The Heritage of the Oil Industry

TICCIH Thematic Study

James Douet

TICCIH

The International Committee for the Conservation of the Industrial Heritage

2020

TICCIH - The International Committee for the Conservation of the Industrial Heritage, is the international association for industrial archaeology and industrial heritage. Its aim is to study, protect, conserve and explain the remains of industrialisation.

For further information and how to join see www.ticcih.org.

An interactive digital edition of this report can be downloaded, along with the other thematic studies, from the TICCIH website.

CONTENTS

EXECUTIVE SUMMARY....5
1. Context....6
1.1 Thematic studies....6
1.2 Objectives....6
1.3 Methodology....6
2. Introduction....8
2.1 Scope....9
2.2 Chronology....10
2.3 Petroleum sites on the World Heritage List....10
2.4 Cooperation....11
3. Terminology....1
4. Historical development....6
4.1 Antiquity - 1840s: petroleum harvesting....6
4.2 1840s - 1860: pre-industrial production....7
4.3 1860 – 1910: the Pennsylvania model....10
4.4 1910 – 1970: global petroleum production....15
6. The petroleum industry as World Heritage....25
6.1 Historical themes....25
6.2 Authenticity and integrity....26
6.3 Conservation priorities....28
7. UNESCO evaluation criteria....32
7.1 Selection criteria....32
8. Case studies: sites for comparison....34
8.1 La Brea Pitch Lake, Trinidad....35
8.2 Oil Springs, Ontario, Canada....37
8.3 Deutsches Erdölmuseum Wietze, Germany....40
8.4 Abadan Company Town, Iran....43
8.5 Wüsteshale Oil Factories, Germany....46
8.6 Turner Valley Gas Plant, Canada....49
8.7 Daqing Oilfield, China....52
8.8 Cerro Sombrero Oil Camp Settlement, Chile....55
8.9 Chu-Hung Keng Mining Landscape, Taiwan....58
8.10 Trans-Arabian Pipeline, Saudi Arabia....61
8.11 Standard Oil building, New York, United States....64
9. Bibliography....67
Appendix: Discovery and Production Timeline....73

Acknowledgements

The initiative for this thematic study of the heritage of the global petroleum industry came from Patricia McGee and Charlie Fairbank of Fairbank Oil Fields, the Oil Springs, National Historic Site in Ontario, Canada, who provided generous support as well as copious information about the early period of the petroleum industry. The study forms one of a series of comparative reports on the heritage of different industrial sectors coordinated by TICCIH for ICOMOS, the International Council for Monuments and Sites.

EXECUTIVE SUMMARY

The petroleum industry is approximately 160 years old, its origin conventionally dated by historians to the oil wells drilled in Ontario and Pennsylvania in the late 1850s. From that quite precise starting date, the development of the new industry and its technical means was very rapid. The volume of petroleum produced rose sharply, and the number of wells from which it was pumped extended to oil fields in many other countries. The range of useful products which could be derived from refining hydrocarbons also grew. Initially sought for producing kerosene illuminating oil, the advent of the combustion engine turned petroleum into the most important energy resource of the 20th century. Petroleum's hegemony was reinforced from the 1950s by the advent of petrochemical products - plastics, textiles, dyes, medicines, solvents, fertilizers, pesticides, and many more.

Today, crude oil and gas provide over 60% of the world's primary energy needs. Burning the products of the petroleum industry has also substantially increased the amount of greenhouse gases in the atmosphere, contributing to global warming.

The heritage of the petroleum industry – the places, structures, sites and landscapes which we might choose to conserve for their historical, technical, social or architectural attributes - has not previously, however, been examined in a comprehensive way or from a global standpoint. This study aims to fill that gap by conducting a comparative review of the development of the industry so that the most significant historic sites related directly to the production and distribution of petroleum and its products might be identified and their historic values safeguarded. This heritage broadens from the production and distribution sites to include the camps and urban areas built for workers and employees, the headquarters and administrative buildings of the private and national oil companies, and the filling stations which became the most visible face of the industry.

While the importance of the historical evidence for this industry is self-evident, it is also challenging from a conservation standpoint. Production infrastructure is potentially costly to conserve, and once obsolete may prove difficult to re-purpose. Technological change, a corrosive environment and ephemeral construction materials often limit the authenticity and integrity of historic sites. The scale of production plants can be vast, and oil and gas distribution networks by pipeline, rail, road and sea are immense. An assessment of the heritage of the petroleum industry must also weigh its contribution to global warming.

In consequence, historic petroleum production sites and landscapes are both rare and fragile. In many cases, the retention and study of documentation and company archives is the best way to conserve the history of the industry.

This report is one in a series of comparative thematic studies coordinated by TICCIH which propose criteria by which the material evidence of different industrial sectors can be assessed. As such it is pertinent for the World Heritage List as well as to guide national and regional heritage inventories. A historical summary identifies when and where the important advances in the petroleum industry took place to help recognize both the outstanding as well as the most representative surviving sites and to locate those which are potentially significant. To aid the comparative analysis of historic properties, the findings of the study are illustrated by a selection of case studies.

At present, the conserved heritage of the petroleum industry on national registers and inventories as well as at the level of World Heritage list understates its importance, and the most important sites should be identified and protected accordingly.

1. Context

1.1 Thematic studies

This report forms part of a series of comparative thematic studies of the heritage of different industrial sectors organized by TICCIH in its role as the designated consultant to lCOMOS in matters related to the study and preservation of industrial heritage. In turn, ICOMOS advises UNESCO on properties to be added to the World Heritage List, drawing on its advice from TICCIH.

In general, these comparative studies summarize the worldwide history of the sector, identifying the periods, locations and authors of the most significant developments, thus providing a contextual framework to help identify the outstanding as well as the most representative plant, buildings, sites and landscapes. Without undertaking new research, thematic studies present a synthesis of the available knowledge of a specific theme at the time they are undertaken. The theoretical and practical considerations of these properties as World Heritage sites are examined in the light of the criteria for Outstanding Universal Value in UNESCO's Operational Guidelines for the Implementation of the World Heritage Convention. Finally, a selection of case studies, written by different authors familiar with each one, contributes to the comparative evaluation of different sites around the world, although without making any recommendations as this might compromise any subsequent evaluation process. The sites which are presented for discussion in Section 8 are illustrative examples, and their inclusion is not intended to uphold their potential as World Heritage properties.

The direct beneficiary of the report is UNESCO, to help it distinguish places eligible for inscription on the World Heritage List, but the criteria are applicable to other national or regional lists and inventories. No national or regional assessments of the heritage of this sector have been found, while this is certainly the first global comparative study assessing the significance of the historic sites and landscapes of the petroleum industry.

1.2 Objectives

This report will

1. summarize the global development of the world petroleum sector, concentrating on the physical infrastructure associated with the production of petroleum and the territories most involved in its history;
2. indicate the types of structure, buildings, sites and landscapes which constitute the tangible remains of the industry with the potential to be conserved as heritage;
3. suggest, based on these surveys, what would be of special historical interest were examples to survive with some degree of integrity and authenticity;
4. provide comparative information to help identify the sites or landscapes which best represent these contributions.

1.3 Methodology

The methodology used for the thematic studies has two parts. The first is a succinct global history of the built infrastructure of the petroleum industry which identifies and highlights what is of particular historical significance, both internally for the development of that industry, and externally for human society in general. And the second consists of criteria to help identify those surviving structures, sites, buildings or landscapes which provide tangible evidence for the historic values previously identified, tempered by the usual considerations of integrity and authenticity.

The process of preparing this report consisted of a desk-based examination of the literature during 2019, consultation with relevant experts in different territories who would give a representative geographical and professional spread, the incorporation of their comments and suggestions, concluding with the presentation of the final document at an international meeting in 2020 to confirm a consensus for the conclusions.

The TICCIH/ICOMOS thematic studies do not recommend specific places, intending rather to help characterize those features of this class of cultural heritage which ought to be taken into consideration in an assessment of historic merit, including UNESCO´s measure of Outstanding Universal Value.

The places included in the discussion or presented as case studies serve to illustrate the theme and their inclusion is not intended as an indication of their potential as World Heritage sites.

2. Introduction

The heritage of the petroleum industry: *The most significant fixed, tangible evidence for the discovery, exploitation, production and consumption of petroleum products and of their impact on human and natural landscapes*.

The tangible global heritage of the petroleum industry has not been approached in a comprehensive way by historians, heritage scholars or by conservation agencies. This study represents the first international comparative evaluation of the sector's historic material remains.

There is an extensive historiography on petroleum, examining its origins and antecedents, the technologies of exploration, production, refining and logistics, and notably business history and geopolitical issues. To these, in the last two decades has been added increasing numbers of studies of the environmental consequences of our energy dependency on this non-renewable resource. There are also numerous broader studies covering such themes as oil and geopolitics, national identity, resource conflict or product branding.

However, there is a dearth of publications (in English, at least) which examine what an industrial archaeologist would recognise as the heritage of this all-pervading global industrial endeavour[1].'The industry has inspired a small set of usefully comprehensive historical studies and economic analyses... Written by industry insiders and policymakers, these works offer largely celebratory, and in some cases explicitly triumphalist, assessments of the rise and development of oil capitalism'. Moreover, '...relatively little scholarship has attempted to account for the myriad ways that oil has saturated... aesthetic practices, cultural forms, and public discourses since the nineteenth century' (Barrett and Worden 2012, 269)[2].

In order to frame and define this little-studied but potentially extensive built heritage, the present work approaches it from two directions. Firstly, by summarising the history of the physical infrastructure of the petroleum industry, the tangible engineering and urbanistic evidence from which its heritage is derived. The EOLSS entry by Macini and Mesini (2018) provides a succinct but comprehensive summary, whilst numerous other publications both specialist and general contribute details and a broad perspective.

Secondly, the wider imprint that the petroleum industry has left on human landscapes is examined through Hein's concept of the 'global Petroleumscape': 'Oil drilling equipment, refineries, storage tanks, pipelines, dedicated road and rail infrastructure, and gas stations [which] serve the physical flows of oil in industrial areas as well as in everyday life' (Hein 2018). In the present work, this is broadened to encompass settlements built or planned to support petroleum production, and the buildings of the major commercial organisations which steered the industry over the past 150 years.

This steps back from considering the global urban environment which has been moulded over the last century by petroleum: of settlements articulated by networks of roads and highways

---

[1] A notable exception is the privately published *19th Century Petroleum Technology in North America*, by Emory Kemp and Michael Caplinger, 2007).

[2]The authors cite Arnold Daum and Harold Francis Williamson's *The American Petroleum Industry* (1959-63), Daniel Yergin's best-selling *The Prize: The Epic Quest for Oil, Money, and Power* (1991), and Roger M Olien and Diana Davids Olien's *Oil and Ideology: The Cultural Creation of the American Petroleum Industry* (2000).

for petroleum-fuelled vehicles and covered with petroleum-derived asphalt. It also leaves for another study the cultural impact of the petroleum industry through the many universities, museums and natural parks which owe their existence to the wealth it has generated.

A firm conceptualisation of the cultural heritage of the petroleum industry may thereby be worked out by bringing together these two fields of study into a single narrative which can help to justify the care and preservation of the most valuable places.

2.1 Scope

The sites which are examined within this study are integral parts of the petroleum industry production chain, which produces, refines, stores and distributes the various products of petroleum from geological formations, as well as the buildings, settlements and landscapes associated with it. The petroleum industry is conveniently divided into three sectors.

Upstream includes the processes of exploration and production. In large part this is by drilling wells down to oil reservoirs, but the shale oil industry, which mines its raw material, has been locally important. In the United States fracking has in recent years produced large volumes of oil shale, known also as tight oil. Bitumen extraction is conventionally included in the petroleum industry setting (e.g. Canadian sands). Oil production is closely related to that of natural gas and is frequently inseparable from it.

The *Midstream* sector groups together field completion and transportation by sea, road and rail tankers and fixed pipeline operations.

The *downstream sector* covers oil refineries, petrochemical plants, petroleum product distribution, retail outlets and natural gas distribution.

The major refined products obtained from petroleum are fuel oil and gasoline (petrol) for vehicle transport, maritime transport and aviation, and oil and gas for power generation. However, the biggest part of the petroleum produced in the world is today the feedstock (raw material) for the petrochemical industry, producing pharmaceuticals, solvents, fertilizers, pesticides, synthetic fragrances, and overall plastics.

Some of the industries which were displaced by the early expansion of the oil industry have bequeathed historical evidence in the shape of buildings and infrastructure. Whale oil processing and refining, for instance, and manufactured (usually coal) gas production, distribution and storage, which have a considerable legacy of historic buildings in many countries are not, however, included in the oil industry thematic study.

Although asphalt is also an important petroleum product, critical to the expansion of the networks on which modern transportation has been based, it is not considered practicable to include roads and highways.

Because production operations have frequently been in isolated or unpopulated territories, they have often generated abrupt movements of population into the oil fields, urban settlements from ephemeral boom towns and temporary work camps to planned company towns are important classes of historic sites. So too are the headquarters buildings and offices commissioned by the oil companies, the visible representation of some of the most significant historical players in the history of oil. A very extensive heritage related to the petroleum industry is that of filling stations for transport fuel (gas or petrol stations). There are singular as well as a smaller number of characteristic examples included on the national inventories and registers of historic sites of many countries.

The study is fundamentally global in its scope, so although the historiography of oil is weighted by the North American experience, (the US was the largest producer country until the 1950s), the development and effect of the petroleum industry in the Middle East, Latin America, Europe and Asia is of course also indispensable. Each country which has produced oil, both in small or large quantities, has followed its own industrial path, leaving an indelible footprint in regional or national cultures. Since the growth of every national oil system is marked by internal economic, social, environmental, and scientific considerations and also influenced by external factors, it is possible to identify those distinctive features – sometimes unique – that characterize the oil history of every country.

2.2 Chronology

Natural seepage wells have been harvested on a small scale since pre-historic times in many parts of the world, and examples can be identified in Arabia, Europe and China. Nevertheless, production remained a craft activity with no skilled labour force in which the oil was not sought through exploration but found where it appeared naturally at the surface, and was only locally important or applied in specialised areas such as for water-proofing vessels or to illuminate religious icons.

The particular focus of this study, therefore, is the industrialised production of petroleum products which dates precisely from the middle of the 19th century, when mechanised techniques of tapping underground sources initiated a rapid development leading to petroleum replacing coal as the main fossil energy source. Beginning with oil for illumination and then for mechanical lubrication, by the early 20th century it had extended to motor transport on both land and sea, and it widened vastly from the 1940s as the petro-chemical industry developed with oil as its feedstock.

The 'natural gas', mostly methane, which accompanies oil deposits only became an important source of energy after the 1950s, previously having been largely released into the atmosphere or burnt (flared) on site.

Consistent with TICCIH's definition in its 2003 Nizhny Tagil Charter, the study considers sites to be of interest once they are obsolete, and thereby potentially at risk of being damaged or destroyed. Oil fields usually become obsolete when the wells run dry, or at least when market value of the oil is lower than the cost of producing it. This means that defunct oil fields may be put back into operation if the price of oil rises sufficiently, or if new technologies or techniques, such as fracking, make production again viable.

Since the 1970s, a scientific consensus has formed around the dominant contribution to global warming of greenhouse gases released by burning petroleum hydrocarbons. UNESCO introduces its report Climate Change and World Heritage thus: '… climate change … has emerged as one of the most serious threats impacting on the conservation of this heritage.' Any evaluation of the heritage of the petroleum industry needs to be considered in the light of our understanding, by that date, of the damaging impact which the industry has had, and continues to have, on the global environment.

2.3 Petroleum sites on the World Heritage List

There are no sites directly associated with the petroleum production currently on the UNESCO World Heritage List, and only one, the Awali oil settlement in Bahrain, on any state's Tentative List. Perhaps the most well-known place associated with naturally occurring hydrocarbons is the temple of Atashgyakh on the Tentative List of Azerbaijan. The 17th century buildings held an 'eternal flame' which was fed from underground deposits until it extinguished in 1969, probably as a consequence of over a century of exploitation of petroleum and gas in the area.

Natural fires around the Absheron peninsula were commented on by many historical visitors over millennia.

The petroleum industry's heritage would primarily be cultural sites, but may also, as with any industry exploiting a natural resource, be associated with natural ones, and so some might be joint cultural and natural sites. The La Brea Pitch Lake is 'the largest, commercial deposit of natural asphalt in the world... re-discovery by Sir Waiter Raleigh in 1595. Raleigh used asphalt from the Lake to caulk his battered ship' (UNESCO 5645), and is on the Tentative List of Trinidad and Tobago. The Binagadi asphalt lake (or Binagadi tar pits) are a cluster of tar pits associated with the famous oil town of Baku, Azerbaijan, and is on that state's Tentative List (UNESCO 1175).The Binagadi 4th Period Fauna and Flora Deposit include a mass of bones and vegetable debris conserved beneath a layer of petroleum.

That said, there are numerous oil and petroleum museums in the world, with important collections of artefacts, a full catalogue of which can be consulted on the 2020 List of Petroleum History Museums. Some of these occupy the sites of former commercial oil wells, such as the Argentine Museo Nacional del Petróleo. However, almost none conserve original in situ infrastructure, ensembles or landscapes of production, the Petrolia Discovery in Canada being one notable exception.

2.4 Cooperation

This thematic review is the result of a wide interdisciplinary effort with a sizable group of colleagues, researchers and scholars. Patricia McGee and Charlie Fairbank provided numerous leads and contacts. Francesco Gerali was especially generous in commenting on the text and sharing sources. Patrick Martin, past President of TICCIH, had a key role in initiating the project and it was developed with the encouragement of Miles Oglethorpe, the TICCIH president, and Stephen Hughes, the former TICCIH Secretary General.

Correspondents

Dr Pía Acevedo Méndez, Chile

Abdullah Khalifa Al-Dossary, Saudi Arabia

Hassan Bazazzadeh, Iran

Dr Liu Boying, China

Dr Graciela Ciselli, Argentina

Professor Michel Cotte, France

Dr Francesco Gerali, Italy

Mohsen Ghomeshi, Iran

Dr Hsiao-Wei Lin, Taiwan

Muhammed Baber Hussain, Saudi Arabia

Stephen Hughes, UK

Dr Björn Lindberg, Norway

Dr Stephan A. Lütgert, Germany

Professor Carola Hein, the Netherlands

Dr Barbara Hausmair, Germany

Professor Patrick E. Martin, United States

Professor Massimo Preite, Italy

Gary May, Canada

Patricia McGee and Charlie Fairbank, Canada

Dr Kaie Metsaots, Estonia

Dr Mir-Yusif Mir-Babayev, Azerbaijan

Dr Bode Morin, United States

Dr Miles Oglethorpe, UK

Elisa Rubalcava, Canada

Norbert Tempel, Germany

3. Terminology

This section briefly defines the principal technical terms used in this report to describe the technology and infrastructure of the petroleum industry. Many definitions are adapted from the Schlumberger Oil Field Glossary, Macini and Mesini (2018), and Glossary of the Technical Terminology Used in the Petroleum Industry, 1890-1950, with some historical terms taken from Kemp and Caplinger (2007). This contains valuable illustrations of historic petroleum production as well as photographs of early industrial technology.

Oil industry or petroleum industry?

The 'oil industry' is that which produces petroleum. It is the name generally used in North America, while most other countries refer to the 'petroleum industry'. Petroleum and crude oil are often used to mean the same thing, but in this report 'petroleum' is the generally used for the broad range of petroleum products including crude oil itself.

Natural materials

Asphalt: A solid form of petroleum.

Bitumen: A dense and extremely viscous form of petroleum, also known as tar and pitch. Most bitumen is not considered as movable (fluid) through the reservoir under normal conditions of flow and must be mined (e.g. bituminous sands).

Bitumen pit: A large area of natural asphalt resulting from petroleum seep where subterranean bitumen leaks to the surface.

Gas: A general term for natural gas methane, often found in association with crude oil.

Gum beds (Canada): Asphalt ponds created by oil seeping to the surface of the ground.

Hydrocarbon: An organic compound composed only of hydrogen and carbon. Hydrocarbons can be gases, liquids, waxes or low melting solids, or polymers. Extracted hydrocarbons in a liquid form are referred to as petroleum.

Natural Gas Liquids: Hydrocarbons found in natural gas which may be extracted or isolated as liquefied petroleum gas and natural gasoline.

Oil: A general term for crude oil, or liquid unrefined petroleum.

Oil shale: A sedimentary rock that contains kerogen, which releases a petroleum-like liquid when the rock is heated.

Oil sands: Loose sands or partially consolidated sandstone containing a naturally occurring mixture of sand, clay, and water, saturated with bitumen. Also known as tar sands or bituminous sands.

Petroleum: The term 'petroleum' refers to all the liquid raw hydrocarbons (crude oils). There are several qualities of petroleum that may differ for density (specific gravity conventionally measured in API gravity) and composition. The petroleum industry acknowledges four types of petroleum: light crude oil has an API gravity higher than 31.1°; medium oil has an API gravity between 22.3 and 31.1°; heavy crude oil has an API gravity below 22.3°; Extra heavy oil has an API gravity below 10.0°. The latter is better known as bitumen and cannot be pumped from the subsoil, but rather is mined.

American Heritage Dictionary: *Petroleum is a thick, flammable, yellow-to-black mixture of gaseous, liquid, and solid hydrocarbons that occurs naturally beneath the earth's surface, can* *be separated into fractions including natural gas, gasoline, naphtha, kerosene, fuel and lubricating oils, paraffin wax, and asphalt and is used as raw material for a wide variety of derivative products*.

Pool (Oil): A subsurface oil accumulation. An oil field can consist of one or more oil pools or distinct reservoirs within a single large trap.

Shale oil (or tight oil): refers to hydrocarbons trapped in formations that are not very porous. The oil is accessed by drilling horizontally across the deposit, and then hydraulic fracking to open up the rock and allow the oil to flow.

Industry sectors: **Upstream**

One of the three commonly used divisions, it includes searching for potential underground or underwater oil and gas fields, drilling of exploratory wells, and subsequently operating the wells that recover and bring the hydrocarbons to the surface. Also known as the exploration and production (E and P) sector.

Barrel: A non-SI Metric Unit System typically used to measure the volume of liquid hydrocarbons. One barrel equals 0.159 m^3. Standard Oil introduced a steel version of the wooden 42-gallon oil barrel in 1902, with the same traditional bilged, cask-like appearance.

Bit: The drilling tool used to cut the rock. The bit is screwed on the bottom of the drillstring and is rotated so that it scrapes or crushes the rock at the bottom hole.

Borehole: The wellbore itself, including the open hole or uncased portion of the well. Borehole may refer to the inside diameter of the wellbore wall, the rock face that bounds the drilled hole.

Casing: Steel pipe lowered into an open hole and cemented in place during the well construction to stabilize the wellbore and to insulate it from surface water. The practice of cased wells completed with production tubing became standard by 1870, and wells were completed with open-hole or cased-hole techniques in the early 20th century.

Central power systems: Consisted of a steam or later oil or gas engine linked to the pump jacks by means of lines of wires, jerker or rod lines which transmitted the motion of the power. The word 'power' can refer just to the heavy iron contraption in the centre of the system, but it includes also the engine, engine house, the belt, the tripods, the rod lines, the jacks and the wells.

The traditional compound (mechanical transmission of power with gears and chains) was replaced by independent electric motors in the 1920s, up to the application of frequency converters and of modern regulation systems.

Condeep: Concrete deepwater drilling structure, gravity-based oil production platforms.

Derrick: The usually pyramidal structure used in the drilling of oil and gas wells as support for the drillstring of a drilling rig lowered into the well. Ephemeral, often removed or burnt, and made of wood until replaced by steel from the 1920s. Traditional derricks were gradually replaced from the 1950s with more easily moved modular masts.

Jackknife derricks are hinged on one side where they join the drilling platform and through winching systems may be raised or lowered in a single piece for transport.

