Georesources for Sustainability

In Cornwall & the Isles of Scilly

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SETTING THE SCENE

This report introduces some of the world-leading examples of georesources being used to ensure sustainable development in Cornwall and the Isles of Scilly. The report is written for all those interested in understanding the diversity and potential of georesources and sustainable development as found in Cornwall and the Isles of Scilly, and aims to inspire debate, innovation and decision making.

WHAT IS THIS REPORT ABOUT?

GEORESOURCES ARE MATERIALS, SERVICES AND SOURCES OF INSPIRATION THAT COME FROM THE GROUND BENEATH OUR FEET – THAT IS, FROM THE SOLID EARTH (THE GEOSPHERE, WHICH INTERACTS WITH THE HYDROSPHERE, ATMOSPHERE AND BIOSPHERE).

These include raw materials that we extract from the surface or subsurface, including: construction materials such as building stone, sand and gravel; minerals containing metals of all kinds; and fossil fuels (coal, oil and natural gas). Georesources also include less obvious physical resources such as subsurface heat and groundwater, soils to sustain agriculture and ecosystems, carbon sinks and other 'buffering' functions against natural and human processes. Finally, they include attributes that contribute to less tangible assets like landscape, cultural identity, human health and wellbeing.

SUSTAINABILITY REFERS TO THE NEED FOR HUMAN SOCIETIES TO EXIST IN HARMONY WITH THEIR ENVIRONMENT, TO ENSURE THE LONG TERM VIABILITY OF BOTH.

The UN World Commission on Environment and Development (1987) defined **sustainable development** as development that 'meets the needs of the present without compromising the ability of future generations to meet their own needs'. This depends in turn on ensuring that present-day human activities do not harm our environment, and that we protect and sustain biodiversity and other aspects of **natural capital**. A closely linked concept is that of **environmental growth** – the regeneration of natural systems and growth of natural capital, providing a greater quantity and quality of environmental goods and services as the basis for a thriving society, a prosperous and resilient economy, and an abundance of wildlife. The **circular economy** will play a vital role in achieving this, encompassing not only recycling, but a wider rethink of how we use materials, designing out waste and pollution, keeping products and materials in use, and progressively decoupling economic activity from the consumption of natural resources. Natural capital also underpins **ecosystem services** – that is, the ways in which we derive societal and economic benefit from the environment.

The responsible use of georesources is integral to a sustainable future. Metals from the ground will be needed for low-carbon energy technologies, from wind turbines to batteries. We can harness geothermal energy from the subsurface as a renewable energy source. Recognising the vital part the geosphere plays in a wide range of ecosystem services will help us protect and regenerate natural capital. We can also learn from unsustainable past behaviours such as the indiscriminate burning of fossil fuels and insensitive approaches to mining, ensuring that georesources are extracted and used in a socially and environmentally responsible way, and that mined materials are then kept in use to meet the needs of future generations as well as our own.

CORNWALL'S PLANS FOR A PROSPEROUS & SUSTAINABLE FUTURE

Cornwall is richly endowed with georesources, and with the capabilities to harness them for sustainable development. These advantages are recognised and embraced by local leaders and communities, who have put them at the heart of Cornwall's ground-breaking and far-sighted plans for sustainable economic and environmental growth, including:

Cornwall's Environmental Growth Strategy 2015-2065, produced by Cornwall Council and Cornwall and Isles of Scilly Local Nature Partnership (and being refreshed in 2021). The first of its kind nationally, the strategy recognises the importance of local natural resources and landscape (including Cornwall's historic mining landscape) for the economy and society.

Climate Change Plan, developed by Cornwall Council in 2019 following its declaration of a climate emergency. This sets the demanding target of making Cornwall carbon neutral by 2030 (compared with a national target of 2050), through investment in renewable energy and associated infrastructure and protecting and enhancing natural carbon sinks, among many other means.

