used to purge the bed following this. Multiple beds are used to create a continuous process and rapid cycles between adsorption and regeneration helps minimise the adsorbent inventory.

Propane Injection

To enrich the calorific value of the natural gas stream and to meet grid specification for flow weighted average CV, propane addition by blending has been assessed.

The amount of propane to be injected to the treated gas depends on its composition and this may vary from well to well. It will be assumed that the amount required for injection will be much less than the amounts required for some of the large gas processing facilities. A propane bullet (or cylinder) and a backup bullet will be placed on a rack and will be put on the back of the truck. The propane bullets will be kept away from heat as this could increase the pressure of propane inside and could lead to the safe limits being exceeded.

2.1.2. Export Gas Pipeline

Installing fixed pipelines would be uneconomical as the facility is anticipated to be transported from one well location to another once the wells have been exhausted. Reusable flowlines will be used to attach the mobile facility through bespoke fitting to live distribution pipelines.

While flexible pipes are known to historically have issues with leakage or high heat loss, there are manufactured flexible pipes that have good quality and are highly reliable, which can ensure a leakproof design and significantly reduced heat loss. The flexible pipe to be chosen should be braided to prevent hose whip. The pipework connections should also be designed to ensure that stresses are not put in the pipe, which can increase failure. Finally, pipes should be replaced in line with manufacturer’s recommendations.

2.1.3. Utilities

The produced water recovered during production will be treated initially and stored on-site with periodic removal. Produced water will be collected by trucks and delivered to a water treatment facility off-site.

A fraction of the gas produced is sent to a genset to power the facility. The requirement for a genset depends on the location of the facility. If it is located in a remote area, it may be difficult to get it to connect to the grid; so, an uninterruptible power supply (UPS) is required for the control system and a genset will still be needed.

2.2. Other Considerations**2.2.1. Facility Location**

The location of the trucks will be chosen away from domestic premises, e.g. houses or public buildings, and safety distances will be established with fencing and security. Warning signs will also be placed to help people identify the hazards present on site.

To minimise possible escalating events, e.g. processed gas from the mobile facility to the distribution network, there will be emergency shutdown valves (ESDVs) located on both ends of the line which will allow it to be shut down in an event of an emergency.

2.2.2. Staffing Levels

To minimise impact to people, there will be restricted access to the facility. Tracking or recording of people will also be considered. Naturally, people will also be trained in use of equipment in emergency situations.

2.3. Notional Layout of the Facility

The units required to process the shale gas depend entirely on the fluid composition and the pipeline requirements.

Conceptually, the equipment installed on the back of the trucks can either be fixed or skid-mounted. Figure 4 shows a notional layout of the gas processing facility. Each piece of equipment is designed for a maximum rate of 1 MMscfd and sized to fit on the back of the trucks. The equipment with rotating parts (i.e. compressors and air coolers) are separated from the static equipment, due to concern on the impact of vibration to the static or contactor beds.

The road transport specification for size and gross weight are described in more detail in Section 2.2.1.