Disposal well: Often a depleted oil or gas well into which waste fluids can be injected for safe disposal.

Drilling: Two general methods of drilling are generally employed: cable or percussion system, and rotary system or boring.

Percussion drilling: A discontinuous method of drilling whereby an impact tool or bit, suspended in the well and dropped repeatedly on the bottom of the hole to crush the rock. The tool was usually fitted with some sort of cuttings basket to trap the cuttings along the side of the tool. After a few impacts on the bottom of the hole, the cable was reeled in and the cuttings basket emptied, the tool reeled back to the bottom of the hole and the process repeated.

In Pennsylvania in the earliest operations a cable of manila hemp or later steel ropes were used to suspend the wooden rods and the drilling tools. This became the commonest drilling method all over the United States. In Canada, and from there Galicia in Poland, rigs evolved into a rigid walking beam with a string of drill rods connected together.

Percussion rigs rapidly lost ground in the 1930s, and by the early 1950s they had practically disappeared from the oilfields.

Wooden cable tool: Due to the low operating cost and greater penetrating depth, these rigs were preferred for speculative work. In many cases once a well was completed or abandoned the derrick would be left standing and stripped of unnecessary or salvageable materials or left to rot away.

Steel cable tool: Cable tool derricks built of steel appear to have become common by the 1930s.

Rotary drilling: An alternative method to percussion of making a hole that relies on continuous circular motion of the entire drill string from the surface to turn the drill bit to break rock at the bottom of the hole. Rotary drilling is a nearly continuous process and so more efficient than cable tool drilling because cuttings are removed as drilling fluids circulate through the bit and up the wellbore to the surface. The first rotary rig for oil exploration was installed in 1894, the Spindletop well was drilled with a rotary rig, and they quickly expanded relative to percussion rigs in the ensuing decades.

Drilling rig: The machine used to drill a wellbore. In onshore operations, the rig includes virtually everything except living quarters. Offshore, the rig includes the same components as onshore, but not those of the vessel or drilling platform itself. The rig is sometimes referred to as the drilling package, particularly offshore. A standardized steam-operated full-size percussion rig was used from the end of the 19th until the middle of the 20th century.

Drill ship: A vessel designed for drilling in deep water without legs or anchors holding it to the sea floor and using dynamic positioning to hold it over the subsea wellhead.

Drillstring: The total string of drill pipe with attached tools and bit.

Exploration: The initial phase in petroleum operations that includes geologic and geophysical prospecting aimed to investigate the subsurface structures for the location of potential hydrocarbon traps and the drilling of an exploration well.

Gathering lines: The pipes used to transport oil and gas from a field to the main pipeline in the area.

Hydraulic fracturing (fracking): The method used to make hard shale rock more porous, thus allowing natural gas to flow through the shale to the wellbore.

Mud: A synonym for drilling fluids used in drilling operations, especially containing significant amounts of suspended solids, emulsified water or oil.

Platform: Structure used in offshore drilling on which the drilling rig, crew quarters and other related items are located.

Offshore drilling: the wellbore is drilled below the seabed.

Pump jacks / Lifting Systems: Structure which stands above an oil well and converts the horizontal reciprocating motion of the power into vertical pumping motion. Metal pump jacks replaced walking-beam pumps. Made of combinations of wood and metal, these have seen little change and development since the late 1920s. The most typical arrangement with counterweights and a walking beam have grown larger as wells have been drilled deeper and bores enlarged to compensate for diminished production.

Rig: The complex of machinery used to drill an oil and gas well (a wellbore or borehole) including the derrick, engine, engine house and other equipment.

Spring pole: Drilling system using wooden pole to bounce the drill head up and down.

Spud (To): To start the well drilling process by removing rock, dirt and other sedimentary material with the drill bit.

Wellhead: The surface structure of a well that incorporates facilities for installing casing during the well construction phase.

Industry sectors: **Midstream**

The sector that processes, stores, markets and transports commodities such as crude oil, natural gas and natural gas liquids such as ethane, propane and butane.

Oil depot (tank farm): An industrial facility for storing oil and/or petrochemical products and from which these products are usually transported to end users or further storage facilities.

Pipeline: A tube or system of tubes used for transporting crude oil and natural gas from the field or gathering system to the refinery, to petrochemical plants or to the end-users. Regularly-spaced pumping stations often followed the line of the pipe, using steam engines in the 19th century.

Separator: A cylindrical or spherical vessel, either horizontal or vertical, used to separate oil, gas and water from the total fluid stream produced at the well head. Two-phase separators deal only with oil and gas, while the three-phase type handles oil, water and gas. Rudimentary separators to recover the gas associated with the oil were introduced in 1863, the first pressurized separator in 1904.

Tank: Container for storing petroleum products. Low-pressure storage tanks widely used from the production fields to the refinery are usually vertical, cylindrical tanks. Pressure storage tanks designed for storing volatile liquids such as gasoline and liquefied petroleum gases, which generate high internal pressures, and are commonly spherical. The earliest petroleum storage tanks were constructed from various types of wood, first above and then below ground, but riveted tanks date back to the early 1900s. Bolted tanks are still used, and non-metallic non-corroding, lightweight tanks are constructed from plastic materials.

Tank farm: A term applied to a battery of storage tanks.

Industry sectors: **Downstream**

This sector includes oil refineries, petrochemical plants, petroleum product distribution, natural gas and retail outlets which connect with consumers.

Catalytic cracking: The process of splitting a large heavy hydrocarbon molecule into smaller, lighter components. The first thermal cracking plants were built in Russia in 1891 and a similar process was patented by Standard Oil in 1913.

Oil refinery: The facility where the characteristics of petroleum or petroleum products are changed. Plants are typically sprawling complexes with extensive piping running throughout, carrying streams of fluids between large chemical processing units, such as distillation columns, with large storage areas of tanks. Oil refineries use much the same technology as chemical plants.

4. Historical development

The following account of the history of the petroleum industry concentrates on key periods of change and on developments for which there is physical evidence in the landscape and the built environment, since this is what may be of value as cultural heritage.

As outlined in section 2.1, the main interest is places and structures which are potentially of historical value and on technologies that are now obsolete. This means concentrating on the period before the 1970s. The Discovery Timeline in the Appendix provides a more complete historical outline.

4.1 Antiquity - 1840s: petroleum harvesting

The earliest knowledge for the use of petroleum gathered from the surface or shallow wells is from archaeological investigation and ancient documentary sources. Naturally occurring oil seepages and outcrops of oil-bearing shale have been put to different uses for many thousands of years, according to the needs and ingenuity of the people who had them to hand. Excavations yield evidence that bitumen was used as an adhesive on weapons and tools by Neanderthals as early as 70,000 years ago. Possibly only in Mesopotamia was there a significant influence on human culture, where by 3,000 BCE it included the use of asphaltic mastic, made by mixing bitumen with chopped straw, clay and sand, for constructing palaces, temples and ziggurats (Kemp 2007). It was applied for roadway coating, served to waterproof containers, to caulk reed and wooden boats, and as a widespread adhesive. Finally, it was considered as a powerful remedy in medical practice, especially as a disinfectant and insecticide, and was used by the ancient Egyptians to prepare mixtures to embalm the corpses of their dead (Connan 1999).

Petroleum is mentioned by Herodotus as a cement used in buildings in the city of Babylon, for medicinal uses and distilled for lighting, as well as by other ancient authors including Diodorus, Josephus Flavius, Vitruvius, Strabo and Pliny the Elder (Macini and Misini 2018). In 600 BCE Confucius refers to brine drilling in China and oil wells were drilled there in 347 CE or earlier using bits attached to bamboo poles down to about 240 m (Kambara 1974). Extensive bamboo pipelines connected oil wells with salt springs in the 10th century. Collecting natural oil is documented in Japan in 720 CE, where toponyms such as 'kusozu' (smelly water) or 'kusodo' (smelly ground) indicate places with petroleum and natural bitumens in the 12th to 15th centuries (Deryugin 2018).

Oil seepages were being exploited on the Absheron Peninsula near Baku, Azerbaijan, in the 9th century, and they became the basis for a major economic activity in Czarist Russia (Mir-Babayev 2017). Oil was distilled in Arab counties in the 9th century using alembics to separate an illuminating oil, a process described in the Kitab al-Asrar (Book of Secrets) by the Persian scholar Rāzi (or Rhazes). The earliest documentation of petroleum in the Americas occurs in Sir Walter Raleigh's 1595 account of the Trinidad Pitch Lake.

'Many other contemporary scholars in [early modern] Europe documented methods of refining petroleum, but these scientific advances had little impact on the socio-economic development of Europe at the time' (Craig et al 2018).

'Petroleum' is a late-Medieval Latin term (*petroleum*, or *oleum petrae*, i.e., rock oil) and was not in use until the 15th century. Different varieties of petroleum were collected in Europe from the early Middle Ages, subject to the vagaries of natural availability, and using methods which barely changed for hundreds of years (Forbes 1959). In France, naphtha was extracted in Pechelbronn in Alsace and asphalt was mined near Clermont-Ferrand. Petroleum was refined in the Northern Apennines in Italy, in Germany at Tegernsee, Bavaria, and in the vicinity of Brunswick and Wietze near Hanover, and in Galicia, spanning modern Poland and Ukraine. Natural paraffin was mined in Romania, the material refined to produce an expensive alternative to animal and vegetable oils. It was used for lubricants, grease, solvents, as a base for pigments, for tonics and ointments, illuminating, and as a waterproofing resin for ships. Asphalt from natural sources was being used in the 1830s in France and Switzerland for making road surfaces and roofs impermeable. Asphalt was spread over the Place de la Concorde in Paris in 1835 and in both Hamburg and Hanover in 1838.

'Petroleum poured from the crevices of mountains, lay in the bottom of caves, oozed onto the surface and accumulated in ponds' (Gerali 2017, 42-45). 18th century settlers moving into Pennsylvania found existing timber-walled pits along the Allegheny used by the indigenous inhabitants for collecting seepages. Ponds and shafts were excavated, the latter sometimes lined with masonry or timber to a depth of 60 or 90 m. (Wells continued to be dug by hand in Romania into the 1920s, with air piped down to the excavators). There are frequent accounts of the use of oil by indigenous people in North America for war paint, for religious purposes as well as for sprains, rheumatism and sores on their horses. All of these early sources were sites of natural seepages rather than places located through exploration; although many of them, including those in Canada, United States, France, Italy, Poland, Ukraine, Romania and especially at Baku, went on to develop into important centres for industrial production.

4.2 1840s - 1860: pre-industrial production

Until the 1860s petroleum was sought in much the same way as water. Different mechanisms for percussion drilling were developed in many parts of the world for water and brine wells, and these would be adapted to access petroleum (Brantly 1971). Extracting oil continued to be a rudimentary activity compared with mining for metal ores or for coal, which were much more highly capitalized with water-powered drainage pumps and a large, skilled labour force. The need for a practical, uncomplicated system for exploiting petroleum resources under relatively primitive conditions or in the early stages of production favoured employing local construction materials, borrowed or recycled equipment, and calling for low fuel requirements.

The conditions began to change as new uses for oil products were developed, critically for lighting. In 1846 the Canadian Abraham Gesner distilled fuel oil and gas for lighting using thick bitumen shipped from the Pitch Lake in Trinidad. Later he distilled it experimentally from bituminous coal and oil shale (Gray, 2008). Commercial production under the patented trademark 'kerosene' followed in 1854, the name soon being extended to all illuminating oils made from minerals. Distilleries or refineries used horizontal cylindrical stills that held 5 to 6 barrels of oil[3]. Refiners raised the temperature of the oil very slowly, removing the unwanted distillates like gasoline to obtain only the lamp oil or kerosene.

Oil historians generally agree that the first oil well mechanically drilled in the world was completed using a percussion rig in 1846 at Bibi-Heybat (Bibi-Eibat) near Baku in the Absheron

[3] One barrel equals approximately 159 litres, 42 US gallons or 35 UK (imperial) gallons.

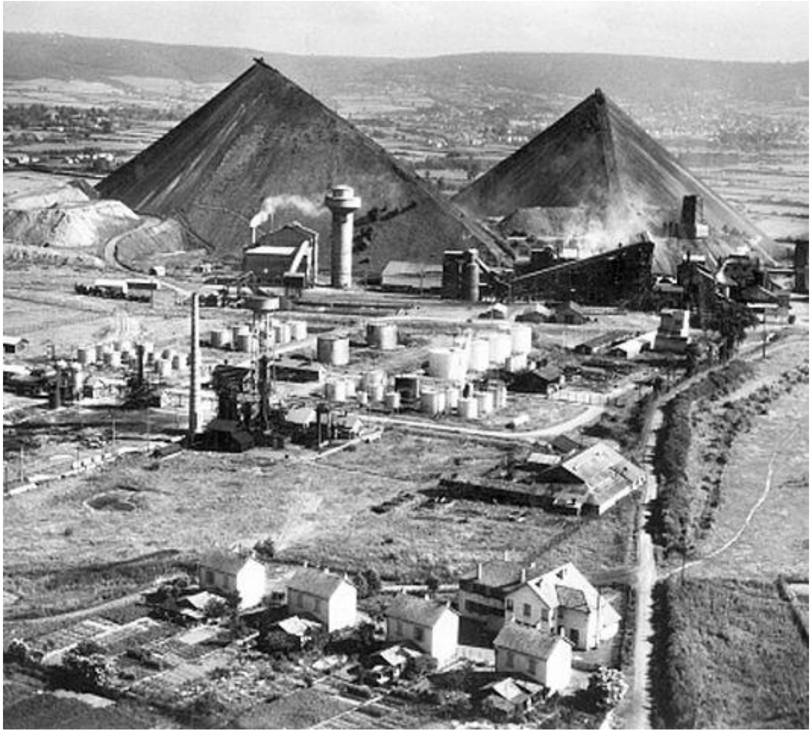
Peninsula close to the Caspian Sea in Azerbaijan. An abundance of oil and gas was found at shallow depths. Samples of Baku oil were displayed by the Russian delegate to the Great Exhibition in London in 1851 and the first refinery of the Caspian area was built in 1859. But the Russian government officially forbade exploration, until the success of the American oil business changed official attitudes (Mir-Babayev 2017).

A patent for distillation of petroleum was granted in 1853 to Ignacy Łukasiewicz and Jan Zehin in Poland. Łukasiewicz was the inventor of an oil lamp fuelled by kerosene which generated bright light with fewer fumes, encouraging further research into the use of oil. One of the earliest rock-oil mines (tunnels used to harvest oil from bituminous rocks) was cut in 1854 in the village of Bóbrka in the Carpathian mountains (then Austro-Hungarian Galicia, today Poland), to supply the local lamp fuel industry. Łukasiewicz is credited with setting up the world's first crude oil refinery in 1856 at Ulaszowice. Oil is still being produced in the Bóbrka Field discovered in 1853 which is considered among the oldest industrial oil fields in the world (Craig et al 2018).

Bucharest became the first city in the world to use refined oil for street lighting in 1857, with 1,000 oil lamps placed along the main streets, supplied from an oil refinery in Ploieşti which was already in operation in 1856.

Oil shale was distilled on a commercial scale in various parts of Europe in the late-18th century and throughout the 19th century. In 1850 Scottish chemist James Young patented a process to obtain naphtha and paraffin from coal, and later from oil shale, establishing 'the first truly commercial oil-works and oil refinery in the world' in West Lothian in Scotland the following year (Dean 2018). It was not the first place to produce oil from shale, but it became one of the largest and most successful and led to major developments in oil refining. Some of the earliest company housing in the petroleum industry had to be built for the workforce that was needed at remote production sites, and villages developed as close communities with their own character. Surface and underground workings, a landscape of waste rock heaps, and the company housing are testament to the local industry.

Oil shale has been worked in many countries, but after 1861 the lower price of petroleum frequently made it uneconomic unless other factors, such as national strategic needs, were in play. As well as Scotland there are historic oil shale production sites in France, Estonia and Germany (see case study 5).



Oil shale was mined in Télots near Autun, France, from 1881, and production continued into the 1950s. Company housing is in the foreground with the refinery and retorts behind. (© Wikipedia Commons).

Up to this time, most oil for lighting was obtained from whaling and refined from the blubber of the sperm whale. Sprawling whale oil refineries were found in coastal cities around Europe and in North America, where the capital of the refining industry was the whaling port of New Bedford, Connecticut (Foster 2014). Another fuel for illumination was gas manufactured from coal (also known as town or coal gas), and the number and later the size of gas works manufacturing gas from coal was expanding from the 1850s. Gasworks with their retort houses and cylindrical gas storage tanks were familiar installations in cities around the world until natural gas replaced them from the 1960s, and many examples in Europe are preserved as museums.

In 1855 James Miller Williams took over an oil company in Ontario producing asphalt and started refining bitumen to create illuminating oil. He dug a well by hand, refined the oil and marketed it as ‘illuminating oil’ or kerosene lamp oil. The site was renamed Oil Springs in 1858. The discovery created North America’s first oil rush which became even more frenzied in 1862 when 32 flowing wells produced prolific amounts of oil. The field has claims to be the first in the world to be exploited on a commercial scale, although contested by historians who assert the primacy of Titusville in the conterminous territory of Pennsylvania as the continent’s first commercial well.

The Oil Springs field petered out by 1866 when salt water invaded the wells. By then, another field had been found nearby at Petrolia where the oil industry established itself as the oil capital of Canada, providing 90% of the country’s oil needs in 1900. It had thousands of wells. In 1879, the Silver Star refinery was the world’s largest and most sophisticated, processing 75,000 gallons of crude at a time, sprawling over 20 hectares.

4.3 1860 – 1910: the Pennsylvania model

Historians of industry agree that the north-western region of Pennsylvania is the starting point of the modern oil industry similar to Derbyshire in England as the locus of the industrial revolution in the eighteenth century. The roots of the almost 160-year oil society were laid in Venago County (Gerali 2019).

The global petroleum industry originated during the 1850s-1860s in several regions. The two oldest were the Carpathian Mountains of Galicia and Romanian within the Austro-Hungarian Empire, and the Absheron peninsular of Azerbaijan, then part of Czarist Russia.

But it was in Pennsylvania, USA, that a definitive modern technological and organisational form was established: 'in a short period of time the most dynamic, innovative and world market-oriented oil industry was developed, which maintained those trends throughout the 20th century'*(*Gennadiy 2018, 37).

The 'Pennsylvania model' consisted of 'the systematic search for oil in the oil region, the process of boring into soil by means of mechanical drilling using a cable tool system, specifically adapted/produced for the task and powered by steam power energy, and the necessity to guarantee a constant supply of petroleum to be used as feedstock for the new and more demanding refining industry' (Gerali 2017, 46).

The search for oil in north-western Pennsylvania was encouraged by the 1854 report from Benjamin Sillman, professor of chemistry, into the practical uses for products distilled from oil. Encouraged by his opinion, a group of entrepreneurs contracted Edwin Drake to drill a well near an oil seep at Titusville. Drake employed salt drillers and their boring technology, powered by a steam engine. They drilled down through rock until at 21 m they struck oil on 27 August 1859, inaugurating the mass-production of petroleum and the modern petroleum industry (Brice 2009).

The consequences of the Drake discovery were immediate and dramatic. A compact urban system was created in a few years along the spine of the Allegheny River to produce oil (Titusville), exchange and manufacture (Oil City), regulate (Franklin) and refine it (Emlenton). Oil boomtowns such as Pithole City appeared, flourished and then faded back into woodland, sometimes within the space of a few months (Black 2000).

Percussive spring-pole drilling, a technique adapted from water wells, gave way to moveable drilling rigs and three-pole derricks using either cables or rods. (A more powerful and better engineered drilling rig became standardised by 1925 and continued up to the 1950s in the USA until made obsolete by advances in engineering and the replacement of steam engines by internal combustion power and electric drilling). Central power sources (steam and later gas engines) were connected to the pump jacks at multiple boreholes using cables and steel rods, or the rigid jerker rods such as those preserved at Oil Springs, Ontario (Kemp 2000). The key piece of equipment was the 'power' unit, which converted the engine's rotary motion into a reciprocating motion suitable for pumping.

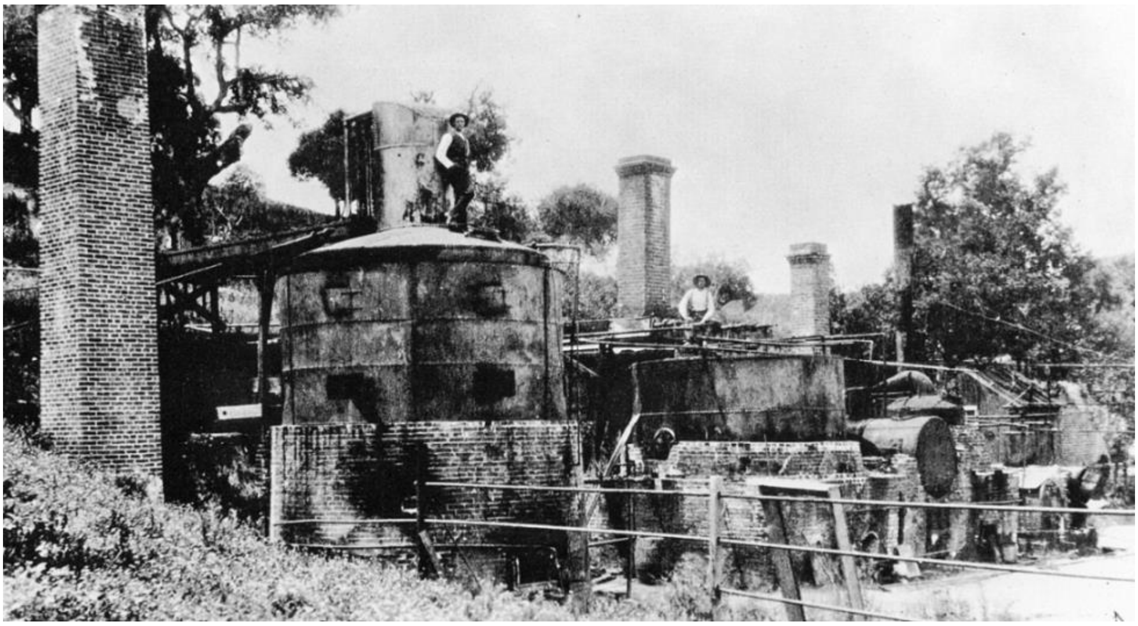
The ingenious mechanical jerker system developed in 1863 in the Ontario oil fields connected dozens of pumps in petroleum wells to a single small steam engine (see case study 8.2).The jerker line system made it economic to produce oil without the costly expense of having a steam engine at each well. Steam engines were also awkward to haul to the well sites which were sometimes in the woods or on soft ground. Although 'of only marginal significance in terms of production, especially as they soon faced unbeatable competition from increasing numbers of newly-opening oilfields elsewhere in the world, [it was] of considerable importance in terms of the particular technological solutions developed there' (Newell 1983).

The unique system of jerker lines connecting the power to the pumps at Oil Springs, Canada (©Al Hayward).

Many of the wells in both Pennsylvania and Ontario were flowing wells and did not require pumping, sometimes gushing from the wellhead under below-ground pressure. Some produced prodigious quantities, 7,500 barrels per day flowing from the Black and Matheson Well in Oil Springs: 'By the end of 1862, there were 1,000 wells producing 12,000 barrels of oil per day' (Kemp and Caplinger 2007, 79-80). The crude oil was initially stored in wooden barrels, tanks or sunken timber-lined pits, and transported in wooden barrels on wagons or barges. These were replaced by metal tanks by 1868, also mounted on rail cars for shipment. Underground storage tanks are still in operation at Oil Springs (Kemp and Caplinger 2007).

Oil exported from the United States was at that time carried in 42-gallon [159 l] barrels, (the size established in 1482 by English king Edward IV as the standard for packing fish). The barrel had, however, had its day as a means of transporting oil, and by 1906 virtually all was being transported by pipelines or in bulk carriers. A short, pioneering gravity pipeline was constructed in 1866 to move 7,000 barrels of oil per day to a terminus at the mouth of the Pithole Creek where a 15,000-barrel iron petroleum storage tank was built in the town of Oleopolis.

Early oil refineries were simple and inexpensive to set up, employing a heater, retort and worm to cool the distillate. First naphtha, then illuminating oil (70-80% of the total) and lastly heavy oil were produced. Oil distilleries opened in Pittsburgh in 1853, but the main centre of industrial oil refining became established in Cleveland, Ohio, on the Great Lakes, where in 1865 John D. Rockefeller's company built the largest oil refinery in the world.



The Pioneer oil refinery in California had four distilleries and mostly produced kerosene. Refineries were soon much bigger operations, and production ended in 1888. (© American Petroleum Institute Photograph and Film Collection)

The Pioneer refinery in Newhall, California, was in production by 1880, and is thought to be one of the oldest surviving examples. Here, heavy residual oil from earlier refining runs fuelled the brick ovens, with their tall brick chimneys, underneath the stills. The petroleum gasses passed into a condenser consisting of a box with layered iron pipes submerged in water. The condensed oils flowed into a lead-lined agitator where they were treated with chemicals and blended with air to improve their burning quality. At the small Oljeön refinery in Sweden the stills were enclosed within a building. Much larger refineries soon made these small, local retorts redundant.

An eightfold production growth from Pennsylvania within two years drove the price of petroleum sharply downwards and put kerosene beyond competition from other illuminating oils. The market for mechanical lubrication was also quickly taken over and the industries refining whale oil and coal-sourced kerosene went into rapid decline, although coal gas production continued for another century. Soon lubricants became the main product, mainly to supply the engineering needs of the railway companies.

The next phase in the development of the petroleum industry was determined less by technological developments than by managerial and financial ones through the operations of the Standard Oil company established by John D. Rockefeller. Rockefeller's strategy, to concentrate American oil production through the control of refining and transportation, provoked the Pennsylvania oil producers to build the first long-distance pipeline. The 110-mile Coastal Pipeline became an outstanding technological achievement, and in May 1879 the first oil ran from the Oil Regions to the railway at Redding. In reply, Standard Oil shortly built four oil pipelines from the Oil Region to Cleveland, New York, Philadelphia and Buffalo, thereby creating the first pipeline system of the US. Standard Oil began building a multiple 506 km pipeline from upstate New York to New Jersey in 1881, with eleven steam pumping stations along its route. Philadelphia emerged as a major refining town thanks to national and overseas rail and maritime transport networks (Hein 2018b).

The Standard Oil Trust was by then the largest corporation in the world, and its monopolistic behaviour and enormous wealth made Rockefeller the archetypal robber baron. Encouraged by the campaigns of Ida Tarbell, the United States government broke up the Standard Oil Trust in 1911. The move was seen as important in reasserting political control over the concentrated form of industrial capitalism which had developed in the Unites States in the second half of the century, and which Standard Oil epitomised. The trust was divided into 34 new companies although these, in different forms and under various names, dominated the petroleum industry for much of the 20th century, until the emergence of national oil companies from the 1970s.

Within two decades, Pennsylvania oilfields were supplying more than 80% of the world's petroleum consumption, and European countries hurried to refine their own oil to compete with the American product. The North American approach to production spread through the transfer of new technology and expertise, stimulating renewed activity in the small European oil fields in the Italian Apennines, Pechelbronn in French Alsace, and Wietze in Germany, while new fields were found in Austria and Croatia.

Oil was already being drilled using a percussion rig in 1847 at Bibi-Eybat in Baku, where a refinery was producing kerosene in 1860. From 1875 the Nobel brothers began to refine lubricating oils in Baku, and oil shipment installations were built with the launch of the first sea-going oil tankers to export Russian oil in 1886 (Schindler 1984). The Nobels encouraged the construction of the Trans-Caucasian railway from Baku to Tbilisi in 1883, and laid a pipeline from Baku to Batum on the Black Sea between 1897 and 1907, then the longest in the world: 833 km of 20-inch diameter pipe, with 16 intermediate pumping stations (Macini and Mesini 2018). The Nobels' shipping business developed into the Shell Transport and Trading company, formed in 1897. Ten years later it merged with the Royal Dutch Petroleum Company, a business founded in 1890 to develop an oilfield in Pangkalan Brandan in Sumatra, now part of Indonesia, creating the Royal Dutch Shell Group in 1907.

Pennsylvanian oil started to be shipped across the Atlantic in the early 1860s, and new oil storage areas were prepared in European ports to handle it. The first oil storage sheds designed specifically for storing barrels of petroleum were erected in Rotterdam in 1865. Tank storage was replacing such buildings from the 1900s, and the dock activity grew with the Royal Dutch Shell Group merger. New strategic storage facilities were started around the world with the changeover from coal-fuelled shipping to oil, such as one built by Shell in Sydney Harbour to supply its outlets in 1901.

Derricks encased in wooden shuttering of the Nobel Brothers Petroleum Company, Branobel, in Balakhani, Baku c. 1890 (© Wikipedia Commons).

Ziemia Gorlicka in Galicia, now part of Poland, was the centre of a petroleum industry which in 1881 was the third in the world behind the USA and Russia with twelve oil distilleries (Frank 2005). Ploiesti in Romania had three refineries in 1856, and Salzbergen in Germany was also a refining centre by 1860. Canadian oilmen transferred their cable drilling technology, the Canadian Rig, to the established oilfields in Galicia, where W H McGarvey 'was able to drill much faster and to greater depths. Whereas 150 m had been the limit in the past, the men could now drill easily to depths over 1,000 m' (Schatzker 2015, 77).

Expert Canadian drillers from Petrolia and Oil Springs were in demand around the world. Starting in 1873, more than 500 drillers worked in 86 countries around the globe. 'The worldwide oil industry has the stamp of Canadian oil men from Petrolia and Oil Springs...Those overseas activities by Canadians provide a well-documented example of the transfer of technology.' (Kemp and Caplinger 2007, 171).

Despite the lack of strong development traditions, and well-known fields with artisanal well extraction in the older petroleum industry of the Carpathians, American oil prospectors and especially the oil refining industry (which controlled the kerosene market) outpaced industrial development in the semi-feudal Austro-Hungarian Empire. Geological conditions in the USA were also advantageous (the great majority of American wells were gusher holes) and the introduction of drilling technology with steam engines, pumps and casing pipes, rail transport and pipelines proceeded rapidly. Social conditions, too, were more favourable in a new, fast-changing business. The founders of the first US oil companies were different to their colleagues from Central and Eastern Europe, notably in their scale of thinking and business organization. These advantages proved to be particularly convincing in the 20th century when a small group of very large, vertically integrated oil companies came to control the global extension of oil production (Gennadiy 2018).

Companies in the United States continued to drive change in the industry in terms of opening new fields, advancing technology, profitable business organisation and, most importantly, the creation of new consumption through growing demand for automotive gasoline and later aircraft fuel (Gennadiy 2019).

Speculative or 'wild-cat' drilling rigs helped move the centre of gravity of oil production away from Pennsylvania. California began producing oil in the 1890s, the first offshore oil well was drilled at the Summerland Oil Field in 1897, and refined products were soon being exported from the West Coast. Texas became an oil state in 1901 when the Spindletop well was drilled, and within a year the nearby town of Beaumont grew from 8,000 to 60,000 people. It was joined by Glenn Pool in Oklahoma, with Tulsa the capital of refining, in 1906 (Gennadiy2019). As in Pennsylvania, these discoveries all resulted in 'oil rushes' of prospectors, creating boom and later ghost towns once production had become formalised or abandoned.

Spindletop […] confirmed, beyond any possible doubt, that oil could be produced in volumes of several orders of magnitude larger than that of wells drilled so far. In the following years, oil was discovered in numerous other places [...], and the industry realized that oil was available in huge quantities and in a wide range of geological areas[...] Hence, crude oil could rightly be regarded no longer as just raw material for lighting, but also as the main form of energy for the new century, marking a drastic change in the field of sea and land transportation. Undoubtedly, the abundance of oil favoured the development of the growing automobile industry, then expanding thanks to the ever-increasing availability of gasoline (Macini and Mesini 2018, 297).

4.4 1910 – 1970: global petroleum production

Starting from the first decade of the 20th century, the importance of petroleum products, a strategic energy source, became paramount issues in world geopolitical, economic and diplomatic history. Oil had become so essential for the economy of the nations that its value, apart from economic, was of a political nature, not purely tied to the mechanisms of demand and supply, but also to those of the various strategies of national foreign policies, intermingled between wars, interests in colonial countries, affairs of the state and large-scale conflicts between financial and industrial groups. (Macini and Mesini 2018, 294).

As demand for gasoline threatened to outstrip supply, geologists, oil prospectors and numerous wildcat entrepreneurs extended their prospecting effort to regions beyond North America (see the discovery and production timeline in the Appendix). Oil discoveries were made and production projects initiated in India (1890), Australia (1892), Mexico (1901), China (1907), Argentina (1907), Venezuela (1913), Columbia (1916), Sarawak (Borneo, 1910). In 1908, British geologists discovered an oil field at Masjid-i-Suleiman in Mohammerah, today part of Iran, the first commercially significant find of oil in the Middle East.

New petroleum infrastructure began to be constructed on an increasingly large scale, with oil fields, refineries and their industrial and commercial hinterlands connected by roads, rails and pipelines to their markets. Companies wishing to exploit oil fields at remote locations had to build work camps and later permanent company towns to attract, house and retain their workforce, sometimes introducing novel contemporary planning ideas and building designs. Corporate architecture became a tangible expression of the 20th century petroleum industry, in the office buildings for senior managers, while vehicle filling stations evolved into the most visible interface between the industry and its global public.

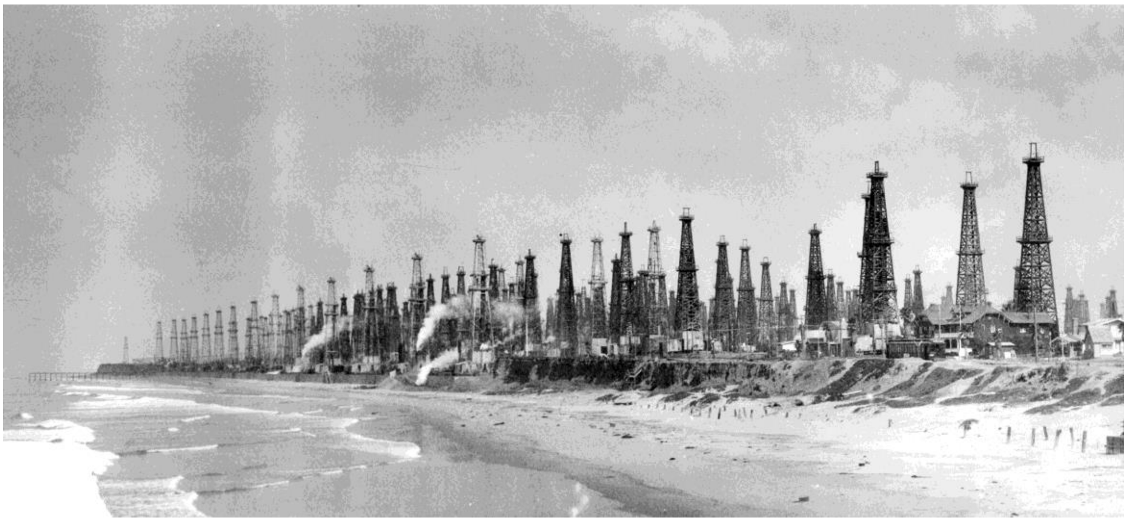
Oil well drilling

From 1880 to 1930, mobile or semi-mobile percussion rigs evolved into very specialized and sophisticated equipment, and from early 1900 rotary drilling became the most effective and reliable technique. Percussion rigs had practically disappeared from the oilfields by the early 1950s. In the United States competition to drill faster and deeper led to the design of easily movable rigs. Traditional steam-driven rig power units were replaced by lighter and more powerful diesel or gas internal combustion engines; the first diesel engine was applied to a rotary rig in 1925. Drilling rigs became modularized and drilling tools standardised, the rig structures constructed from high quality steel.

Modularity, automation, standardization and easy moving were the guidelines for the development of rigs from the 1950s onwards. Traditional derricks were gradually replaced with modular masts, easier to transport, and soon the traditional compound rig (mechanical transmission of power with gears and chains) was replaced by independent electric motors (Macini and Mesini 307).

Off-shore production

Drilling for petroleum moved off the shore and into the water by the end of the 19th century, with rigs reached by trestles or piers driven out into shallow waters in Baku, California and Lake Maracaibo, Venezuela.



Steel derricks at Huntington Beach on the California coast in 1926 (© Orange County Archives).

By 1938 a mile-long wooden trestle with railway tracks ending with a derrick had been built out into the Gulf of Mexico. In the same year, seismic testing showed how to locate salt domes, and in the late 1940s fixed steel platforms and tethered floating platforms were drilling out of sight of land. Self-elevating platforms called jack-ups were able to stand with their legs on the sea bottom and to operate over several tens of meters of water depth. Semi-submersible drilling rigs were devised in the mid-1950s, consisting of a triangular, rectangular or pentagonal shaped platform connected with submerged hulls by means of large columns.

The first transportable, submersible drilling rig, 'Mr. Charlie', which started prospecting in 1954 for Shell OIl in the Gulf of Mexico near the mouth of the Mississippi is exhibited by the

International Petroleum Museum and Exposition, Louisiana. An adapted Ocean Star 1969 offshore drilling rig moored in the harbour in Galveston, Texas, is now the Offshore Drilling Rig Museum and Education Center.

In the early 1970s, the reservoirs discovered in the North Sea and in the Gulf of Mexico gave boost to the development of more and more specialized technologies for offshore hydrocarbon production (Macini and Mesini 2018). Exploration in the North Sea, extrapolating from on-shore fields in England and Holland, led to the discovery of huge oil and gas resources, first in the Norwegian sector in 1969 in the Ekofisk Field, followed by the Forties Field in the UK sector the year after. From the 1970s, enormous steel platforms were built, transported, and installed on the seabed in water depths ranging from 60 to 1,000 m. Concrete deepwater structures called condeeps were developed in Norway with a base of concrete oil storage tanks from which one, three or four concrete shafts rose up to above the surface. The largest condeep platform, Troll, was almost 500 m tall and weighed over 1m metric tons. Britain, Norway, Denmark and the Netherlands were largely self-sufficient in oil and gas by the late 1970s. The economy and national identity of Norway, in particular, was radically changed by the way in which it managed its oil revenues.

It was not considered feasible to conserve any of these platforms when production began rapidly to decline in the early 2000s. Characteristically, little direct physical evidence relative to the technical and economic importance of North Sea oil and gas has been conserved, although the Norwegian national museum of the petroleum industry Norsk Oljemuseum has a comprehensive programme of collecting documentary material about the history of North Sea oil extraction (Sandberg and Gjerde 2017). 3D digital recording of petroleum infrastructure is also an importance technique which has been developed in the North Sea industry.

Natural gas

As early as 1821, a limited local provision of natural gas for urban lighting had been established in cities close to the gas source, such as in Fredonia, New York, and in Chicago. But the technical problems of storing and transporting natural gas restricted its development, which was taken up by manufactured or coal gas.

At the end of the 19th century improved pipelines with leak-proof couplings allowed longer distribution networks to be built, with compressors to move the gas. The Turner Valley gas plant (see case study 8.6), western Canada's first natural gas processing and refining facility and now a National Historic Site of Canada, was built from 1914. Millions of cubic feet of gas were flared every day until a pipeline was built to Calgary, and by 1921 gas was flowing to a secure market. The cold conditions meant the 'open' style of processing plants which were built in warmer regions were not possible, for the plant needed to scrub hydrogen sulphide from the natural gas and to compress the gas for movement to consumers. The infrastructure for natural gas entails treatment facilities to separate liquids and gases and remove hydrogen sulphide and other compounds, storage vessels and pipelines. Buildings and equipment at Turner Valley reflect decades of development and innovation.

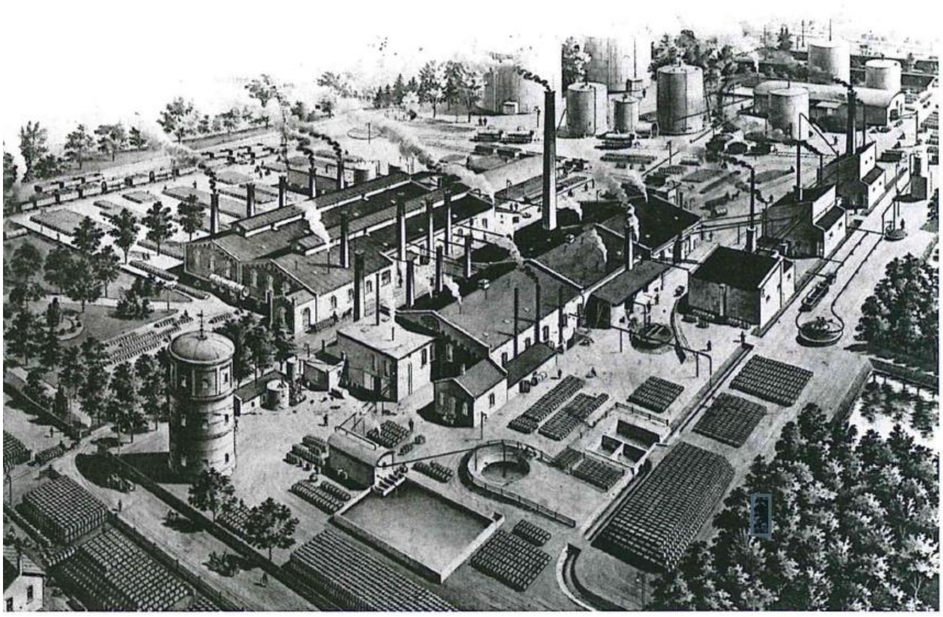
After World War II, new welding techniques, along with advances in pipe rolling and forging, further improved pipeline reliability and fed a pipeline construction boom as gas became a preferred fuel for domestic and industrial customers.

Petroleum refineries and petrochemical plants

Refineries are a key element in the petroleum production and consumption chain. Moreover, refineries are key drivers in the creation of built environments, materially transforming neighbouring cities and landscapes — precisely because they themselves are highly specialized, expensive, large, long-lasting, and spatially fixed entities. (Hein 2018b, 452)

By the 20th century petroleum refineries had become large, sprawling chemical plants whose location was tied into international logistical networks as well as the primary sources of their raw material. They are often remarkably long-lasting plants, renewed, rebuilt or reinvented sometimes over more than a century as technology, products and markets changed. Consequently, it is rare for original historic structures, plant or buildings to survive.

An illustrative example is Salzbergen refinery in Lower Saxony, Germany, considered among the oldest in world. Founded in 1860 to refine paraffin from oil shale, in 1863 it began distilling Pennsylvania crude oil. By the 1870s was producing fine lubricating oils for textile machinery, and from 1890s heavier cold-resistant oils for railway trains, using oil shipped from Baku. In 1908 it began refining local oil from Wietze(see case study 8.5). It was very badly bombed in 1945 but rebuilt after the war, was almost closed by BASF in 1994 before being bought out by two former customers, and now makes oil products including lipstick, packaging and textiles (Oehlke 2010). Another example of a long-lasting plant is the Philadelphia refinery, built by the Atlantic Petroleum Storage Company beside the Delaware River in 1870. When threatened by closure, it was revived with the arrival of shale oil from fracking in North Dakota. The Baton Rouge refinery built in 1908 by Standard Oil on the banks of the Mississippi River to process the Texas oil fields was still, in 2016, the thirteenth largest in the world.



Two images of the Salzbergen refinery from 1903 and 2010 illustrate how radically these plants have changed (© Oehlke 2010).

From the late 1930s, Dow Chemicals opted for an 'open architecture' for its new Louisiana petrochemicals plant, deciding that enclosing the vast tangle of pipes and tanks in a building envelope, as in the north of the country, would be unnecessary in the mild climate of the Gulf coast (Allen 2006). Oil processing plants became larger and increasingly automated complexes. The progress of the industry along the Louisiana 'Chemical Corridor' demonstrates this trend. A cracking process was independently developed and patented in 1913 by Standard Oil for converting oil to gasoline and allowing chemical engineers to process crude and petroleum distillates efficiently. Standard Oil's Baton Rouge refinery signalled the beginning of the development of the lower Mississippi River petrochemical refineries.

A series of significant discoveries of oil and gas were made after 1910 and accelerated from 1940, while by 1947 off-shore drilling had receded out of sight of land. By then there were '177 refineries and chemical plants in Louisiana, and their numbers continued to grow: 211 in 1962, 284 in 1981, 320 in 2002. Along the lower Mississippi River the number of oil-refining and chemical-processing plants rose from 126 in 1962 to 196 in 2002. A landscape once dominated by sugarcane fields had been thoroughly transformed' (Colten 2006, 95-6). In Ontario, the oldest North American oil fields led to a massive petrochemical complex in Sarnia, known as Chemical Valley, which began during World War II and today has 62 facilities and refineries.

It is not evident, however, which of these structures might be considered as historic resources capable of testifying to this remarkable pattern of industrial development. Moreover, as well as the region's claim to be the birthplace of the petrochemical industry, Louisiana is also 'among the most toxic places in the United States, the site of acrimonious struggles between residents over air and water pollution and one of the cradles of the environmental justice movement' (Allen 2006, 116).

Settlements and architecture

In countries where government institutions run the oil industry and control planning, the link between the location and design of extraction sites, regional and urban development, functional and symbolic architecture, monumental statements and petroleum-generated money is even more intense. In those countries, the oil industry's manifestations as well as all associated functions, from street infrastructures to housing developments, and from hospitals to universities, are used to make political statements. (Hein 2009, 39)

The petroleum industry is visible in the built environment far beyond its production and distribution sites, extending from company towns providing housing and services for the elite of managers as well as for oil workers and their families, through headquarters buildings and office towers, to the globally ubiquitous filling stations. These also manifest the corporate structure of the industry, visible like the skeleton below the skin, and extend from the early private companies like Standard Oil, Branobel or the Anglo-Persian Oil Company, through the years between the 1940s and 1970s of the Seven Sisters oligarchy, to the modern national oil corporations like Petronas, ARAMCO and Gazprom.

Oil camps and company towns

The remote locations of newly discovered oil fields and the production facilities which were developed in the 20th century often obliged both private and national oil companies to construct temporary work camps and later stable company towns to house the workforce and their families. As well as accommodation, these might include sporting facilities, places of religious worship, social clubs, schools and shops, sometimes applying town planning concepts transferred from Europe or North America. Professional and social hierarchies and divisions within the companies were also represented and reinforced spatially.

The arrival of petroleum companies in the Arabian Gulf, for instance, brought abrupt changes associated with industrialisation. The discovery of oil at Masjed Soleyman, in 1908, and the subsequent development of the oil fields accelerated the urbanization process in the Khuzestan province, now part of Iran. The Anglo Persian Oil Company (later Anglo-Iranian Oil Company) erected gathering lines, storage tanks, pipelines, workshops, accommodation and, from 1910, the Abadan refinery(see case study 8.4), with an enormous increase in the labour force. Ancient nomadic settlement patterns and traditional occupations like pearl fishing and date farming were swept away by the abrupt intrusion of the petroleum industry.

Oil strikes in Awali, Bahrain, in 1932, and Dhahran in the AI Hasa province of Saudi Arabia, in 1938, saw similar developments, with drilling camps, oil storage depots, gas separation tanks and marine terminals generating new settlements, both planned and spontaneous, for the rapidly-growing labour force. The second world war first slowed, and then accelerated, the growth of the Gulf industry, with wells in Kuwait and Qatar entering into production after 1945.