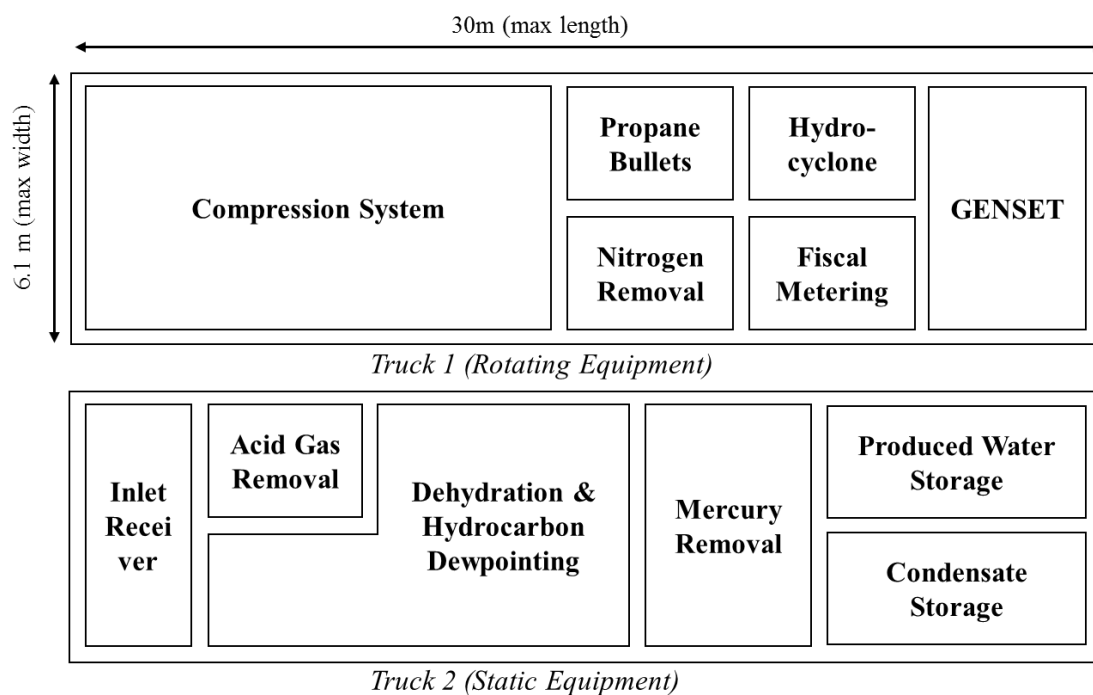


Figure 4. Hypothetical mobile gas processing facility layout.

2.3.1. Vehicle / Trailer Load Limits

A contemplating factor in this study is the vehicle weight and dimension limits in the UK roads. This is a crucial aspect in the feasibility assessment to determine whether the facility can be transported from one well site to another.

In the UK, the maximum permitted gross weight of a semi-trailer truck is 44,000 kg and any other vehicle heavier than this, but with indivisible loads, is permitted but is required to display a Special Type General Order (STGO) plate, travel at an authorised route and have an escort.

These provisions in UK roads concerning the width, height, length and weight of vehicles, are regulated and are under Part 2 of the Road Traffic Act (Department of Transport, 2003). Table 2 summarises the maximum allowable limits in the UK roads. It should be noted that notifications for abnormal indivisible loads are required for these.

Table 2. Maximum allowable load and dimension limits on UK roads

Gross Weight	150,000 kgs (147.63 tonnes)
Width	6.1 metres (20')
Length	30 metres (98' 5")

Note: The UK has no legal height limit, but most road networks can accommodate trucks up to a height of 4.9 m.

3. Conclusions

The UK is highly reliant on imported natural gas, but if shale gas resources are exploited, it could provide the country with gas supply for around 50 years and lead to significant economic benefits. Shale gas development is still in its infancy in the UK and drilling and testing more wells are necessary to prove that shale gas development is technically and economically viable.

The proposed gas processing facility design should assist operators to achieve their social licenses to operate. The processing facility reduces the need for flaring, which helps minimise environmental footprint of shale gas development. The facility is also temporary and it reduces the footprint to minimum. This gives assurance to the local communities that, once the wells have been exhausted and production period is finished, all equipment is removed and the area is restored to its original state. This conceptual design should thus help make shale gas in the UK a reality.

4. References

- BEIS. (2015). 2015 UK Greenhouse Gas Emissions Final Figures, National Statistics. Retrieved from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/589602/2015_Final_Emissions_Statistics_one_page_summary.pdf
- BEIS. (2016). *Digest of United Kingdom Energy Statistics (DUKES) 2016 - Annexes E - J and long term trends chapters*. Department for Business, Energy & Industrial Strategy.
- Committee on Climate Change. (2017). *UK Regulations: the Climate Change Act*. Retrieved from <https://www.theccc.org.uk/tackling-climate-change/the-legal-landscape/global-action-on-climate-change/>
- DECC. (2014). *The Unconventional Hydrocarbon Resources of Britain's Onshore Basins - Shale Gas*. Department of Energy & Climate Change.
- Department of Transport. (2003). *The Road Vehicles (Authorisation of Special Types) (General) Order 2003*.
- Earp, M. (2016, October). *Oil and Gas Authority (OGA)*. Retrieved from <https://www.ogauthority.co.uk/media/1549/oga-production-projections-october-2016.pdf>
- Future Billing Method*. (2017). Retrieved from <http://futurebillingmethodology.com/key-contacts/>
- MacKay, D., & Stone, T. (2013). *Potential Greenhouse Gas Emissions Associated with Shale Gas Extraction and Use*. Department of Energy and Climate Change.
- Project CLoCC*. (2017). Retrieved from <http://projectclocc.com/>
- U.S. EIA/ARI. (2015). *Technically Recoverable Shale Oil and Shale Gas Resources: United Kingdom*. U.S. Department of Energy. Retrieved from <https://www.bgs.ac.uk/shalegas/>
- U.S. Energy Information Administration. (2013). *Technically Recoverable Shale Oil and Shale Gas Resources: An Assessment of 137 Shale Formations in 41 Countries Outside the United States*. U.S. Department of Energy.