Temporary field camps developed into permanent towns which broke completely with the established local oasis or desert settlement traditions. The Arabian American Oil Company (ARAMCO) planned and built new towns on the American pattern next to each camp. These contained thousands of bungalows, each set in their own garden, for the American employees and their families, and were equipped with cinemas, clubhouses, swimming pools, tennis courts and other recreational facilities. The urban layout of Awali, planned and built by the

Bahrain Petroleum Company (BAPCO) from 1934, was also inspired by European planning ideals. Most of these company towns were strictly segregated by ethnicity and by occupational status, giving rise to sharp breaks between adjacent population groups of markedly different status (Seccombe and Lawless 1986).

The construction in 1947 of the Trans-Arabian Pipeline or Tapline (see case study 8.9) from Saudi Arabia across the desert to Lebanon was accompanied by a number of completely new and virtually self-sufficient settlements, built around the four pumping stations along the route of the pipeline. They housed both expatriate and Saudi employees and included housing, hospitals, schools, repair shops, recreation facilities and airstrips, with a *suq* or market to supply the surrounding district.

A comparable process took place in South America. After oil was found in remote Tierra del Fuego in 1945, the Chilean oil enterprise Empresa Nacional del Petróleo (ENAP) built the Cerro Sombrero camp and commissioned an urban plan from the University of Chile, with modern buildings designed by American architects Skidmore, Owings and Merrill (see case study 8.7). The settlement of Comodoro Rivadavia in Patagonia, Argentina, was organised under the control of the state oil company YPF which, as well as constructing housing, provided services for health, education, religion and recreation (Acevedo et al 2016).

In each country, several of these ‘pueblos petroleros’ built by the state oil companies developed into independent settlements with an important role in structuring their territories. The positive identification of local citizens with the national companies led to ‘enapina’ communities in Chile, after the company´s acronym ENAP, and in Argentina workers for Yacimientos Petrolíferos Fiscales (YPF) were referred to as ‘ypefeanos’.

In Venezuela during the 20th century, all the new settlements, with the exception of Ciudad Guayana, were created for the oil industry. Shell built a company town alongside the enormous Paraguanà refinery. Construction of the world’s largest catalytic converter started in 1946, and five years later Skidmore, Owings and Merrill were appointed to plan Cardón, originally known as Campo Shell, and Judibana, formerly Champ Creole. Surrounded by an electrified fence, Campo Shell had a low-density, organic layout containing 1,662 houses, two churches, four schools, a civic centre, parks, hospital, airport, four social clubs, cinema restaurants and hotel (Sanchez 2014).

Offices and control centres

The corporate headquarters building is one of the clearest expressions of the oil industry and its geography, commercial supremacy and political importance. This began with the decision of Rockefeller and his associates to relocate Standard Oil’s centre of operations to a new building in Lower Manhattan, New York, in 1885 (see case study 8.10). The idea of a corporate headquarters was itself innovative, and Rockefeller`s new office building at 26 Broadway became the symbol of the dominant young American petroleum industry. Other imposing and representational buildings were soon being built for rival oil companies in Europe. The 1915 headquarters of Royal Dutch Shell in Amsterdam was in a neo-Medieval style. The London offices of the Anglo-Persian Oil Company, Britannic House (1920–1924), were designed by the person most associated with British imperial architecture, Edwin Lutyens. The façade included sculptures of Arabic women. His one-time colleague James Morrison later produced many buildings for the company in Iraq and Iran, including the Abadan refinery settlement.

The Anglo-Persian Oil Company commissioned the favourite architect of the British Empire, Edwin Lutyens, to build its London office. (© Jamie Barras)

As Houston grew into an oil capital after the Spindletop strike, the Texas oil companies built themselves assertive office towers - the Texas Company Building in 1915, the Humble Building in 1921, the Petroleum Building in 1924-27, and the Gulf Building in 1929. Other oil towers in Houston designed by well-known architects included Skidmore, Owings and Merrill's Tenneco Building (1963) and One Shell Plaza (1971) and Phillip Johnson/John Burgee's Pennsoil Place (1976) (Galicki 1997).

The national oil companies which took over from Western corporations after the oil shock of 1973 have also been assertive in their architectural statements, as befits the role played by oil in their countries' contemporary history. César Pelli's twin tower design for Malaysia's Petronas in Kuala Lumpur is reputedly underpinned by an eight-point Muslim star. The headquarters of the Norwegian oil company Equinor, formerly Statoil, claims to reflect national myths, in this case the landscape of the country's fjords, while the massive form of the CNPC building in Beijing is said to imply a connection with the Great Wall of China. The headquarters of Abu Dhabi's national oil company, ADNOC, uses height for its effect of power and authority, as will Gazprom's Lakhta Centre in St. Petersburg.

Filling stations

The start of Model T car manufacture by Henry Ford's company at the Piquette Avenue plant in Detroit in 1908 marked the appearance of both the product and the manufacturing system, the moving assembly line, which would make petroleum the most sought-for natural commodity of the 20th century. Two years later production moved to the much larger purpose-built Highland Park factory, designed for Ford by Albert Kahn.

Twenty years earlier, Bertha Benz had bought petroleum solvent for her pioneer drive at apothecary shops which she passed along her route. By 1905, fuel in America was being sold from simple curbside pumps, often appendages to other businesses such as hardware stores or groceries. By the time Ford's inexpensive vehicle was being mass-produced, early pumping or gasoline fill-up stations were beginning to appear to supply motorists with fuel in place of cans, with the first drive-up gasoline station opening in Pittsburgh in 1913.

Filling stations became the most familiar, universal and emblematic architectural expressions of the 20th century petroleum industry. As the number of car drivers increased, competition to sell them a non-differentiable commodity encouraged petroleum companies to develop distinctive brands and signature building forms, sometimes combining the two in programmatic or novelty architecture, decked with symbolic language referring to the consumption of the company's product, vehicle fuel.

Despite their vitality as an architectural sign, filling stations are a precise building typology. They commonly consist of three components: a forecourt, the space in which vehicles can access the pumps, connected to the underground fuel storage deposit; a building for the point of sale and also a varying range of associated services (food retailing, spare parts, car repairs, garage services, café); and some form of canopy to protect the drivers whilst they refuel their vehicles. The canopy developed, alongside the proprietary signage, into the most expressive component of the filling station's design.

During the early years, when the combustion engine was competing with established means of transport, based on the horse, stations were sometimes adaptations of domestic buildings such as stables or cottages, or were designed in various revivalist styles purposely to resemble such familiar structures. Once the motorcar had evolved into a powerful symbol of modernity, companies began to apply contemporary architectural modes to their filling stations: Art Deco, Functionalist and International Style designs appeared from the 1920s, often exploiting the cantilevering capacity of reinforced concrete to form striking canopies. Willem Dudok and Arne Jacobson's austere 1936 structure in Skovshoved, Denmark, is a minimalist example, while the Futurist Fiat Tagliero service station in Asmara, Eritrea, designed by the Italian architect Giuseppe Pettazzi, makes a more dramatic use of the canopy with 30 m cantilevered wings shading the forecourt. Frank Lloyd Wright's only filling station, built in 1958 in Cloquet, Minnesota, as part of his Broadacre City concept, also has a distinctive cantilevered roof, covered with copper shingles.

The futurist Tagliero filling station could be part of a proposed World Heritage nomination of the 20th century architecture of Asmara, Eritrea. (© David Stanley)

After World War II, standardised filling station designs incorporating company imagery were developed, a notable example being the 1960s Pegasus programme of architect Eliot Noyes for the Mobil company. Canopies featured raking profiles, hyperboloids, folded plate roofs, and boomerang-shaped supports continued the exploration of their expressive possibilities, a trend which continues to the present day.

6. The petroleum industry as World Heritage

6.1 Historical themes

In order to evaluate the heritage of the petroleum industry it is useful to identify those key periods of change and continuity for which structures, sites and landscapes provide illuminating physical evidence. This section draws on the previous discussion to propose global historical themes which make sites of the petroleum industry of particular significance, and indicates some of the attributes which would justify their selection and conservation on national lists as well as supporting their inscription as World Heritage sites.

The preceding historical review suggests five major historical themes on which the criteria for identifying the most significant sites can be founded.

1. People in many parts of the world took advantage of naturally occurring hydrocarbons for thousands of years. Production was a small-scale artisanal activity, only rarely leaving significant traces or becoming important in human societies. Some put hydrocarbons' natural properties to practical use, for instance as a construction binding medium or for waterproofing ships, while others sought to exploit the perceived medicinal or therapeutic qualities of this curious substance.
2. A series of technical advances in the 1840s and 1850s led to a radical reassessment of the value of hydrocarbons for advanced industrialised societies. Improved ways of separating petroleum produced new products; important new applications were found for some of these, notably for lighting and for mechanical lubrication; while dramatic breakthroughs were made in extracting petroleum from underground oil fields in far larger quantities than had hitherto been achieved. Over the fifty years following the historic strikes at Titusville, Pennsylvania and Oil Springs, Ontario, the upstream, midstream and downstream sectors of this new industry all developed rapidly, and it became consolidated under the control of a small number of powerful integrated corporations in North America and Europe.
3. As petroleum became the hegemonic global energy source in the first half of the 20^{th}century production extended to many other regions of the world, notably the Middle East, to parts of Latin America, and to east Asia. The consequent economic and urban growth in the territories affected radically changed older patterns of territorial development, urbanization, wealth distribution, political organisation and national identity.
4. By the first world war, two particular petroleum products, fuel for vehicle combustion engines and asphalt for road construction, were facilitating new means of social interaction which would characterise the 20^{th}century. Cars and the roads on which they were driven reduced distances between human communities, metaphorically as well as physically, and transformed urban and rural landscapes. Since the 1970s the evidence for global warming caused by two centuries of burning hydrocarbons, including fuel for transportation on land, sea and in the air, has negatively affected perceptions of the benefits of petroleum production.
5. Finally, from the middle of the century the growing quantity and variety of petrochemical products, for which petroleum is the feedstock, began to affect almost every aspect of human societies. A brief list would include synthetic fibres and dyes, plastics, drugs, perfumes, fertilisers and insecticides. The usefulness, quantity, durability and universality of these materials means that their pervasiveness has also

become, by the early 21st century, a global environmental challenge and potentially an existential risk for numerous species.

6.2 Authenticity and integrity

Today at Spindletop, there is not a hint of a hill or any other indication of the Lucas well site. Sulphur mining in the post-war period by the Texas Gulf Sulphur Company caused the land to subside. Tourists are directed a mile away to a pink, granite obelisk dedicated in 1941 to Spindletop and the Lucas gusher. (Galicki 1997, 46)

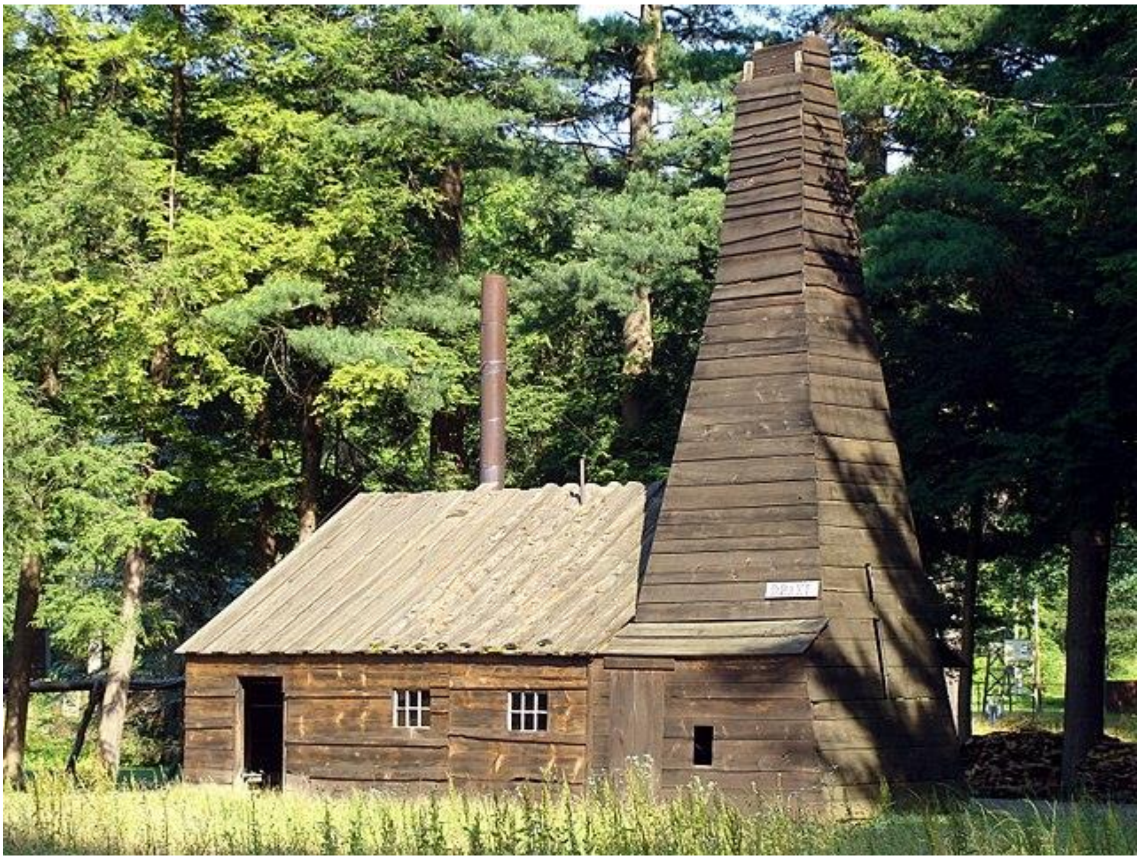
Both authenticity and integrity have to be satisfied as part of the assessment of Outstanding Universal Value. The authenticity of heritage sites means that their cultural value is 'truthfully and credibly expressed through a variety of attributes' (UNESCO 2017). These are both tangible attributes, expressed in form, design, materials, use or function; and intangible ones, as in techniques and management systems, or traditions, customs and beliefs. For integrity, UNESCO understands that the historic resource is sufficiently complete for its Outstanding Universal Value to be recognizable. In other words, its physical attributes must still survive and be evident so that they are able to communicate this value.

When applied to the remains of industrial activity, integrity and authenticity should extend beyond their material and structural attributes to also include the functional integrity of the site and of the productive processes which took place there. Innovation, reflecting the progress of knowledge, is an important attribute of the most significant industrial sites (Cotte 2012).Continual renewal, updating and maintenance are intrinsic to their character, an aspect already recognized in the Nara Declaration on Authenticity, as well as the World Heritage thematic studies of canals (Hughes 1996) and railways (Coulls 1999), and the *Operational guidelines for the implementation of the World Heritage Convention*, in the annex on historic transportation corridors (UNESCO 2017, 76).

The technical characteristics of petroleum production and its rate of change and obsolescence, compounded by the complexities of the physical remains of the industry, mean that extensive historical remains from petroleum production are rare. In general, the construction materials and many of the building typologies employed for petroleum production do not have the monumental, durable or re-usable qualities that favour an extensive legacy.

Historically important early extraction sites in north America highlight this issue: 'the tall derricks that gave such a distinctive look to the landscapes of the oil fields were usually built in a hurry and remained within the American tradition of wood construction into the 1920s, when steel frames became common. These wooden drilling rigs were rough, impermanent, yet sturdy and resilient structures.' Moreover, 'derricks might be pulled down soon after a well went into production; pipes, pumping apparatus, tanks, and shops were important only as long as the oil flowed (Gordon and Malone 1994, 290-1). This underlines the specific importance of sites which survive from these pioneering years in any degree of authenticity.

The physical evidence of oil production was often actively erased by salvage companies recovering resalable equipment from above and below the ground. Fire destroyed plant and buildings, especially before the 20th century when almost everything was made from wood. The archetypal early boom town of Pithole, Pennsylvania, was ravaged by arsonists' fires even before the wells ran dry and it was abandoned (Black 2000, 167). Modernisation and adaptation of processing plants because of rapid obsolescence, coupled with the corrosive effects of petroleum products, is often so radical that both structural and mechanical evidence has largely disappeared. Contamination of the ground by filtration of hazardous chemicals is a further constraint on the possibilities of preserving or repurposing historic sites. Monumental, durable structures of masonry or building typologies which might be suitable for adaptation to new uses may be limited to company towns and the headquarters buildings of the oil companies.



The site of the original Drake well in Pennsylvania is occupied by a careful replica commissioned in 1945 and based on photographic documentation. The site is a National Historic Landmark as well as a Historic Mechanical Engineering Landmark designated by the American Society of Mechanical Engineers. (© Creative Commons)

Photographic documentation is the only way now to conserve, for example, the landscapes of dense clusters of derricks in an oil-boom area, the uninterrupted concentrations of the Mississippi petrochemical corridor, giant refineries like Abadan, or the isolated deep-water oil platforms which once stood out in the middle of the North Sea.

As with any resource industry, oil extraction only continues for as long as there are obtainable reserves, and once it is no longer profitable to extract these, the activity usually comes to an end. For the petroleum industry, production may extend over centuries as in Ploiesti, Romania, or the Absheron peninsular in Azerbaijan, or it may be over within a matter of months. This transitory quality is sometimes an attribute of the petroleum industry heritage which can be traced in the camps and boom towns that have accompanied the discovery of new oil deposits, notably in the United States.

The strategic military value of oil made production and refining installations military targets from the First World War to the two Gulf Wars. The historic Carpathian oil fields in Ploiesti, Romania were seized by Germany in late 1940 and twice severely damaged by Allied bombing raids (Craig 2018), and Middle East oilfields have, of course, been regularly targeted in more recent times.

Mining and processing activities of extraction industries often create interesting and evidence-rich landscapes associated with their waste products. Notable examples lifted from the World Heritage List include the stone quarries of ancient Egypt, Roman gold mines of Las Médulas in Spain, the Idrija mercury mine in Romania, Cornish tin and copper mines in Britain or the coal landscapes of northern France. In contrast, oil extraction has left neither a visitable 'negative' landscape underground, nor evocative accumulations of tailings and waste which might be studied, admired for their intriguing qualities or renatured. Even the pronounced rise of the Spindletop salt dome that first drew the attention of geologists has since sunk into the coastal Gulf landscape. The petroleum industry has notoriously used rivers and the atmosphere to dispose of its waste liquids and gases. Oil sands tailings ponds or pools of toxic liquids behind artificial dams are unlikely to be conserved for their heritage values.

The principal exception is the oil shale industry, which created landscapes of open-cast extraction and mountains of waste rock such as the preserved spoil heaps at Broxburn and West Calder in Scotland, and can be visited at the Museum of the Scottish Shale Oil Industry and the Museum of Oil Shale in Estonia.

6.3 Conservation priorities

Taking account of the nature of the heritage that has been left by the global exploitation of oil reserves, a number of priorities for conservation suggest themselves. Sites should be considered of historic significance whose heritage features and attributes provide evidence for the following, taking into consideration their integrity and authenticity as discussed above.

These are grouped following the usual divisions of the three main sectors of the petroleum industry.

Upstream

1. Pre-industrial exploitations of surface oil seepages. These are likely to be anthropogenic elements of the landscape in which ancient or original patterns of accessing and removing natural, untreated petroleum can be discerned, such as gum beds and seeper wells. Archaeological evidence for such exploitations should also be valued.
2. Pioneering oil sites from the start of industrial production. Sites which contain original, in situ plant from between 1850 and 1900 related to drilling, pumping, power supply, refining, storage or transportation should be valued highly, and comprehensive production systems including equipment and support structures especially so.

   Much of the equipment used to drill a well could be adapted to pump it, and derricks were left in place to pull the pump rods or well casing. 19th century oil fields had centrally powered pumping systems connecting multiple wells by shackle (jerker, pull or rod) lines linked to a prime mover. Landscapes of closely spaced derricks became a characteristic image of oilfields in many parts of the world but despite their impact they are highly ephemeral.

   Pump jacks are the most frequently-conserved historic structures associated with petroleum production in numerous active or former oilfields. They stood above each oil well and transmitted the reciprocating motion of the motor to vertical pumping motion of the borehole pumps.

A pump jack at the Bóbrka oil mine, Museum of Oil and Gas Industry IgnacyŁukasiewicz, in Poland. (© Stanislaw Szydlo, Creative Commons)

Local landscapes may exhibit surface evidence of mining or of subsidence (as well, of course, as pollution). Oil shale mining has a much larger impact than the production of oil or gas.

3. Sites and landscapes associated with major regional or national patterns of development caused by the growth of the petroleum industry.

   The discovery and production of oil, sometimes brief and in other cases lasting over centuries, radically altered land use, the built environment, settlement patterns and the natural landscape, as well as having a powerful effect on intangible attributes such as local identity, class structure or skills. Rural regions like Pennsylvania, Texas or Louisiana became industrialized, the economic situation of nations including Venezuela and Norway were transformed, and whole national cultures were radically altered as in the experiences of, for instance, Brunei or Saudi Arabia.

A preserved pump jack in the Seria oil field in Brunei. Darussalam.Oil was first discovered here in 1929 and has been in near continuous production since. (© Michael Elleray)

Several European countries, among them France, Germany and Italy, have an important oil heritage, rich in invention and technology, despite the fact that they never achieved globally significant levels of conventional oil production. This influenced attempts to develop alternative sources of energy, in France on oil shales, in Germany on coal hydrogenation, while Italy had diversified strategies involving lignite and hydroelectricity (Craig et al 2018).

A waste heap in Estonia with remains of an inclined plain, formed from extracting shale oil from oil shale. (© Siim Sepp)

4. Urban developments including ephemeral boom towns, work camps and planned company towns which provide evidence for petroleum production and for the natural, social, economic or industrial consequences which accompanied it.

Midstream

5. Pipelines and distribution networks. Pipelines have been instrumental in making production viable by moving petroleum from remote oil fields to ports and refineries. Instances are those laid in the 1880s from the Oil Regions in Pennsylvania and from Baku to the coast cited above, or the 1977 Trans-Alaska Pipeline. 19th century pipelines were built with regular steam pumping stations. The pumping stations along the Trans-Arabian Pipeline (Tapline) in Saudi Arabia developed into new settlements. Galveston and Aberdeen are examples of ports with strong associations with oil production. The importance of distribution networks as heritage sites will depend, as outlined above, on the survival of historic attributes.

Downstream

6. Petroleum refineries. 19th century sites for small-scale refining or distilling provide evidence for the beginning of the technology for separating different fractions of oil and producing products needed by the societies of their day. The location of major 20th century refineries often needed new urban areas to be built for employees and their families. Large refineries are key points in the global petroleum system. As adaptable and long-lasting sites they potentially have considerable historic interest, but this is likely to be very limited for the reasons discussed in the previous section. Production areas are often, moreover, severely contaminated by filtrations and they may be unsuitable for new uses without major clean-up operations.
7. Corporate headquarters and administration buildings manifest the key role of the major oil companies in the history of oil production and its geographical extension around the world. The 1885 Standard Oil offices in Manhattan, New York, is a relatively modest architectural statement if placed alongside other headquarters architecture, not least in New York itself. But it stands at the beginning of a line which continues through regional oil capitals such as Tulsa, Houston and Calgary to the enormous statement buildings of petroleum economies in Abu Dhabi, Singapore or Kuala Lumpur.
8. Petrol distribution/consumption. Gasoline filling stations are conceptually a part of the petroleum industry and an important and highly visual element in the 'petroleumscape'. They are a ubiquitous and evocative testimony to oil's place in 20th century culture, and a typology moreover which enjoys considerable popular appreciation. Mid-20th century filling stations incorporated architectural bravura or evocative designs to attract consumers.

   There are many filling stations in the USA converted into small local museums, and American and European heritage inventories include many typical or classic stations as well as notable architectural designs.
9. Finally, sites and ensembles which bring together the often dispersed and disconnected components of the process chain, linking together the three steams of petroleum production, have the potential to make the overall industry more easily visible and comprehensible to a non-specialist public.

7. UNESCO evaluation criteria

One aim of this report is to establish whether the most significant historic resources of the petroleum industry can be considered as having 'Outstanding Universal Value', and, if so, on what grounds and how they should be evaluated.

This attribute is defined by UNESCO as 'cultural and/or natural significance which is so exceptional as to transcend national boundaries and to be of common importance for present and future generations of all humanity' (UNSCO 2017, 11).

7.1 Selection criteria

The criteria for choosing World Heritage are defined in the revised Operational Guidelines for the Implementation of the World Heritage Convention.

(i) to represent a masterpiece of human creative genius;

The very rapid growth of oil production between 1860 and 1910, and of the modern form of organisation of the petroleum industry and its transfer to other territories and countries, can be attributed to the influence of individuals. Properties selected under this criterion would illustrate the special contributions made by people whose ingenuity, knowledge, imagination, persistence, or vision were determining factors in the establishment and development of modern petroleum industry and to its geographical diffusion.

(ii) to exhibit an important interchange of human values, over a span of time or within a cultural area of the world, on developments in architecture or technology, monumental arts, town-planning or landscape design;

Since the development of the industry has been driven by the search for oil and its production in particular localities, this is a strong attribute related to petroleum production. Few industrial activities have had such an influence, directly or indirectly, on 20th century human values. The flow of petroleum products is an expressive metaphor for the process known in recent decades as globalisation, with the concomitant sharing and transfer of ideas and knowledge about architecture, technology and planning.

Many locations in North America were transformed by the discovery of oil; petroleum production over centuries in regions such as Baku or the Carpathian mountains has resulted in distinct cultural and natural landscapes; the wealth resulting from oil and gas reserves completely changed the direction of the countries bordering the Arabian Gulf, of Norway or of Venezuela, replacing traditional lifestyles, settlement patterns and economies. Oil production in many of these regions has stimulated the exchange of technology, of cultural forms and social behaviour, and radically influenced local political systems, and these developments can be seen in the built environment as well as the natural one.

(iii) to bear a unique or at least exceptional testimony to a cultural tradition or to a civilization which is living or which has disappeared;

Petroleum products are the literal and metaphorical lubricants of modern civilisation, essential for transport, medicine, food production, clothing, and innumerable daily products. Those places which bear most eloquent testimony to the development of the modern oil-based civilisation are potentially of outstanding value.

Pre-industrial uses of oil seeps sustained older cultural traditions such as construction with bitumen in Mesopotamia, the use of religious lighting oils in Azerbaijan, in Tsarist Russia, or brine/petroleum drilling in China. Early oil exploration and production using simple technologies, known as wild-catting, encouraged an individualistic, craft approach to drilling and producing petroleum.

(iv) to be an outstanding example of a type of building, architectural or technological ensemble or landscape which illustrates (a) significant stage(s) in human history;

This is also a strong criterion for the built heritage of an industry whose products define the past century of human history. The most representative typologies of building or ensembles include early drilling and production sites or refineries from the 19th century; influential or strategically important pipelines and their pumping stations; the corporate HQs of the major oil companies; early 20th century gas/petrol stations, or bravura designs which are indications of the importance of the car culture; and urban ensembles and model company towns associated with the arrival of significant petroleum production, including housing and cultural buildings.

(v) to be an outstanding example of a traditional human settlement, land-use, or sea-use which is representative of a culture (or cultures), or human interaction with the environment especially when it has become vulnerable under the impact of irreversible change;

The intense and sometimes explosive interaction of the petroleum industry and the geological reserves of oil and gas can be demonstrated in a variety of places. These include sites which have seen centuries of exploitation of petroleum resources, pre-industrial and industrial, superficial and below ground, with landscapes, settlements and or buildings adapted to that activity. Examples of these are in Mesopotamia, China, the Carpathian mountains, or Absheron peninsular.

Ephemeral or boom towns associated with the early search for oil and brief output are characteristic of the early decades of oil industry, notably in the USA and Canada in such places as Titusville, Pennsylvania or Volcano, West Virginia, or Petrolia, Ontario.

Planned settlements for workers and their families close to oil fields are characteristic of the involvement of private and public companies, which often had to provide housing, schools, hospitals and churches to sustain production teams in particular environments. The results are frequently indicative of prevalent social arrangements, and of the transfer of ideas of spatial planning between different societies.

(vi) to be directly or tangibly associated with events or living traditions, with ideas, or with beliefs, with artistic and literary works of outstanding universal significance. (The Committee considers that this criterion should preferably be used in conjunction with other criteria);

8. Case studies: sites for comparison

This section presents sites of historical oil production around the world. They have been prepared by or with the help of people familiar with their heritage values. The intention is to provide a selection of case studies by which heritage managers and others might make comparisons to gain a better idea of the relative significance of other sites and the importance of different attributes.

All of them include significant elements; their inclusion does not imply any recommendation, and the same applies to places not discussed here.

The case studies have been edited so that they conform as closely as possible to a regular format to help make comparisons.

8.1 La Brea Pitch Lake, Trinidad

© Creative Commons

Presentation and analysis of the site

Location: La Brea in southwest Trinidad.

General description: 41 h lake is estimated to be 76 m deep in the centre and holds about 10 m tons of pitch.

Brief history of the site or landscape: The lake is formed by natural petroleum rising to the surface where it collects in a volcanic crater. Lighter elements of the oil evaporate, leaving behind the heavy asphalt, a mix of oil, clay and water.

In 1595, the English explorer Sir Walter Raleigh used the substance for caulking his ships. He took several barrels back home with him. Mining of the lake started in 1867, since when an estimated 10 million tons of asphalt has been extracted. It is employed in a variety of applications from high-quality road construction to insulating compounds for the cable and electrical industries. People occasionally swim in the waters of the pitch lake which some say is therapeutic because of the sulphur content.

Cultural and symbolic dimension of the site:

Comparative analysis: The largest of only three natural asphalt lakes in the world, the other two being the La Brea Tar Pits in Los Angeles and Lake Guanoco in Venezuela. Naturally occurring petroleum seeps to the earth's surface in many places and has been exploited to differing degrees. Binagadi asphalt lake (or Binagadi tar pits) are a cluster of tar pits associated with the oil town of Baku, Azerbaijan.

There are numerous places where natural seepages were developed for pre-industrial asphalt extraction. The Ironbridge Tar Tunnel in England is a horizontal shaft which struck a gushing spring of natural bitumen in 1787. The bitumen was refined for lamps, waterproofing and health remedy. The Riutort petroleum mine near Barcelona was excavated into a natural seep in 1905 in search for petroleum. It failed to make an economic return but is a conserved heritage site.

Present site management

Present use: The lake is a natural site from which the Lake Asphalt of Trinidad and Tobago company, a state-owned enterprise, mines, processes and exports asphalt around the world for paving roads, runways and racetracks.

Protection regime: The lake is on the World Heritage Tentative List of Trinidad and Tobago.

Bibliography

8.2 Oil Springs, Ontario, Canada

Pat McGee and Charles Fairbank, Fairbank Oil Fields

A part of the jerker line system which conveys pumping motion from the central power to the wells. (© Fairbank Oil)

Presentation and analysis

Location: Oil Springs, Enniskillen Township, Lambton County, Ontario, Canada

General description: Oil Springs has continually produced oil for commercial use for more than 160 years. Fairbank Oil Fields is not a museum. On the original oilfield, Fairbank Oil Fields annually pumps 24,000 barrels of oil in a 600-acre landscape of grasslands, woods, wetlands and farmed fields.

Long before the 1850s, indigenous people used local oil seepages for medicines and waterproofing. Springs burst into being in 1858 when oil was struck and refined into illuminating oil, kick-starting North America's first oil boom. Today, Oil Springs has roughly 700 people and the Oil Museum of Canada site, established by the County of Lambton in 1960, contains the Williams Discovery Well of 1858.

The site of Canada's first gusher, the Shaw Well of 1862, is on Fairbank Oil Fields, a four-generation family oil business pumping oil since 1861. Fairbank Oil Fields operates 350 oil wells on 365 days of the year, with the majority using a complete system of authentic 19th century technology for extracting and storing crude oil. This includes the jerker line system for pumping multiple oil wells, devised by John Henry Fairbank in 1863. The oil is trucked to the Imperial Oil refinery in Sarnia.

Fairbank Oil is a continuing evolved cultural landscape of the 1860s, the site of pumpjacks, crops and sheep, plus the unique rhythmic sounds of the jerker and the pervasive smell of oil.

Black Creek meanders through Fairbank Oil Fields, adding immensely to the biodiversity of the area.

Brief inventory: More than 700 built and fixed artifacts have been inventoried at Fairbank OIl, not including many thousand more moving parts. Fairbank Oil continues to use six central power houses with massive bullwheels, and 12 km. of wooden jerker line system to deliver power to 300 wooden pump jacks. Twelve cast iron field wheels act as hubs for the jerker line. Separating tanks remove the water, brine disposal is directed underground, and oil is piped to receiving stations. Other elements include underground wooden tanks, Imperial Oil's last receiving station, a blacksmith shop, dug wells from the 1850s and 1860s, and abandoned-in-place relics.

The Oil Museum of Canada has more than 9,000 artifacts including letters and many "exotic" items collected from around the world by Lambton County's early International Drillers.

History: In 1849, the Geological Survey of Canada reported the bitumen of Oil Springs would have value for manufacturing illuminating gas. On reading this, Charles Nelson Tripp distilled the bitumen but chose to create asphalt instead. By 1854, he incorporated North America's first oil company, The International Mining and Manufacturing Company, which predated the Pennsylvania Rock Company.

In 1856, James Miller Williams acquired Tripp's land and refined the bitumen to produce illuminating oil. In 1858, a year before Pennsylvania's Drake Well, his hand-dug well struck oil at 4.2 m, producing 60-90 barrels each day. Refining it and marketing it as illuminating oil, he even shipped it to New York, thereby creating the first integrated oil company, revolutionizing domestic lives, farming, trade and transportation.

In 1862, John Shaw drilled through 38 m of rock before hitting the gusher at a depth of 52 m, using percussive spring poles to break into bedrock and steam-powered rigs to attain greater depth. More than 30 spectacular and prolific flowing wells followed. That year, Oil Springs was shipping oil to Liverpool, UK. In 1863, John Henry Fairbank devised the wooden jerker rod system, linking several wells to one power source, making oil production in these shallow wells economic.

The oil boom of 1858-1866 spurred the creation of roads to rail, great leaps in oil technology and expertise, and exploration of nearby and foreign oil fields. Oil Springs was a hotbed of innovation and the first village with kerosene streetlamps.

In 1925, the combined sites of the Oil Museum of Canada and Fairbank Oil were designated a National Historic Site. In 2010, the Oil Heritage Conservation District was established under the Ontario Heritage Act.

Cultural and symbolic dimensions: Oil Springs is the outstanding cultural heritage landscape in the world representing the early oil industry, containing a complete preserved, authentic, and fully operational early oil field. As such it is the only place in the world where original equipment from the 1860s can be experienced, from the first phase of the major energy shift from coal to petroleum, with authentic uses, sights, sounds and smells. The oil industry of south-western Ontario 'predates, by several years, the rise of the oil industry in western Pennsylvania centred on Drake's Well. It is not merely a case of being the pioneers in terms of modern industry, but also the location of the 'jerker line' rod system for pumping a large number of low producing wells from a single source and the Canadian 'rod system' for drilling wells' (Kemp and Caplinger 2007, xvi).

The site also has an important international dimension. Starting in 1873, international drillers from Oil Springs and nearby Petrolia advanced oil development worldwide, taking the highly adaptable Canadian pole-drilling method to 86 countries. Canadian William McGarvey, revolutionized Poland's oil industry and in Malaysian Borneo, the first well is called Canada Hill after its Canadian engineer, McAlpine. By 1942, oil would lead to Sarnia building a large petrochemical industry, which is still the main driver of the city's economy. In 2001, Ontario produced 1.6 million barrels of oil.

Today, Oil Springs attracts tourists, academics, artists, oil businesspeople and wildlife enthusiasts.

Comparative analysis: There is no other site which contains a complete and fully-functioning system of authentic 19th century oil technology to produce 24,000 barrels annually. Poland's Bóbkra Museum has remnants of its early technology and also a Canadian steam-driven drilling rig. Pennsylvania's Drake Well Museum has a 1939 replica of Drake's engine house and derrick. His original well pumps the same barrel of oil repeatedly for demonstrations. There is another replica of an early rig at Bibi-Heybat, in Baku. Original drilling equipment from the 1901 Spindletop strike is conserved at theTexas Energy Museum in Beaumont, Texas. Other early production plant is at the Magyar Olajipari Műseum, Hungary, the German Petroleum Museumjn Weitz (see case study) and the Polish oil museums in Libusza.

Present site management

Present use: The Oil Museum of Canada and Fairbank Oil Fields attract visitors and researchers to see the oil fields in operation. Fairbank Oil produces sour crude for refining.

Protection regime: The oil fields are managed according to the National Historic Site designation, the guidance of the provincial Heritage Conservation District, and the active support of the owner who stewards the legacy of the oil fields.

Management: The County of Lambton operates the oil museum and Charles Fairbank operates Fairbank Oil. The Ontario Ministry of Natural Resources and Forestry tightly regulates the oilfield.

Bibliography

Kemp, Emory and Caplinger, Michael W., *19th Century Petroleum Technology in North America* , Browns Printing, Petrolia, ON, 2007

County of Lambton Planning and Development. Oil, Wendy Shearer, Wyoming ON, 2010

Gray, Earle, *Ontario's Petroleum Legacy: The Birth, Evolution and Challenges of a Global Industry* Edmonton, AB, Heritage Community Foundation, 2008

Cochrane. Robert, O. and Fairbank, Charles O, *Oil Heritage Tour of Lambton County: the Birthplace of the Canadian Oil Industry*, Ontario Petroleum Institute, London, ON, 2000

8.3 Deutsches Erdölmuseum Wietze, Germany

Dr. Stephan A. Lütgert, Director, Deutschen Erdölmuseum Wietze

The collection in the oil museum was in operation on the Wietzer oil field until 1963, and are still in their original place. They date from 1904-1910, when the Wietze oil field experienced its biggest boom. (© Stephan A. Lütgert)

Presentation and analysis

Location: Deutsches Erdölmuseum Wietze (German Petroleum Museum), Schwarzer Weg 7-9, D-29323 Wietze

General description: Wietze is the birthplace of the German oil industry. The municipality lies on the edge of the Lueneburg Heath, 18 km west of the former ducal residence Celle. In 1871 the village consisted only of a handful of farmhouses with some 130 inhabitants. After the beginning of the oil boom around 1899 the appearance, size and social structure changed radically: dozens of derricks, a railway station, a refinery, an oil port, pipelines and several oil tanks (including the 'biggest on the continent'), operation buildings and lodgings were erected. After the end of the production era the Petroleum Museum Wietze was established by the Deutsche Erdöl AG (DEA), which re-opened as a public museum in 1970.

Brief inventory: The park-like museum grounds comprise an area of 18,000 m^2 and form part of the former oil field. There are over 65 early boreholes known on site. The former premises include various and singular functioning technical pre-war relics: four production derricks with original sucker rod pumps driven simultaneously by a bull wheel, an oil separator, an underground riveted tank, two drainage basins for the reservoir water, a duplex pump and a mobile workover winch. Moreover the open-air exhibition comprises drilling and extraction equipment and utility vehicles from the decades after that. A 54-metre-high derrick built in 1961 with a floor which is to be made accessible again for guided tours after the restoration is one of the special highlights. Visitors are able to set many of the objects in motion themselves. There is also a narrow-gauge railway with a track length of around 400 m (combined 600 and 900 mm!) which visitors can ride. The permanent exhibition demonstrates the formation of crude oil and how it is explored, produced and processed.

Brief history of the site: Petroleum was first mentioned here in 1652. Heavy oil was extracted above ground in so-called 'tar pits' and traded as a lubricant and medicine from the middle of the 17th century. There was small-scale harvesting of oil from sands during the 19th century. Economic interest in the raw material grew in the 1830s and plans were developed as early as 1841 to expand oil extraction for the purposes of asphalt production. Around 1847 the oil from the largest oil pit was being traded in 24 villages in Lower Saxony.

The first oil well (some 36 m deep, unfinished) was drilled by hand in 1858/59, predating the Drake well in Pennsylvania, by order of the Royal Hanoverian Government within a geological research project under scientific supervision of Prof Konrad Hunaeus (1802-82). Several drillings followed from 1875 onwards, financed by Russian, British and German firms.

From 1899 the oil field was developed rapidly. In 1907 there were over 30 drilling firms on the spot, but they were soon merged. Until 1920, around 80% of the German oil production came from Wietze. Before 1930 around 2,000 wells had been drilled and between 1920 and 1963 there was even an oil mine with a tunnel length measuring at last 95 kilometres. Production ended in Wietze in 1963, by when the oil field had produced over 2.7 million tons of crude oil, but Celle is still a technology centre.

Cultural and symbolic dimension of the site: Beyond the museum grounds with its original production equipment one can find different traces of the industrial history on site. The oil boom in the rural Lueneburg heath and its environmental and social implications had been a cause for concern even 100 years ago, as is documented not least in several works by the famous 'heath poet' Hermann Loens (1866-1914). EH 69 probe has been producing oil since 1928 being thus the oldest active petroleum probe in Germany.

Comparative analysis: Wietze can be compared with the sites of petroleum production in Ontario or Pennsylvania, and more closely with the European sites in Ukraine, Poland or Romania. Oljeön in Engelsbergs, Sweden, may be the oldest surviving oil refinery building, from 1875. It includes two chimneys for the 12 retorts for distillation, a paraffin press, a central boiler-room and a storehouse. The licensed capacity was later increased to 1,500 barrels a year, and the refinery was eventually shutdown in 1902.

Present site management

Present use: A museum, part of the museum association of Lower Saxony, owned by the municipality.

Protection regime: Until now not under preservation order (should be reviewed).

Management: Museum manager, assisted by professional conservators.

Bibliography

Hoffmann, Dietrich, *Die Erdölgewinnung in Norddeutschland. Von den Anfängenvorüber 400 Jahren bis heute*(Hamburg 1970).

Lütgert, Stephan A., *Die Vorgeschichte der industriellenErdölgewinnung in Norddeutschland am BeispielWietze*. *Eine* *grundlegendeNeubewertunganhandbislangunbekannterhistorischerQuellen* (with English summary). Der Anschnitt, 1/2017, S. 10-17.

Idem, *Die Anfänge der Erdölgewinnung in Niedersachsen bis zum Ende des ErstenWeltkriegs. Ein ÜberblickunterEinbeziehungneuerForschungsergebnisse.* NeuesArchivfür Niedersachsen 1/2020 (in preparation).

Wolter, Rolf, *Der Ölschacht in Wietze.* Werdegang des ehemaligenErdölbergwerkesWietze (2nd edition, Wietze 2018).

8.4 Abadan Company Town, Iran

Hassan Bazaz Zadeh, Ph.D. Candidate, Poznan University of Technology and Mohsen Ghomeshi, architectural heritage restoration, Tehran University

The Abadan Institute of Technology was built in 1939 to James Morrison's design. (© Creative Commons)

Presentation and analysis

General description: Abadan, in south-western of Iran, is the earliest example in the Gulf of a modern oil camp settlement. Centred on what was once the world's largest oil refinery, it also includes a large petrochemical plant and both planned and unplanned settlements which were built for company employees of differing skills, ethnicities, cultures and origins.

Brief inventory: The oil city of Abadan consists of oil infrastructure including refinery, petrochemical complex and storage depots, with associated residential complexes, notably Braim and Bwardeh, sports clubs, ports, a dock, an airport and a modern hospital. Oil production from its refinery was 2,500 barrels per day at the time of its establishment.

Brief history of the site: Abadan was a barren island rarely inhabited by Arab nomads who used the island to raise water buffalo and plant date palms.

One year after the discovery of oil sources in Masjed-i-Soleyman in 1909, the necessity of constructing additional facilities became evident. Abadan was identified by British experts of the Anglo-Persian Oil Company (APOC, later AIOC, the Anglo-Iranian Oil Company) as an appropriate place to build the refinery, having sufficient water resources for refinery operations and easy access to the sea. By 1911 a pipeline was completed from the oil field in the hills 130 miles away to the island of Abadan on the Shatt-al-Arab River. The company purchased one square mile of land and in 1912 the world's largest refinery started to operate. This expanded greatly to provide more fuel for warships in the first world war and was producing 25,000 barrels of fuel per day during the second world war as fuel for Allied airplanes played a vital role to their victory.

The earliest bungalow housing was constructed soon after the refinery in the settlement of Braim, with communal buildings such as the Gymkhana Club as well as gardens. From the early 1930s a company town with clear planning principles developed following company policy to employ more Iranians, and professionally laid out residential estates were planned under the British architect James Morrison Wilson. 'Housing, like Company employees, was divided into three classes: fully-furnished housing for British staff and the few senior Iranians; partly-furnished accommodation for non-European junior staff; and unfurnished facilities for wage-earning labour' (Crinson 1997, 347). Wilson used a variety of styles but worked around the Garden Suburb concept in his planning. Abadan grew rapidly from the 1920s when it became a boom town until the AIOC was expelled from Iran in 1951.

Cultural and symbolic dimension of the site: Abadan stands out as the most modern city of the country before Iranians start the widespread process of modernization. Although Masjed-i-Soleyman is famous as the city of firsts, Abadan was the most populated city with modern facilities. The magnitude of oil production was massive enough to attract labour to Abadan. Soon the mix of foreigners and Iranians created a society completely different from other cities of Iran. Abadan became the symbol of modernization and its facilities were known popularly as the most advanced amenities a city could enjoy.

From the beginning, Abadan was inhabited by Arab nomads, then English engineers, Indian labour come, and at the end, Persians headed to the city. There are Indian temples, European churches and Iranian mosques showing the mixture of cultures. Nevertheless, the definite culture of Abadan was Modernism: modern residential settlements, urban facilities, hospitals, cinemas and so on are all icons for Abadan culture

Comparative analysis: The oil strike in Masjed-i-Soleyman and Kermanshah is one of the most significant in the history of petroleum, and an event with major geopolitical consequences. It also started the transformation of the economies and in time cultures of all the states of the region. Abadan refinery was at the centre of this process. The urban development associated with the industrial plant pioneered the work camp and then company town model of petroleum production here and in other oil producing regions during the 20th century. Abadan is the origin of the evolution of planned company towns for oil production, and as such the progenitor of numerous oil settlements in Saudi Arabia (1935), Bahrain (1937), Kuwait (1950) and Qatar (1946), as well as in Latin America, Asia and Australia.

After some years, the exploitation of oil was in progress in several sites. Some sites acted as refineries like Ahwaz or transportation nodes, such as Khorramshar. There were also sites known for petrochemical complexes like Mahshahr. What makes Abadan outstanding among oil cities is that it enjoys all types of oil technology from exploitation to transportation.

Present site management

Present use: The majority of sites, including the petrochemical complex and the refinery, are fully or partially active, with a significant role in Iran's oil production, and are owned by the National Iranian Oil Products Distribution Company (NIOPDC). It has been planned that a specific part of the Abadan refinery will serve as a museum. Some buildings in Braim and Bawarda are in poor condition or abandoned, despite being on the national register of historic property.

Protection regime: Notable examples related to the oil industry are registered on the National Heritage List including labour houses, engineers' bungalows, cinema, dock, the base of the Akwan floating crane, currently 124 sites in total. The oldest filling station of Iran has been turned into a museum in Abadan, as has the 1934 Davazeh Dowlat filling station in Tehran.

Management: In order to protect valuable sites, the organization of cultural heritage, handicrafts and tourism of Abadan works alongside NIOPDC. NIOPDC has established the Iran Petroleum Museum and Documents Centre, in 2013 to recognize, document, conserve and introduce valuable sites in Abadan.

Bibliography:

Crinson, Mark. (1997). Abadan: Planning and Architecture under the Anglo-Iranian Oil Company. *Planning Perspectives* 12 (3): 341-35 9.

Ehsani, Kaveh. (2018). Disappearing the workers: how labor in the oil complex has been made visible. In Working for Oil: Comparative Social Histories of Labor in *The Global Oil Industry*, by Touraj Atabaki, Elisabetta Bini and Kaveh Ehsani, 11-33. Palgrave Macmillan.

Hein, Carola, and Sedighi, Mohammad. (2016). Iran's Global Petroleumscape: The Role of Oil in Shaping Khuzestan and Tehran. *Architectural Theory Review* 21 (3): 349-374.

Seccombe, Ian J, and Lawless, Richard. (1987). Work camps and company towns: Settlement patterns and the Gulf oil industry. *Occasional Papers Series*, 36.

8.5 Wüsteshale Oil Factories, Germany

Dr Barbara Hausmair, archaeologist, State Office for Cultural Heritage Baden-Württemberg (LAD BW)

Remains of the the Wüste 10 factory near Zepfenhan. (© Barbara Hausmair)

Presentation and analysis

Location: 14 sites of former shale oil factories in the Tübingen, Zollernalbkreis and Rottweil districts, Baden-Wurttemberg.

General description: The Unternehmen Wüste (Operation Desert) was a shale oil project launched by the Nazi regime towards the end of the second world war. Four test facilities and ten shale oil factories were built, accompanied by seven concentration camps. Vast areas of land were confiscated and altered through mining, oil shale piles, processing facilities, tailings and extensive networks of field railways and pipelines. The entire project turned out to be a technological failure. After the war, almost all the facilities were dismantled and levelled. Since the 1980s local memorial initiatives have developed educational trails along the remaining heritage that follow the history of the Nazi oil industry and forced labour.

Brief inventory: The site ensemble consists mostly of archaeology (traceable above ground as crop marks in fields or through terrain alterations - railway-footprints, foundations of processing facilities, back-filled mining pits, remnants of shale piles, and iron waste such as rail spikes scattered in fields. In Wüste 4 an entire shale pile (21,000m^3) is preserved. Buildings for the factories' electrical substations are preserved at five sites. In Wüste 10 almost the entire concrete infrastructure of the condensation facilities has survived, including foundations of various machines, settling basins, storage tanks and pipeline pillars. The mine of Wüste 2 still exists as a prominent incision in the landscape around 600m long, as do a storage tank and the concrete shell of the fan system. In Frommern/LIAS, the building which housed the furnaces as well as the boiler house is intact and currently used as an art studio. The underground mine of the KÖU still exists but was sealed-off after the war for safety reasons. Some sinkholes are perceivable as depressions in the modern surface. The KÖU's tailing covers approximately 1ha of land. The DÖLF-facility has been largely overbuilt. The PZ-factory has been developed into a modern cement plant, run by Holocim Süddeutschland GmbH.

Associated with this industrial heritage are the archaeological sites of seven concentration camps and three cemeteries where concentration camp victims are buried.

Brief history of the site or landscape: Until the mid-19th century, the study area was a poorly developed agricultural region. The geology consists of posidonia shale (Lias epsilon, c. 5% oil content). Following an unrealistically high estimation of the shale's oil content by Friedrich Quenstedt, professor of Geology at the University of Tübingen, the earliest attempts to exploit shale oil were made in the 1850s, with the establishment of the Julihütten factory in Bisingen. Low-profitability and growing market competition through American crude oil brought the Swabian oil industry to a rapid end. During the first world war, systematic exploration of the local shale was commissioned by the state, but was brought to halt when Germany gained access to the Romanian oil fields. Further attempts to establish shale oil factories were made in the 1920s. All these endeavours turned out to be non-profitable and were eventually discontinued.

A stable fuel supply became an increasing concern for Nazi Germany during the second world war. In 1942/43 the regime ordered the implementation of four test facilities for developing new approaches for the extraction of shale oil. LIAS/Frommern, DÖLF/Schömberg and PZ/Dotternhausen tested processes based on open-cast mining and different techniques of carbonization and condensation. The KÖU factory in Schörzingen operated an underground mine with in-situ processing. In 1943/44 Germany lost access to Estonian and Romanian oil fields. Allied air raids heavily damaged most of the Reich's synthetic oil plants. Consequently, an emergency program (Geilenbergstab) was launched to secure the fuel supply for the army. In this framework, the Unternehmen Wüste was initiated.

Based on the technology developed by DÖLF (extraction of oil by pyrolysis in large shale piles followed by condensation), ten oil factories, Wüste 1–10, were built across 20km along the foot of the Swabian Alb. Despite the catastrophic war situation, an enormous amount of material resources and technical knowledge (such as engineers from the Leuna plants) were mobilized. Prisoners-of-war, civilian forced labourers and more than 12,000 concentration camp prisoners were deported for the construction works. Due to bad planning and shortness of building materials only four factories went into production until the end of the war. But the Meilerverschwelung turned out to be highly inefficient: the total yield of all operating Wüste-factories was only 840 tons of low-quality oil. The French occupation government initially continued production, but then closed all remaining factories until 1948 due to low profitability. Machines and metal infrastructure were dismantled and sold off, most buildings were blown up, levelled and the land partially re-cultivated. The local population had to cope with environmental pollution for decades: contaminated water bodies and air pollution caused by auto-ignition of shale piles or sinkholes of the collapsing KÖU-mine. In the 1980s grass-root initiatives started to research the Nazi oil industry's entanglement with forced labor and the concentration camp system. Technical documents of the Unternehmen Wüste are rare as it is assumed that the Nazis destroyed many records. Also, allied intelligence units (e.g. the

Technical Oil Mission) seized technical records in the post-war period. Their whereabouts and if or how they were used is uncertain.

Cultural and symbolic dimension of the site: The Wüste factories are an example of technical innovation gone wrong, characterized by war-related turmoil, bad planning and insufficient implementation. The sites are also significant for the social and environmental dimensions. The entire project could be only realized through the confiscation of vast areas of privately-owned land and the exploitation of un-free labour. It had a considerable impact on the local landscape, social fabric and environment. At least 3,470 people died due to inhumane working and living conditions. The destruction of the factories after the war is part of processes in Germany's collective memory that aimed to forget Nazi crimes and to silence questions of responsibility. The heritage of the Unternehmen Wüste exemplifies these disastrous entanglements of war, oil industry and the ruthless exploitation of thousands of people from across Europe under the Nazi regime.

Comparative analysis: Commercial shale oil production has left extensive landscapes in Scotland, in Estonia and in France, while Joadja in Australia is also testimony to the sometimes frustrating efforts to extract oil from shale.

The Kohtla oil shale mine in Estonia was established in 1937 by the British company New Consolidated Gold Fields Ltd, in order to supply the oil industries with oil shale. Kohtla, as one of the centres of the Ida-Virumaa mining area, was special because of the simultaneous underground and opencast mining, as well as the unique hand sorting premises built in 1957, where manual work by women was the main tool used for beneficiation of oil shale, until the mine was closed in 2001.

Present site management

Present use: mainly agriculture; partially over-built/reused; partially integrated into history trails established by KZ Gedenkstätte Bisingen, Gedenkinitative Eckerwald, Arbeitskreis Wüste-Balingen. The Museum KZ-Gedenkstätte Bisingen runs an exhibition on the history of the Unternehmen Wüste.

Protection regime: currently being assessed by LAD BW; parts are already under heritage protection. The sites of the Wüste concentration camps were awarded with the European Heritage Label in 2018 as part of the Natzweiler concentration camp complex.

Management: local memorial initiatives supported by local authorities and recently by the LAD BW.

Bibliography

Glauning, Christine. *Entgrenzung und KZ-System. Das Unternehmen Wüste und das Konzentrationslager in Bisingen 1944/45*. Berlin: Metropol, 2006.

Hausmair, Barbara. *From 'campscape' to 'landscape'. Eine Archäologie des NS-Terrors als Archäologie von Vernichtungslandschaften*. In Ulrich Müller (Ed.), Archäologie der Moderne.

Kiel, forthcoming.

Montag, Ursula, and Daniel Strasdeit. *Unternehmen Wüste Ölschieferabbau im heutigen Zollernalbkreis zur Zeit des 3. Reiches.* BA thesis, HW Nürtingen-Geislingen, 2011.

Walther, Michael. *Schieferölprojekt und Unternehmen ‚Wüste'. Polykratisches Kompetenzchaos oder flexible Netzwerk?*

Zeitschrift für Hohenzollerische Geschichte 53/54, 2018, 295–369.

8.6 Turner Valley Gas Plant, Canada

Elisa Rubalcava Cobo, conservator

View of the complete Turner Valley Gas Plant from the south side of the Sheep River. (© Elisa Rubalcava)

Presentation and analysis

Location: Town of Turner Valley, Municipality of Foothills, Alberta

General description: The Turner Valley Gas Plant, Provincial Historic Resource and National Historic Site, is an industrial complex that was used to extract and process natural gas and gasoline from 1914 until 1985. Several processes and technologies used at Turner Valley were the first of their kind in Canada. The site was developed and modified several times throughout its operating history according to the production demands of the time. The site contains 29 intact historic industrial structures, some dating from the early 1920s to the 1950s. Together the buildings and machinery illustrate the evolution of the refining technology, and the production processes required to extract marketable gas and its by-products.

Brief inventory: The site is approximately 150 acres and contains 19buildings and ten large equipment features. The buildings enclose a relatively intact collection of machinery and industrial equipment used in gas extraction and processing. Most of the buildings were built with steel frames, corrugated metal cladding, and multi-pane windows, with concrete slabs and concrete foundations. Structures directly related to the extraction and processing of oil and natural gas include the Light Plant- originally built as the Absorption plant in 1921, now used as an interpretive centre; the Scrubbing Plant (1935); the Compressor Plant (1938); the Absorption Plant (1933); the Sulphur Plant (1952);and the Gasoline Plant (1933). The Propane Plant was built as an addition to the Gasoline Plant in 1952.

The site also contains several buildings that provided supporting functions, such as maintenance areas, warehouses and the office and laboratory building. Other features include the locations of the original Dingman #1 and Dingman #2 wells, marked and interpreted due to their historical importance; the Horton spheres, used for the storage of aviation fuel; and numerous storage tanks and underground features such as valve pits and pipes. The site also preserves the original pathway system that served to connect the buildings and other infrastructure.

Brief history of the site or landscape: The first settlers of the region were ranchers. The town of Turner Valley depended on coal mining as the main economy of the area until the discovery of oil and gas. On May 14, 1914, the Dingman #1 well owned by the Calgary Petroleum Products Company Limited (CPP) struck a gas reservoir with a high content of natural gasoline known as naphtha. It was the largest gas discovery in Western Canada and marked the beginning of the petrochemical industry in Alberta. The Turner Valley Gas Plant was an important part of three major oil boom periods in Alberta and underwent several development stages and changes in ownership throughout its history. One of the most important transformations was the plant's reconstruction after a devastating fire in1920. As a result, the plant layout was revised with structures located further apart to prevent fire spread in case of an incident. Original timber buildings and structures that were destroyed by fire were reconstructed in steel, with metal cladding and concrete foundations. These modifications to the plant became the model and standard for future petrochemical facilities in Alberta.

In 1985, the plant was decommissioned and closed, ending 71 years of operation at the longest-functioning petroleum facility in western Canada. One of the most significant legacies of the Turner Valley Gas Plant was the development and perfection of the equipment and techniques for processing sour gas globally. It also played an important role in the creation of regulatory frameworks in Alberta, to ensure the effective use of oil and gas resources, to limit waste and to maximize economic potential. Turner Valley Gas Plant was an important driver in Alberta's economic power that profoundly impacted every aspect of the society, changing the history of the province forever.

The cultural and symbolic dimension of the site: Turner Valley was the birthplace and model of the modern oil and gas industry in western Canada. Given that the Turner Valley Gas Plant was the first petroleum product processing centre in Western Canada and is the only remaining example of a gas industry complex from the pioneer era in Canada, its cultural significance is exceptional. A virtually intact collection of industrial structures and machinery tell the story of the challenges of early stages of the oil and gas industry, and reflect the technological developments implemented to overcome those challenges. The site structures and machinery are tangible evidence of the evolution of gas extraction and processing throughout its years of operations.

Comparative analysis: Historic gas production sites such as this are very rare anywhere in the world, and this is probably the only conserved example. In terms of its significance, the closest comparison to Turner Valley Gas Plant would be Leduc No. 1 Discovery Well, Provincial Historic Resource and National Historic Site. Though both sites were important for positioning Alberta in the world of oil and gas producers, Leduc No. 1 (1947) came 33 years after Turner Valley and only produced oil and gas until it was decommissioned in 1974.

Present site management

Present use: The site is owned and operated by the Government of Alberta. The Alberta Ministry of Culture, Multiculturalism and Status of Women is responsible for the site's conservation, operation and programming. Seasonal guided tours are offered at the site. The Lab/Office Building was restored and rehabilitated in 2015 to accommodate site offices and visitor services.

Protection regime: The site was designated as a National Historic Site in 1990 and as a Provincial Historic Resource in 1989. The site is legally protected under the terms of the Alberta Historical Resources Act.

Management: The administration of Alberta's Historical Resources Act (HRA) is the responsibility of the Heritage Division of Alberta Culture, Multiculturalism and Status of Women. The Historic Resources Management Branch Program areas, within the Historic Places Stewardship section of the branch, are responsible for the site's heritage conservation, environmental management, construction, and maintenance. The Standards and Guidelines for the Conservation of Historic Places in Canada were formally adopted by the Province of Alberta in 2003, and serve as the basis for all conservation works at Turner Valley Gas Plant.

Bibliography

Finch, D. (1998).Turner Valley Gas Plant: Site and Building History. Edmonton: Parks Canada and Alberta Community Development.

Hermis.alberta.ca. (2019, September 12). Alberta Register of Historic Places.

Pc.gc.ca. (2019, September 12). Parks Canada - Turner Valley Gas Plant National Historic Site of Canada.

Ambrosi, J, Roder, L, and Stark, J.(1989). Report: Turner Valley Gas Plant: Photo inventory as found conditions, Alberta Culture and Multiculturalism.

Kerr, A. and Porter, J. (2005). Turner Valley: Seven Veils of a Giant Hydrocarbon Field. *Canadian Society of Petroleum Geologist Annual Convention*.

8.7 Daqing Oilfield, China

Professor Liu Boying, Chairman of Industrial Heritage Committee of CRAC, and Liu Xiaohui, Tsinghua University

The Iron Man Well, Sa55 Well (Image Source)

Presentation and analysis of the site

Location: Midwestern Heilongjiang Province

General description: Daqing Oilfield, discovered in 1959 and exploited in 1960, is the largest oilfield in China and one of the few large-scale continental sandstone oilfields in the world. The oilfield has devoted to delivering China’s ‘industrial blood’ for industrial construction for 60 years. The discovery and exploitation of Daqing Oilfield proved that continental stratum can produce oil and form large oilfields. It enriched and contributed to the theory of petroleum geology, changed the backward status of the Chinese petroleum industry, and had a great impact on China's industrial development.

Brief history of the site: China is one of the first countries in the world to discover and utilize petroleum and natural gas. The earliest record of oil was described in the book Yijing·Gegua (BCE. 1046-771）; the earliest published record of oil utilization appeared in Han History Geography (AC. 25-220; Shen Kuo first used the scientific name petroleum in the book Meng Xi Bi Tan (1031-1095). The Ancient Chinese invented the Zhuotong salt well drilling technique between 1041-1053, which is similar to modern percussion drilling, and discovered the oil and natural gas stored underground by using the drilling technology of Zhuotong well.

China's modern petroleum industry began in the late-19th century. In 1877, Miaoli oilfield in Taiwan successfully produced petroleum with small-scale percussion drill purchased from the US. In 1907, Yanchang oilfield in Shanxi Province produced petroleum with Japan-made, steam-powered percussion drill, the first modern oil well in mainland China. In 1909, Xinjiang Dushanzi oilfield purchased Russian rigs to excavate oil wells. During the 1930s and 1940s Chinese modern petroleum industry developed slowly due to the Anti-Japanese War. After the founding of the Peoples' Republic of China, four petroleum and natural gas bases in Yumen, Xinjiang, Qinghai and Sichuan were established. From 1960 to 1965, the new Daqing oil base and a new oil base in Bohai Bay were established, marking the milestone of achieving oil self-sufficiency and ending the reliance on imports of "foreign oil".

From 1955, the Ministry of Petroleum and the Ministry of Geology carried out a geological survey in the North China Plain and Songliao Basin. On September 26th 1959, industrial oil was extracted from Songji No,3 Well with 1357-1382 m drilling depth, marking the birth of Daqing Oilfield. At the end of 1963, Daqing Oilfield ended its experimental development and started comprehensive development and construction. It has successively developed three major oil fields, Sartu, Xingshugang and Lamadian, increased production by an average of 3 million tons per year and prepared a number of new oil fields for future development. Since 1976, Daqing Oilfield has achieved an annual output of more than 50 million tons for 27 consecutive years.

Cultural and symbolic dimension of the site: Daqing Oilfield is of great significance to China's oil industry. In the 60 years of Daqing Oilfield's development, it has created the "three firsts": first in crude oil production, up to the first half of 2019, it produced 2.39 billion tons of crude oil; first in profits and taxation, it contributed to the development of the national economy; first in oil recovery rate, the main oilfield's recovery rate has exceeded 60%, reaching the international leading level. It informed geological development theory and engineering technology for heterogeneous large-scale sandstone oilfields.

Songji No. 3 well is a discovery well in Daqing Oilfield, in the Yongyue village. It produced oil on September 1958. October 1, 1959 is the 10th anniversary of the founding of PRC, and Daqing city was born. Sa55 well is the first oil well that Wang Jinxi, the Iron Man, led the 1205 drilling team from Yumen to Daqing to participate in the Petroleum Battle in April 1960. The 'iron man spirit' represented by Wang Jinxi reflected the spiritual outlook of Chinese workers. They worked under extremely difficult conditions and triumphed over the big oilfield in only three years, marking the end of oil insufficiency. The slogan 'Take Daqing as an example' has encouraged Chinese to work hard.

Daqing has a distinctive industrial city landscape. With the development and construction of the oilfield, a functionally-supported mining area and a petroleum industrial city in Daqing have been gradually built. Drilling tower, oil pumping, oil refining, oil pipeline and other facilities are distributed in city, together with workers' houses and parks, forming a unique landscape. The site and objects of mud pit, oil pit, duty room and underground cellar where workers lived are still preserved near the oil well.

Comparative analysis

Compared with other oil fields in China, Daqing Oilfield is undoubtedly the largest and most important. It witnessed the industrialization path of the PRC and the institutional advantages of the socialist ideology of 'concentrating power to do big things'.

Present site management

Present use: Daqing Oilfield is continuing its crude oil production business. The unique landscape of the city has become a tourist attraction.

Protection regime: There are 319 heritage sites at various levels in Daqing as of the third census of cultural relics (2007-2011), among them, 51 are industrial heritage and 2 oil wells (Songji No. 3 and Sa55) are industrial heritage listed in the National Key Cultural Relics Protection Units. In January 2018, Daqing Oilfield was selected into China's Industrial Heritage Protection List.

Daqing currently has four oil-related museums: Daqing Museum, Daqing Oilfield Science and Technology Museum, Daqing Oilfield History Exhibition Hall and Iron Man Wang Jinxi Memorial Hall. These museums show the whole history and development of Daqing Oilfield.

Bibliography

Liang Hua, Liu Jinwen, *China Petroleum History*, China Petrochemical Press, Beijing, 2003

Sun Zhimin, Ma Lingyong, Li Jingwei, Xue Ting, Li Qing, Composition and Characteristic of Industrial Heritage in Daqing , *Industrial Construction*, 2016 Vol. 46 (7): 81-86

Hou Li, Building for Oil: Daqing and the Formation of the Chinese Socialist State, Harvard University Press, 2018/02

Wang Kun, *Big footprints-the exploration and development process of Daqing Oilfield*, Petroleum Industry Press, Beijing, 2014

Li Bocong, Yin Ruiyu, Zhai Guangming, *Engineering Philosophy of Daqing Oilfield: Practice and Theory*, Petroleum Industry Press, Beijing, 2017

8.8 Cerro Sombrero Oil Camp Settlement, Chile

Dr. Pía Acevedo Méndez, Pontificia Universidad Católica de Chile

Plaza Cerro Sombrero, Tierra del Fuego Chile. (© Eduardo Hernández)

Presentation and analysis of the site

Location: Ex-Cerro Sombrero petroleum camp, Tierra del Fuego, Magallanes and Chilean Antarctica.

General description: A town, originally a workers' oil camp, designed to high social and urbanistic standards by the national oil company in a remote and inhospitable region of Tierra de Fuego.

Brief history of the site or landscape: The discovery of oil in Chile, particularly in the Magallanes region, occurred on December 29, 1945, and the development of the industry for its extraction marked a milestone in the economic development of the region. The process transformed productive practices and the way to inhabit the most extreme space of the national territory, Tierra del Fuego (Martinic 2002).

In the first instance, the State exploited the resource through the Corporation for the Promotion of Production (CORFO), an agency that created the National Petroleum Company (ENAP) in 1950, dedicated to the oil activity in Magallanes. ENAP also generated the appropriate living conditions for the well-being of oil workers in the different productive and extractive spaces of the island (Garcés 2013).

After the first years of oil exploration, ENAP considered the construction of permanent workers' settlements that allowed the transfer of the whole family (Martinic 2002). The urbanization of Tierra del Fuego designed by ENAP sought to bring together housing and work in the same space, which also had to have the basic services to meet both needs.

Between 1945 and 1962 ENAP built five camps for the oil workers in Tierra del Fuego (Acevedo and Rojas 2015). The most complex was the Cerro Sombrero camp (1958). The head of the Department of Architecture of ENAP, Julio Ríos Boettiger, architect of the University of Chile, together with Flora Vera Larraguibel, undertook the design.

ENAP erected the Cerro Sombrero camp between 1958 and 1961, as the first ex novo town centre planned in Tierra del Fuego (Dominguez, 2011). This oil enclave promoted a path towards the progress and modernization of the country, in which the *Enapino* workers would be protagonists.

Cultural and symbolic dimension of the site: Since its inception, this camp pursued a design based on basic precepts such as having areas for living, recreation, circulation and work. First, the industrial zone was far from the Civic Centre and residential areas, with direct access to the roads that connected the points of oil exploitation and production. In the housing area, three differentiated housing sectors were planned according to the work of the worker in the company (Hecht 2002). Finally, ENAP had spaces to meet the needs of recreation, food, education and health, in addition to religion. Thus, the gymnasium was built with a large greenhouse, which within it would have fountains of water and vegetation projected as a small indoor park due to inclement weather.

Cerro Sombrero represents very advanced planning for the time in Chile, while the effort in human and logistic resources for its construction was considerable. The task of raising this camp required overcoming both adverse climatic conditions and technical challenges of building an *ex nihilo* city in the middle of the Chilean Fuegian pampa.

In 1965 Cerro Sombrero stopped being a camp and formally became a town settlement linked to the State and the Magallanes Region. The aim of this was to activate the southern part of the region, giving the possibility to inhabitants who were not linked to ENAP to inhabit the island (Martinic 2002).

Brief inventory: The former Cerro Sombrero camp enjoys a series of heritage attributes, both architectural and urban and social. Each building of the civic centre has national heritage protection, including the sports centre, cinema, supermarket, school, astronomical observatory (currently municipal library), church and fuel pump. Houses built for drivers, workers and employees of oil retain their original characteristics, since the heritage protection of this camp obliges their maintenance and non-modification, thus preserving the original characteristics that earned it the heritage recognition. From a social perspective, it is possible to identify workers how possess decades of experience of oil work, their experience helping to making sense of each of the protected buildings. In this sense, materiality and immateriality complement one another.

Cultural and symbolic dimension of the site: Cerro Sombrero, from its origins, was considered as a contribution to the architecture and industry of Magallanes and Chile. Its characteristics, the technical and technological advances with which it was counted for its design and construction, in addition to the hiring of qualified personnel for this process made this camp, the southernmost of its kind in the world, a recognizable space also at the international level. The distance from population centres accounts for the high level of the construction of camps provided by ENAP for workers and their families in an area with low population density and few basic services. Likewise, the fact that it continues to be inhabited with most of its original buildings shows that the national oil industry of a state character had the knowledge from the beginning to raise this type of spaces. Most of the other camps were built in Chile for mining or industrial operations had private capital and low state intervention.

Comparative analysis: There are temporary camps and more elaborate company settlements associated with many oilfields in under-populated regions, including Oil Springs village, Ontario, Abadan, Iran, or Awali, Bahrain. The Chilean example is notable for the care with which the settlement was planned and managed.

At the Latin American level, the most recognizable cases of oil production are Argentina (Comodoro Rivadavia) and Venezuela (Comunidad Cardón and Judibana, Venzuela), but these have been private projects, even though in the case of Argentina there was a state entity dedicated exclusively to these tasks, Fiscal Oilfields (YPF). On the other hand, the Chilean situation is particular, as the geographical and climatic characteristics where oil was discovered shaped its production, since Tierra del Fuego did not have the conditions to meet the needs of ENAP.

Resent site management

Present use: Currently Cerro Sombrero continues to be inhabited and due to its national heritage protection, much of its original urban fabric and architecture has not suffered major alterations, being possible to identify and recognize the remote oil legacy. The buildings of this former oil camp are used by the local community as well as by workers dedicated to the different tasks that this area of the country is home to, including sheep farming and oil exploitation, as well as public services.

Protection regime: Cerro Sombrero received the Bicentennial Work Award along with 18 more works for its incalculable heritage value unique in Chile, in addition to the southernmost in the country. The State further declared under Monuments Law No. 17,288 as Historic Monument (MH) the buildings that make up the civic centre (cinema, school, astronomical observatory, church, former worker's casino and sports centre) (Acevedo, Ciselli and Rojas 2016).

Management: The former camp is under the Municipality of Primavera, which together with the National Petroleum Company (ENAP) is responsible for its administration, maintenance and resolution of the multiple needs of its inhabitants.

Bibliography

Acevedo, Pía, Ciselli, Graciela and Rojas, Carlos (2016). El patrimonio industrial petrolero en la Patagonia: Comodoro Rivadavia (Argentina) y Cerro Sombrero (Chile) una perspectiva comparada, *Revista de Turismo y Patrimonio Cultural PASOS* (Universidad de La Laguna, España FECYT-SCOPUS), nº 4, Vol 14: 977-993.

Acevedo, Pía and Rojas, Carlos (editores) (2015). Enapinos. *Los campamentos petroleros del Fin del Mundo. Un patrimonio industrial por armar. Etapa fundacional (1945-1962*). Santiago: Consejo Nacional de la Cultura y las Artes.

Domínguez Bastidas, Pamela, (2011). *Cerro Sombrero, Arquitectura Moderna en Tierra del Fuego*. Santiago, Consejo Nacional de la Cultura y las Artes.

Hecht, Romy (2002). Trazado, paisaje y territorio: Cerro Sombrero y la arquitectura del petróleo en Magallanes, *ARQ*, nº 51: 64-67.

Martinic, Mateo (2002). *Breve Historia de Magallanes*. Punta Arenas: Ediciones de la Universidad de Magallanes.

8.9 Chu-Hung Keng Mining Landscape, Taiwan

Dr Hsiao-Wei Lin, Yu-Yu Huang and Chung-Ming Huang, Chung Yuan Christian University, Tao Yuan City, Taiwan

Presentation and analysis of the site:

Location: Kaikuang Village, Gongguan Township, Miaoli County, Taiwan.

General description: The Chuhuangkeng Cultural Landscape preserves a complete oil industrial town with oil drilling derricks, cable tramway, storage tanks, refining facilities, factories, Japanese style office, workers' accommodation and private settlements. The development of Chuhuangkeng area was controlled by the oil industry which generated abrupt movements of population into the oil fields. The settlements, offices and facilities are the visible representation of one of the most significant historical mining sites in the industrial development of Taiwan.

The first record of oil production in the Chuhuangkeng area dated from 1861. A large number of oil wells were drilled in the area during the Japanese Colonial period in Taiwan (1895-1945). The Chinese Petroleum Corporation (CPC) began to extract natural gas after 1945 and still operates today. It is considered the second oldest oil field in the world as oil production began only two years after production started at the Drake well in the United States.

Ten years later American drilling technology was transferred from the USA when the Qing government purchased a set of cable-tool drilling equipment and invited two oil engineers from the Pennsylvania Petroleum Bureau to come to Taiwan. During the Japanese occupation period, the Japanese government recruited geologists and mineralogists from Tokyo Imperial University which was a breakthrough in technology, equipment, numbers of wells, and the oil output for the development of this area.

Brief inventory: The main heritage elements include the original oil drilling derricks, cable tramway, storage tanks, refining facilities, factories, the old clinic, Japanese style office and accommodation. In addition, the complete living quarter has two areas, Beiliao and Nanliao, which includes the school, City God Temple, shops, the Monument to the Victims of Occupational Fatalities and the Memorial Park for Chuhuangkengs's Well. The unique anticline geography of Chuhuangkeng is the oldest oil field in Asia and represents an unique geographical landscape in some part of the field.

Brief history of the site: The first recorded discovery of petroleum in Taiwan was by Wu Linfang who accidently discovered oil floating on water by the banks of Houlong River in 1817. However, it was not until Qiu Gou who found the source of the oil claimed ownership of the spot, and start to excavate an oil well, the oil industry of Taiwan began.

At the beginning, the well was dug by hand to around 1 m down. It produced over 24 kg of oil per day. Later Qiu Gou sold the well to a British company, Dodd and Co. In 1877, the Ching government nationalized oil exploration and purchased the American machinery. This was the first successful use of steam power mechanized oil drilling in Taiwan.

In 1895, the Qing government ceded Taiwan to Japan. The Japanese government designated the Chuhuangkeng oil field as 'an oil field reserved for Navy use' and prohibited private oil extraction in this area. The use of new rotary drilling system enabled the oil field to its peak period of high output between 1927 and 1930.

Production became more active and opened to private Japanese companies to apply for the extraction. Since then, Chuhuangkeng has become a complete town with more wells, natural gas pipe, cable system, oil refinery, office, workers' dormitories, recreational facilities and clinic.

After Taiwan was returned to China in 1946, the Taiwan Petroleum Exploration Office took over the management of Chuhuangkeng. The site was in a poor state because equipment had been transferred to Southeast Asia by the Japanese during the war. However, in 1952, the Chinese Petroleum Corporation (CPC) set a training program. The United Nations and US government sent engineers to help drill two new wells. Although output of oil was not impressive the development of the communities led to new schools, auditoriums and public space.

In 1959, the CPC purchased two sets of large-scale drilling equipment from the USA and started the exploration and development of deep oil and gas reservoirs. Until 2011, a total of 147 wells had been drilled at this area. The Well No. 145 had been drilled down to a depth of 3800 m. It is estimated that around 50000 m^3 of natural gas can be exploited for the next 20 years. Chuhuangkeng oil field is still a living heritage site.

Cultural and symbolic dimension of the site: The cultural and symbolic dimension of the site includes the possibility of the second oil well in the world with its complete preserved oil industrial facility, settlement and landscape. Moreover, it is a still an operational site (now focused on the production of natural gas). In addition, due to the need of manpower of oil industry, the Hakka ethnic culture is developed here as majority of workers are Hakka.

Comparative analysis: Chuhuangkeng is considered among the earliest places of industrial petroleum extraction, and it is certainly one of the first in Asia. In Japan, Niigata Prefecture had early records of oil production in 1874. Niigata City has the historic Shinjin Oilfield Kanazu Mining Site (新津油田神奈礦場) which also used American machinery. It was officially designated as Japan Heritage. In 1985, Petroleum Village Park in Akiba-ku was planned with the remains of oil industry as a 'geology hike' to observe the oil heritage, rocks around Mount Bodera. It is managed by the Community Association of Petroleum Association and additionally has a World Petroleum Museum nearby.

Present site management

Present use: Chuhuangkeng was listed by the Cultural Heritage Preservation Act Taiwan in 2008, and is now a protected cultural landscape by law. The CPC and Maili County work together on the conservation and reuse projects since 2008. Several Japanese style buildings have been restored and will be open to public in 2019. The Taiwan Oil Field Exhibition Hall was originally built in 1981 and the building and exhibition was remodelled in 2018. The site and Museum are regularly open to the public. There are still many projects on the way such as the Ecomuseum and the restoration of five workers' houses.

Bibliography

Chen, Zheng-san (2005), *Record of Oil Drilling at Chuhuangkeng*, Lishi Zhiku Publishing, Ltd.

Chung Hua University (2009), *Survey of Ecological Resources in the Chuhuangkeng District of Micoli County*, International Culture and Tourism Bureau, Miaoli County Government.

Gan, Bi-tong, ed.(2012), *The Chujuangkeng Historic Oil Field Cultural Park,* International Culture and Tourism Bureau, Miaoli County Government.

Huang, Chun-Ming (Chung Yuan Christian University) (2008), *A Survey of Oil Industry Related Cultural Landscape Preservation and Re-vitalization at Chuhuangkeng, Gongguan Township, Miaoll County*, International Culture and Tourism Bureau, Miaoli County Government

Liu, Yan-Liang, 2009, *The Research on the Petroleum Facilities Development of Chu-Huang Keng Mine,* Master Thesis, Chung Yuan Christian University.

Shi, Wan-hui (2009), *Retired Oil-workers from Chuhuangkeng Tell Their Stories*, International Culture and Tourism Bureau, Miaoli County Government.

Xu, Jin-rong and Dan, Yun-xi (2007), *Landscaping Proposal for Chuhuangkeng*- The "Oil Field Country" Miaoli New Community Association.

8.10 Trans-Arabian Pipeline, Saudi Arabia

Majed Salal Al-Mutlaq and Matar Ayed Al-Anizi, Northern Area Cultural Society, Abdullah Khalifa Al-Dossary and Abdulrahman Farid Al-Hussain, Ministry of Culture, Saudi Arabia

The Tapline. (© Creative Commons)

Presentation and analysis of the site

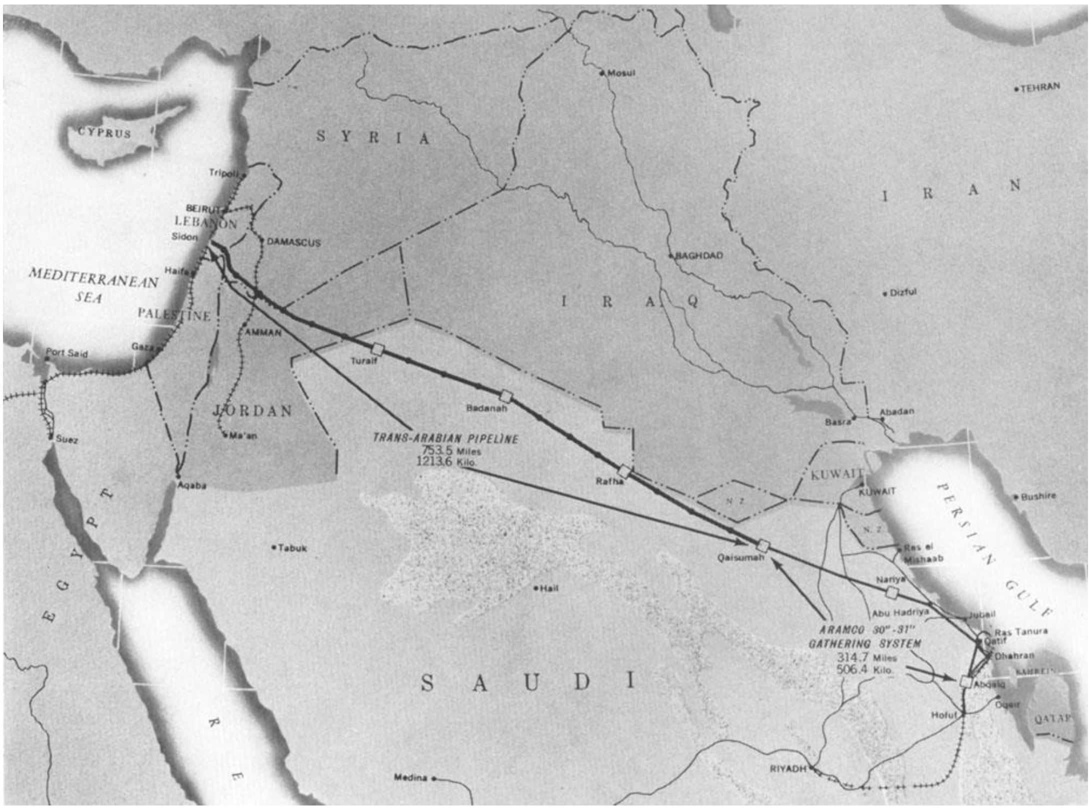
General description: The Tapline was the longest oil pipeline in the world (total length 1,213 km) when it was put into operation, connecting the Gulf oilfields with the Mediterranean port of Sidon, from which oil was shipped to Europe, the whole operation being much more efficient than using tankers.

The transportation of large quantities of oil from the Arabian Gulf to the Mediterranean on its way to European markets is in itself a major challenge. During the mid-20th twentieth century, a tanker sailing between Ras Tanura and the Mediterranean used to take ten days each way and costs $ 30,000 per tanker to pass Suez Canal. Therefore, the idea came of constructing a pipeline across the deserts of Arabia during 1940s.

Trans-Arabian Pipe Line Company or Tapline was established in 1945 in Delaware, US, the same state where Saudi Aramco is established. The project was mainly driven economically in order to secure the energy demand of the world. The original route of the pipeline was from eastern Saudi Arabia to ports in Palestine but due to political conflicts it was rerouted to pass through Jordan and over the Golan Heights in Syria and to end at Sidon in Lebanon.

The project with its large scale was constructed in very short period of time, 1948 -1950. More than 200,000 pipe joints were used with the utilization of 3,000 pieces of heavy equipment at total construction cost of $230 m.

In September 1950, Tapline started operation and required two months to be completely pressurized and filled. The first tanker left Sidon port on the 2 December, 1950. Aramco owns and operates the eastern portion of the pipeline system, up to and including the tank farm at Qaisumah. The portion owned and operated by the Trans-Arabian Pipeline Company extends from Qaisumah to the five-berth tanker loading terminal near Sidon, Lebanon. Tapline section has four main pumping stations, all in Saudi Arabia including Qaisumah, Rafha, Badanah (Arar) and Turaif. Locations selected in the open desert have become small communities and grown into four cities.



The route of the Trans-Arabian Pipeline.

The end of pipeline operations was also instigated by political tension in the region, sabotage and related problems with the section passing over the Golan Heights. Tapline western (Syrian and Lebanese) portions of the line ceased in 1978 due to civil war in Lebanon. In 1983, crude transport was limited to Jordan serving Al-Zargha Refinery only with limited quantity. Due to the 1990Gulf War, Tapline operations officially ceased. In early 2000, the four Saudi pumping stations were demolished.

Brief inventory: Tapline assets include 1,213 km of steel pipeline with 30-inch and 31-inch diameter which is still in place. Four main pumping stations (Qaisomah, Rafha, Arar and Turaif in Saudi) have been removed but their land areas are enclosed and protected by local authorities. Of the four auxiliary pumping stations (Al-Shabah, Al-Uaigaliyah, and Hizam Al-Jalameed in Saudi and Al-Ghariatin in Jordan) only the Jordanian station is still in existence, although not operational. Sidon terminal is now the site of a large, modern electrical power station and a modest petroleum importing terminal.

Cultural and symbolic dimension of the site: Tapline was an important factor in the global trade of petroleum, national development of the Arab countries involved, and affected Middle Eastern political relations.

The importance of Tapline is not, however, limited to its global economy impact and energy security but also its social and economic development which resulted in establishing four cities in the kingdom with a total population of 360,000 people. Most of the line crosses desert lands previously occupied only by Bedouins. Tapline contributed significantly to the welfare of these cities based on the agreement signed with the kingdom in 1947. The company's contribution to the community included but was not limited to: water wells development, new job opportunities, infrastructure planning, construction and operation including roads, electricity and municipality services, education, and healthcare including specialty hospital, and shaping the region's cultural identity. The original route surveyors, and the drillers who put down water wells for the proposed pumping stations, were the first Westerners to set foot on some parts of the route.

The project faced multiple complicated technical challenges that required innovative interventions that ventured into new grounds or set new records at the time. Special equipment was designed and built to weld three joints together mechanically at the construction terminals in order to accelerate the construction process by reducing the number of manual welds.

The Sky-Hook at Ras Misha'ab, where port, camp and construction facilities were established, was a major innovation developed by Tapline, an overhead cable system, nearly five kilometres in length, over which pipe joints were carried from ship to shore. Although the basic idea was borrowed from the logging industry, changes in design and special construction of the equipment were required for this project.

Comparative analysis: Pipelines have played important strategic roles since the beginning of the industrial production, with early technical innovations being worked out in Pennsylvania, Ontario and Baku. Nevertheless, sections of oil pipeline have not hitherto been conserved.

The Smithsonian Institution celebrated the 1977 Trans-Alaska Pipeline with an exhibition that noted the immense construction challenge and significant impact which it had on oil supplies to America, as well as the new climatological context and unprecedented environmental opposition to what has been labelled 'history's most expensive private engineering enterprise' (Coates 1999).

Present site management

Present use: Disused. The sites are not being protected legally by all the countries where it does pass, and the government of Saudi Arabia is guarding the pump stations sites by local administration.

Bibliography

Excerpts from *Handbook for American Employees*, Volume 1, 1952 as issued by Arabian American Oil Company by Roy Lebkicher.

Energy to the world - Saudi Aramco, volume 2, 2011 as issued by Aramco Services Company by Scott Mcmurray

The kingdom and Saudi Aramco, 2007, by Saad Ayed Al-Gharni.

Oil, wealth and 50 years of executive management, 2013, by Ibrahim Al-Munaif.

Northern Area authenticity and culture, 2017, MatarAyed Al-Enizi

8.11 Standard Oil building, New York, United States

This study is based on the New York Landmarks Preservation Commission Designation

No. 26 Broadway, New York (© Creative Commons)

Presentation and analysis

Location: 26 Broadway, New York

General description: An imposing office building with a Renaissance Revival style facade, built in three phases between 1885 and 1928.

Brief inventory: The headquarters of John D. Rockefeller's Standard Oil (SO) incorporates the company's original offices designed by Ebenezer L. Roberts, built in 1884-85 and enlarged in 1895. It was finally completed in 1928 by the architectural firm of Carrère and Hastings. The building is notable for its distinctive tower, one of the southernmost spires in the Manhattan skyline, and the sweeping curve of the Broadway facade. The powerful sculptural massing and arresting silhouette of the enlarged Standard Oil Building represented the new set-back skyscraper forms that emerged during the early 1920s. The exterior features boldly carved elements, columns at the top of the base and upper tier of the tower. Lamps and torches are used to represent the oil business.

Brief history of the site: The first SO headquarters was built in 1885 on 26 Broadway when John D. Rockefeller, who had founded the firm in 1870, relocated its operations from the refinery town of Cleveland, Ohio, to the symbolic business centre of lower Manhattan. It was enlarged as Standard Oil approached its fiftieth year of operation, reinforcing the presence of the oil industry giant in the heart of New York City's financial and shipping centre. Many late-19th century offices in lower Manhattan were replaced in the 1920s with larger structures bearing the name or logo of the corporation.

From the headquarters building at No. 26 Broadway, Rockefeller's associates directed the Standard Oil Company which monopolized the American oil industry. After the American Congress' decision to break it up, Standard Oil of New Jersey remained the largest of the Standard Oil group, retaining its headquarters in the Standard Oil Building and its dominant place in the international oil business.

Although Standard Oil's successor firm sold the structure in 1956, the building at No. 26 Broadway has remained a prominent address.

Cultural and symbolic dimension of the site: The Standard Oil building is the clearest tangible manifestation of the rapid growth of the petroleum industry in the United States to its position of global dominance within twenty-five years of the Drake oil strike, and of the part which Rockefeller´s company played in that ascent. The company was responsible for important technical developments as well as consolidating production into a vertically integrated company which was a global model for other ambitious corporations. It drove the growth of the industry in the United States and stimulated rival operations elsewhere in the world.

In response to anti-monopoly legislation, the Standard Oil Trust was born at 26 Broadway in 1899, and the building symbolises the immense influence and wealth that the oil company and other US industrial corporations achieved during the late 19th century. It also symbolises the anti-trust efforts of citizens, journalists and government that tried to counter that concentration of power and their success in forming critical attitudes toward monopoly capitalism.

Among the reasons for designating the Standard Oil Building in 1995, the NY Landmark Preservation Committee noted that 'the veneer-like limestone curtain walls are enriched with large-scale Renaissance ornamentation and reinforce the building's picturesque quality, particularly at the upper stories; that the distinctive tower, one of the southernmost spires in the Manhattan skyline and loosely based on the Mausoleum of Halicarnassus, is a symbol of corporate power and a prominent element in the iconographic program of the building'.

Comparative analysis: The Standard Oil building is the first of the corporate headquarters constructed by the global oil companies, of which SO was the forerunner and model, and which are clear, tangible evidence for the enormous industrial, commercial and political influence that they wielded through the 20th century. Contemporary business rivals British Petroleum and Royal Dutch Shell built imposing headquarters in London and Amsterdam, and from the 1920s the big oil corporations based in regional oil capitals such as Tulsa, Houston and Calgary followed the New York example of statement company offices. Modern national oil companies have taken the model to new lengths with their massive towers in Kuala Lumpur, Dubai, Beijing or St Petersburg.

Present site management

Present use: Offices let to various tenants.

Protection regime: New York City historic landmark

Bibliography

Landmarks Preservation Commission, September 19, 1995, Designation List266 LP-1930, prepared by Betsy Bradley, Research Department

9. Bibliography

TICCIH Thematic studies:

Bergeron, L. (1995). Les villages ouvriers comme éléments du patrimoine de l'industrie

Coulls, A. (1999). Railways as World Heritage sites

Delony, E. (1996). Context for World Heritage bridges

Gwyn, D. (2016). Stone quarrying landscapes as World Heritage sites (unpublished)

Hughes, S (1996). The International Canal Monuments List

Hughes, S. (2001). The International Collieries Study

Douet, J (2018). The Water Industry as World Heritage

Allen, B. L. (2006). Cradle of a Revolution?: The Industrial Transformation of Louisiana's Lower Mississippi River. *Technology and Culture*, *47*(1), 112–119.

American Petroleum Institute. Division of Production. (1961). *History of petroleum engineering*. New York: New York.

Barrett, R., and Worden, D. (2012). Oil Culture: Guest Editors' Introduction. *Journal of American Studies*, *46*(2), 269–272.

Black, B. (2000). *Petrolia: the landscape of America's first oil boom*. Baltimore, MD: Johns Hopkins University Press.

Brantly, J. E. (1971). *History of oil well drilling*. Houston: Euromoney Institutional Investor PLC : Book Division, Gulf Pub. Co.

Brice, W. R. (2009). *Myth, legend, reality: Edwin Laurentine Drake and the early oil industry*. Oil City, PA: Oil Region Alliance of Business, Industry and Tourism.

Clark, J. S. (1958). *The oil century, from the Drake well to the conservation era /*. Norman,: University of Oklahoma Press.

Colten, C. E. (2006). The Rusting of the Chemical Corridor. *Technology and Culture*, *47*(1), 95–101.

Connan, J. (1999). Use and trade of bitumen in antiquity and prehistory: Molecular archaeology reveals secrets of past civilizations. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *354*.

Cotte, Michel, in Douet, J. (2015). *Industrial Heritage Re-tooled: The TICCIH Guide to Industrial Heritage Conservation*. London; New York: Routledge.

Craig, J., Gerali, F., MacAulay, F., and Sorkhabi, R. (2018). The history of the European oil and gas industry (1600s–2000s). *Geological Society, London, Special Publications*, *465*(1), 1-24.

Crinson, Mark. (1997). Abadan: Planning and Architecture under the Anglo-Iranian Oil Company. *Planning Perspectives 12 (3)*, pp. 341-35 9.

Dean, G. (2018). The Scottish oil-shale industry from the viewpoint of the modern-day shale-gas industry. *Geological Society, London, Special Publications*, *465*(1), 53–69.

Forbes, R. J. (1958). *Studies in Early Petroleum History*. Brill Archive.

Forbes, R. J. (1959). *More studies in early petroleum history*. Brill Archive.

Frank, A. F. (2005). *Oil empire: visions of prosperity in Austrian Galicia*. Cambridge, Mass: Harvard University Press.

Frantál, B., and Urbánková, R. (2017). Energy tourism: An emerging field of study. *Current Issues in Tourism*, *20*(13), 1395–1412.

Fuccaro, Nelida. (2013). Histories of Oil and Urban Modernity in the Middle East. *Thematic Issue of Comperative Studies of South Asia, Africa, and the Middle East 33 (1).*

Gennadiy, G., and Volodymyr, B. (2018). Development of the oil industry in the US (Part II). *РОЗВИТОК НАФТОВОЇ ПРОМИСЛОВОСТІ В США У ХХ Ст. (ЧАСТИНА ІІ)*, *158*(6), 41–45.

Gennadiy, Gayko, and Volodymyr, Biletsky. (2018). Development of the oil industry in the US (Part I). *Схід, Vol 0, Iss 4(156), Pp 37-40 (2018)*, (4(156)), 37.

Gerali, F., and Gregory, J. (2017a). Harsh oil: finding petroleum in early twentieth century Western Australia. *Geological Society, London, Special Publications*, *442*(1), 425–436.

Gerali, F., and Gregory, J. (2017b). Understanding and finding oil over the centuries: The case of the Wallachian Petroleum Company in Romania. *Earth Sciences History*, *36*(1), 41–62.

Gerali, F., and Riguzzi, P. (2017). Gushers, science and luck: Everette Lee DeGolyer and the Mexican oil upsurge, 1909–19. *Geological Society, London, Special Publications*, *442*(1), 413–424.

Gerali, F., Craig, J., MacAulay, F., and Sorkhabi, R. (2018). Gazetteer of oil and gas museums in Europe. *Geological Society, London, Special Publications*, *465*(1), 1-1.

Gerali, F. (2019). *An historical overview over the development of the drilling fluids technology in the 19th century.* De Re Metallica Special Issue "Historia de los Hidrocarburos". Instituto Geológico y Minero de España (IGME).

Giddens, P. H. (1938). *The birth of the oil industry*. The Macmillan Company.

Giddens, P. H. (1947). *Pennsylvania petroleum, 1750-1872 : a documentary history.* Titusville: Drake Well Memorial Park, Pennsylvania Historical and Museum Commission.

Giddens, P. H. (1948). *Early Days of Oil. A pictorial history of the beginning of the industry in Pennsylvania*. Princeton University Press, Princeton.

Gordon, R. B., and Malone, P. M. (1994). *The texture of industry: An archaeological view of the industrialization of North America*. New York: Oxford University Press.

Gray, E. (1970). *The great Canadian oil patch*. Maclean-Hunter.

Gray, E. (2008). Gesner, Williams and the Birth of the Oil Industry. *Oil-Industry History*, *9*.

Hatley, A. G., and American Association of Petroleum Geologists (Eds.). (1992). *The oil finders: a collection of stories about exploration*. S.l.: American Association of Petroleum Geologists.

Hein, C. (2009). Global Landscapes of Oil. *New Geographies 02: Landscapes of Energy, Edited by Rania Ghosn*, 33–42.

Hein, C. (2018a). Oil Spaces: The Global Petroleumscape in the Rotterdam/The Hague Area. *Journal of Urban History*, *44*(5), 887–929.

Hein, C. (2018b). Old Refineries Rarely Die: Port City Refineries as Key Nodes in The Global Petroleumscape. *Canadian Journal of History*, *53, winter*, 450–479.

Hein, C., and Sedighi, M. (2016). Iran's Global Petroleumscape: The Role of Oil in Shaping Khuzestan and Tehran. *Architectural Theory Review*, *21*(3), 349–374.

Jack, R. I. (1995). Joadja, New South Wales; The Paragon of Early Oil-Shale Communities. *Australasian Historical Archaeology*, 13, 31–40.

Kambara, T. (1974). The Petroleum Industry in China. *The China Quarterly*, *60*, 699-719.

Kemp, E. L. (2000). Archeology in the Ontario Oil Field. *Oil-Industry History*, *1*(1).

Kemp, E. L., and Caplinger, Michael. (2007). *19th century petroleum technology in North America*. Morgantown, West Virginia: Institute for the History of Technology and Industrial Archeology.

Kemp, E. L., R. O. (1984). *Fundamentals of the Petroleum Industry*. Norman: University of Oklahoma Press.

Macini, P. and Mesini, E, (2018). History of petroleum and petroleum engineering. In *PETROLEUM ENGINEERING – UPSTREAM*: *Vol.IV*. *EOLSS*. Eolss Publishers Co. Ltd.

Méndez, P. A., Ciselli, G., andSancristoful, C. R. (2016). El patrimonio industrial petrolero en la Patagonia: Comodoro Rivadavia (Argentina) y Cerro Sombrero (Chile). Una perspectiva comparada. *PASOS. Revista de Turismo y Patrimonio Cultural*, *14*(4), 981–997.

Metsaots, K., Printsmann, A., and Sepp, K. (2015). Public Opinions on Oil Shale Mining Heritage and its Tourism Potential. *Scandinavian Journal of Hospitality and Tourism*, *15*(4), 380–399.

Mir-Babayev, Mir-Yusif. (2017). Brief history of the first drilled oil well; and the people involved. Oil Industry History, 18(1), 25–34.

Morritt, Hope. (1993). *Rivers of oil: the founding of North America's petroleum industry*. Kingston, Ont.: Quarry.

Oehlke, Andreas. (2010). 150 Jahre Raffinerie Salzbergen. *Industriekultur*, pp. 9–11.

Oil's first century; papers. (1960). [Cambridge]: Harvard Graduate School of Business Administration.

Purdy, Gordon A. (1958). *Petroleum: prehistoric to petrochemicals*. Vancouver: Copp Clark Publishing Co ; New York.

Sánchez Figueroa, L. (2014). Le patrimoine industriel pétrolier vénézuélien: Un patrimoine toujours en activité. *e-Phaïstos. Revue d'histoire des techniques / Journal of the history of technology*, *III*(III-1), 112-122.

Sandberg, Finn, and Gjerde, Kristin. (2017). *Preserving Norway's Oil Heritage*. Artefacts. Studies in the History of Science and Technology. Volume 11. 150.

Seccombe, Ian J., and Lawless, Richard. (1987). Work camps and company towns: Settlement patterns and the Gulf oil industry. *Occasional Papers Series*, *36*. University of Durham, Centre for Middle Eastern and Islamic Studies, Durham.

Serra, R. (2010). *La Mina de petroli de Riutort (Guardiola de Berguedà)*. Manresa] : [Cercs: ZenobitaEdicions ; Consorci Ruta Minera.

Talbot, F. A. (1914). *The oil conquest of the world*. London: Heinemann.

Thomas, R. (2018). The development of the manufactured gas industry in Europe. *Geological Society, London, Special Publications*, *465*(1), 137–164.

Tolf, R. W. (1976). *The Russian Rockefellers: the saga of the Nobel family and the Russian oil industry*. Stanford, Calif: Hoover Institution Press, Stanford University.

UNESCO World Heritage Committee. (2017). *The Operational Guidelines for the Implementation of the World Heritage Convention*.

Vassiliou, M. S. (2009). *Historical Dictionary of the Petroleum Industry*. Scarecrow Press.

Visvanath, S. N. (1991). *Hundred Years of Oil: Narrative Account of the Search for Oil in India*. New Delhi: Vikas Publishing House Pvt Ltd.

Williams, C. E. (2008). *Western Pennsylvania's oil heritage*. Charleston, S.C.: Arcadia Pub.

Williamson, Harold F., and Daum, Arnold R. (1959). *The American Petroleum Industry: The Age of Illumination, 1859–1899* (Vol. 34). Evanston: Northwestern University Press.

Yergin, D. (2008). *The prize: the epic quest for oil, money and power*. New York: Free Press.

Appendix: Discovery and Production Timeline

This brief summary presents major events in the discovery of petroleum around the world up to the 1990s, first as natural seepages, from the mid-19th century by drilling, and during the 20th century over almost the entire surface of the world, on land as well as below the sea.

It has been largely compiled by Dr Francesco Gerali drawing on primary and secondary sources, with contributions from the timeline prepared by Clinton Tippett, President of the Petroleum History Society, in 2014.

- ca. 4,000 BCE: Archaeological exploration locates the site of an oil seep on the banks of the Euphrates River (today Iraq) where asphalt was quarried for use as mortar.
- 1450 BCE: First artificial lighting by censers fuelled by petroleum matter.
- 900 BCE: Natural gas utilized by the Chinese.
- 500 BCE: First man-made oil well dug in Mesopotamia during the reign of Darius the Great.
- 450 BCE: Herodotus describes the so-called pitch spring in the island of Zante, an oil seepage still flowing today.
- 400 BCE: Streets in Jerusalem and Antioch are lighted at night by burning petroleum.
- 38 BCE: Natural gas found in salt wells in Szechuan Province, China.
- 66 CE: Plutarch mentions petroleum found near what is now the Kirkuk field, Iraq.
- 100: Coptic alchemists report on the petroleum distillation method in which vapour is delivered to a thin-necked vessel cooled with air or sponges.
- 100: Pliny observes that the Sicilian Oil seeping in the lake near Agrigentum, Sicily, is burned in the lamps of the Temple of Jupiter.
- 3rd century: Bitumen is mined under a Roman concession in the region Abruzzo, central Italy.
- 10th century: Arabian traveller visits and describes the Absheron Peninsula, petroleum recognised as a valuable article.
- 10th century: Chinese reported piping gas through bamboo tubes for lighting. This is the first documented use of pipelining.
- 1273: Marco Polo records a visit to the Persian city of Baku, on the shores of the Caspian Sea, where he sees oil being collected from seeps for use in medicine and lighting, and views the Eternal Fires.
- 1436: Oil from a spring near the St. Quirinus Abbey of Tegernsee, in Bavaria, attains medicinal fame and it is sold as St. Quirinus oil.
- 1498: Documentation refers to oil seepage in the area around Pechelbronn in Alsace. The residents obtain oil from seeps and shallow pits.
- 16th century: Oil from seeps in the Carpathian Mountains in Poland burned in street lamps in the Polish town of Krosno.
- 1594: Oil wells are hand dug at Baku down to 35 m in depth.
- 1596: Sir Walter Raleigh uses bitumen from the Pitch Lake, Trinidad.

- 1627: Father Joseph de la Roche d'Allion, Franciscan French missionary, describes a *fontaine de bitumen* (spring of petroleum), near the village of Cuba, New York.
- 1650: Hand-dug oil shafts producing in the Bacau district of Moldavia, today Rumania.
- 1723-1725: Russian Emperor Peter the Great conquers the Khanate of Baku and grants concessions in the Baku district to private individuals who dig wells by hand and produce some oil.
- 1710: Eyrini d'Eyrinis discovers *asphaltum* at Val-de-Travers near Neuchâtel in Switzerland, and establishes a bitumen mine called de la Presta which will operate until 1986.
- 1735: Tunnels are sunk into the hillsides of the Pechelbronn oil springs. In 1745, the district starts producing bituminous asphalt, a business that would last until mid-20th century.
- 1748-1750: North America is visited by Swedish naturalist Peter Kahn who publishes a map indicating the oil springs at the Oil Creek in Pennsylvania.
- 1781: Captain Voynovich, chief of the Russian Naval Fleet in the Caspian Sea, finds the signs of oil and gas off-shore near the Absheron Peninsula and charts a detailed map.
- 1803: Offshore oil production reported in Bibi-Heybat Bay in the Caspian Sea (Azerbaijan) from two hand-dug wells 18m and 30m from the shoreline.
- 1806-08: David and Joseph Ruffner in West Virginia complete brine wells using the percussive or hammering method, and design the spring-pole rig to raise and lower their cutting tool. This is considered to be the first drilling operation with a direct influence on the petroleum drilling in the decades to come.
- 1825: Michael Faraday uses the expression *hydrocarbons* for the first time in his article *On New Compounds of Carbon and Hydrogen, and on Certain Other Products Obtained during the Decomposition of Oil by Heat*.
- 1829: The French missionary Laurent Imbert wrote about the common Chinese drilling practice: the borehole was lined up with wooden pipes (casing); thumping up and down inside the pipes, suspended by a rattan cable, there was a metal drilling tool.
- 1841: James Young in Scotland develops a process to extract hydrocarbon liquids from shale.
- 1845: French engineer Pierre-Pascal Fauvelle drills in just 54 days a water well in Perpignan, France, to 219 m using a water-flushed set of tools called hydraulic drill.
- 1846: The first modern oil well is drilled to 21 m northeast of Bibi-Heybat, Baku.
- 1846: Canadian Physician and geologist Abraham Gesner lights lamps filled with oil distilled from Albertite. He then distils lamp fuel, patented in 1850, and coins the term Kerosene from the Greek *keros*, wax and *elain*, oil.
- 1849-1850: Samuel Martin Kier starts experimenting in the United States with distillation. He implements the first attempts to process liquid petroleum as oil lamp fuel for large-scale production.
- 1853: The first commercial petroleum wells in Europe are drilled 30 to 50 m at Bóbrka, Poland.
- 1854: Charter for the world's first petroleum company, the International Mining and Manufacturing Company, granted to Charles Nelson Tripp in Oil Springs, Ontario.

- 1855: The chemist Benjamin Silliman, of Yale University, proves that crude oil could be decomposed through a process of fractional distillation into a range of fuels and lubricants.
- 1855: Telega Tunggal No 1 in Sumatra is the first oil well in Indonesia.
- 1857: First drilling of oil wells at Bend on the Romanian side of the Carpathians.
- 1857: Bucharest public illumination is entirely fuelled by national petroleum.
- 1858: James Miller Williams digs first commercial oil well in North America at Oil Springs in Ontario, Canada. This is also site of the world's first integrated oil company, producing, refining and marketing oil.
- 1859: Edwin Drake drilling for the sole purpose of finding oil is successful in Titusville, Pennsylvania, US. His achievement is conventionally considered the point zero of the modern petroleum industry.
- 1860: At Salzbergen, Germany, the first modern refinery of the country opens.
- 1860: First commercial oil production in Ploiesti, Romania.
- 1861: In New Jersey, a small refinery accidentally produces *gasoline* by overcooking lamp kerosene a foul-smelling, almost colourless liquid that ignites very easily.
- 1861: First recorded international shipping of oil, from Pennsylvania to London.
- 1863: The diamond drill rotary system is developed by the French engineer Rodolphe Leschot.
- 1865: The first oil processing plant of the Netherlands is established in Pakhuismeesteren, close to Rotterdam.
- 1865: First percussive mechanical drilling and modern refinery operating in Italy in the Abruzzo region.
- 1866: Oil Well Supply Company established in Petrolia. It manufactured and shipped equipment (steam engines, drilling rig, air blowers etc.) to South America, Asia, Australia, Africa and Europe.
- 1866-1876: The introduction by Amos and James Densmore of a 3,400 gallon tank car composed of two vertical positioned cylindrical vats first, and later the riveted wrought iron, horizontal boiler-type, instigates the bulk transportation of petroleum via railways.
- 1872: The 42-gallon oil barrel standard acknowledged by the Petroleum Producers Association.
- 1875: The Nobel Brothers open the first modern refinery in the Caucasus.
- 1876: First oil production in California from the San Fernando Valley.
- 1877: The pump jack is patented by Plackross. It will replace the wooden walking beam used to pump out oil since the beginnings of the industry.
- 1878: First oil drilling at Lake Maracaibo, Venezuela.
- 1880: Imperial Oil formed by sixteen refiners in London, Ontario, Canada in an attempt to prevent Standard Oil from taking over Canadian oil interests.
- 1883: Discovery of natural gas at Langevin Siding in what is now south-eastern Alberta, Canada.
- 1883: The Balakhany Field on the Absheron Peninsula in Azerbaijan has 375 active wells.

- 1886: Delivery of the first modern ocean-going oil tanker.
- 1889: Austrian engineer Albert Fauck introduces his improved type of percussion drill which used a master-flush method and called the Fauck Express.
- 1882-1893: First successful applications of rotary drilling with fluids down hole circulation in Iowa, Minnesota, Louisiana, and Texas. This technology will be fundamental for the 20th century Texas oil boom and the boost to the global oil exploration and development.
- 1890: Discovery of oil at Digboi, India.
- 1891: Vladimir Grigoryevich Shukhov together with Sergei Gavrilov successfully develop a continuous thermal cracking process in Tsarist Russia. This process remained almost unnoticed because there was almost no use for gasoline at the time.
- 1891: The first patent for adjusting and steering the direction of the drill bits.
- 1892: First oil exploration well in Australia.
- 1893: Francis H. Davis in Western Australia patents the Calyx drilling system, an effective rotary device effective at low depths.
- 1894: Discovery of the Midway-Sunset Oil Field in California, US.
- 1895: Extraction of bitumen from bituminous sand using hot water at Carpenteria, California, US.
- 1896: First successful offshore oil production from a pier at Summerland, California, US.
- 1897: First significant oil drilling at Dushantsi, China.
- 1899: Gushing well struck at Karashungul, Kazakhastan.
- 1901: Spindletop gusher blows out, recalibrating the potential of oil as a global energy source and heralding the birth of the Texas oil industry.
- 1902: Discovery of oil at Waterton, Alberta, Canada.
- 1904: Mexican oil production begins in commercial quantities.
- 1905: Glenn Pool field, Oklahoma, US, is the turning point for the development of the oil industry in the state.
- 1906: Gasoline stations opening across the United States.
- 1907: Comodoro Rivadavia oil discovery in Argentina.
- 1907: First commercial oil discovery in Trinidad.
- 1908: Oil discovered in Iran.
- 1908: First oil discovery in Egypt.
- 1909: Howard Hughes, Sr. invents the roller cone drilling bit, fostering the diffusion and establishment of rotary drilling.
- 1910: First discovery of oil in Malaysian Borneo, Sarawak.
- 1910: First major oil discovery in Tampico, Mexico. The Potrero de Llano 4 well equals the result of Spindletop and launches the modern Mexican oil industry.
- 1911: The US Supreme Court orders the dissolution of Standard Oil Trust, resulting in the creation 34 new refining companies.

- 1913: Offshore drilling initiated from platform in shallow waters of Lake Erie in Canada.
- 1913: The Burton-Humphreys thermal cracking process for the enhanced production of gasoline from crude oil is patented by William Merriam Burton and Robert E. Humphreys.
- 1914: The Turner Valley Field, Alberta, Canada, extracting and processing natural gas and gasoline.
- 1915: Production of natural gas from fractured shales begins in the Big Sandy Field, Kentucky, US.
- 1916: Beginning of oil exploration campaign in Western Australia.
- 1916: Discovery of the Infanatas Field, Columbia.
- 1916: Ventura Field is successfully drilled in California, US.
- 1916: Tampico discoveries, Mexico.
- 1917: First commercial production of LNG.
- 1918: Panhandle Field, in Texas, US, is struck and boosts the state oil production.
- 1919: Britain's first oil discovery at Hardstoft in Derbyshire.
- 1920s: The US Coast and Geodetic Survey conducted a series of experiments to determine the feasibility of the pendulum method to locate petroleum deposits.
- 1920: Huntington Beach Field, California, US.
- 1920: Norman Wells Field, Northwest Territories, Canada.
- 1922: Las Barrosos Field, Maracaibo, Venezuela. The discovery matches with the beginning of the industrial oil production in the country - today the richest of oil deposits in Latin American.
- 1922-1929: Italian, British, American and Albanian companies started the industrial development of the petroleum fields in Albania.
- 1926: The giant Yates Field, Texas, US, is found.
- 1927: Slant hole drilling at Huntington Beach, California taps offshore reserves.
- 1927: Discovery of the Kirkuk Field, Iraq.
- 1930: Discovery of the East Texas Field, Texas, US.
- 1932: First oil discovery in Bahrain.
- 1932: Wilmington Field discovery, California, US.
- 1932: The electromagnetic teleclinometer was introduced to determine the angle of inclination of the axis of a drill hole in relation to the vertical and the azimuth (of this inclination) and referring to the magnetic North.
- 1933: The first submersible drilling barge was used in the estuaries (Lake Pelto) Louisiana, US.
- 1938: Oil discovered in Kuwait (Bergan) and Saudi Arabia (Dammam).
- 1938: First freestanding offshore drilling operation, Creole Field, Louisiana, US.
- 1939: Oil discovery in Lachunmia Field, China.
- 1947: First producing oil well on the Outer Continental Shelf off Louisiana, US.

- 1948: Ghawar Field discovered in Saudi Arabia: the largest conventional oil field in the world.
- 1949: First offshore oil drilling at Oil Rocks (Neft Dashlari) in the Caspian Sea off Azerbaijan.
- 1949: Oil and gas discovered in Algeria.
- 1953: Oil discovered in the United Arab Emirates in the Murban field.
- 1953: Oil discovered in Western Australia, AUS, in the Rough Range field.
- 1955: First oil discovery in Angola.
- 1955: First commercial oil discovery in Nigeria.
- 1956: First offshore drillship.
- 1956: First offshore jack-up rig.
- 1956: Discovery of oil in Saharan Algeria.
- 1957: First Brazilian onshore oil discovery.
- 1958: Opening of the Trans-Canada natural gas pipeline from Alberta to Ontario.
- 1959: Natural gas discovered in Groningen Field, Netherlands.
- 1959: First commercial oil discovery in Libya.
- 1962: First offshore semi-submersible drilling rig and first offshore subsea well completion.
- 1963: Daqing oilfield in China put into production.
- 1965: The Norwegian Continental Shelf (NCS) is opened for petroleum exploration and drilling in 1965.
- 1967: First commercial production of the largest oil resource in the world, tar sands north of Fort McMurray, Alberta, Canada.
- 1968: Oil discovered at Prudhoe Bay, Alaska, US.
- 1969: Discovery of natural gas at the Drake Point Field, High Arctic of the Northwest Territories, Canada.
- 1969-1970: Oil discovered in commercial quantities in the Norwegian Ekofisk Field, North Sea.
- 1971: First mobile offshore production put in operation.
- 1972: First well drilled from an offshore self-stabilized drillship without anchors.
- 1972: First massive discovery of oil in Tabasco and Chiapas States, Mexico.
- 1973: First oil prices crisis generated by the oil embargo imposed by the Organization of Petroleum Exporting Countries (OPEC).
- 1975: First oil production from the North Sea, both in the UK and Norway sectors.
- 1978: Cognac production platform, Gulf of Mexico, US, is the first to operate deeper than 300 m.
- 1982: First attempted the vertical hydraulic fracturing into shale rocks for producing gas.
- 1986: First massive hydraulic frac in a vertical well in the Barnett Shale, Texas, US.

- 1984-1986: Off-Shore discovery of the Amauligak Field, Beaufort Sea, in the Canadian Artic.
- 1991: First horizontal fractured well is completed in the Barnett Shale, Texas, US.