The Cornwall Plan 2020-2050, developed by the CIoS Leadership Board. This highlights the major economic potential of the 'green and blue economy', bringing together (mineral) georesources, renewable energy and marine technologies. It envisages deep geothermal, floating offshore wind power and lithium production in Cornwall resourcing a carbon-neutral Cornwall by 2030, and contributing to decarbonisation of the UK; and a sustainable tourism sector drawing on sense of place and cultural identity, as part of a more diversified economy.

Cornwall and Isles of Scilly (CIoS) Industrial Strategy, led by the CIoS Local Enterprise Partnership (draft, awaiting sign-off by the UK government). This builds on the earlier Strategic Economic Plan for CIoS and the more recent 10 Opportunities document. It seeks to address social and environmental imbalances arising from past narrow conceptions of economic growth, to deliver inclusive, clean and circular growth. It identifies five areas of distinctive opportunity for Cornwall, including clean energy (including geothermal) and georesources (referring to mineral resources, especially for the low-carbon economy).

Georesources are fundamental to delivering these plans, using Cornwall's natural resources to build sustainable and advanced industries, improve productivity and opportunity for all, and enhance the environment and quality of life.

WHO IS THIS REPORT FOR?

The topics outlined in this report are relevant to all those interested in delivering environmental growth and sustainable economic development in Cornwall. These include policy makers and others working in national and local government, companies, economic development bodies, voluntary and civil society organisations, and local communities. They also include geoscientists, environmental and social scientists, and other researchers and practitioners working to ensure that Cornwall's georesources are used responsibly, in the service of sustainable development. An aim of the report is to stimulate and inform dialogue between these groups and communities, and to help them engage wider public audiences in decision making about Cornwall's future.

MORE INFO

- **Cornwall's Environmental Growth Strategy 2015-2065**
  https://www.cornwall.gov.uk/environmentalgrowth
- **CIoS Draft Industrial Strategy**
  https://www.cioslep.com/vision/local-industrial-strategy
- **Cornwall Plan 2020-2050**
  https://www.tinyurl.com/cornwallplan

KYNANCE COVE

This stunning coastal site is enjoyed by Cornwall's communities and visitors, provides a habitat to distinctive flora and fauna, and helps us understand the Earth's deep past so we can live more sustainably on it in future. p 14 - 15

WHEAL JANE

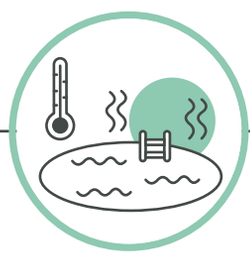
Now the site of a unique Earth Science Park, rising groundwater at this former mine site caused major contamination of the Carnon River and Fal Estuary in 1992, but it has since become an exemplar of mine site regeneration and mine water treatment. p 12 - 13

HEARTLANDS

This former mine at the heart of the UNESCO Cornwall and West Devon Mining Landscape World Heritage Site celebrates Cornwall's mining heritage, and offers a wide range of activities and amenities to visitors from near and far, helping to stimulate sustainable economic regeneration. p 6 - 7

JUBILEE POOL

This beautiful historic art deco lido is the largest in the UK, and features a geothermal pool, sustainably heated using energy from beneath the ground. p 10 - 11

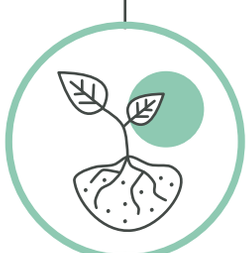


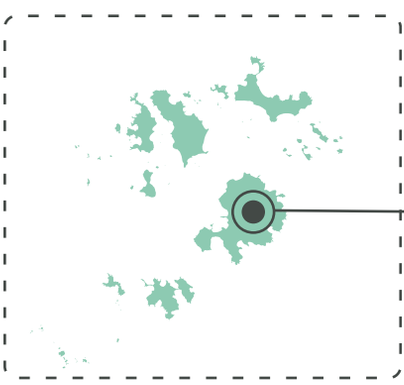
GEEVOR TIN MINE

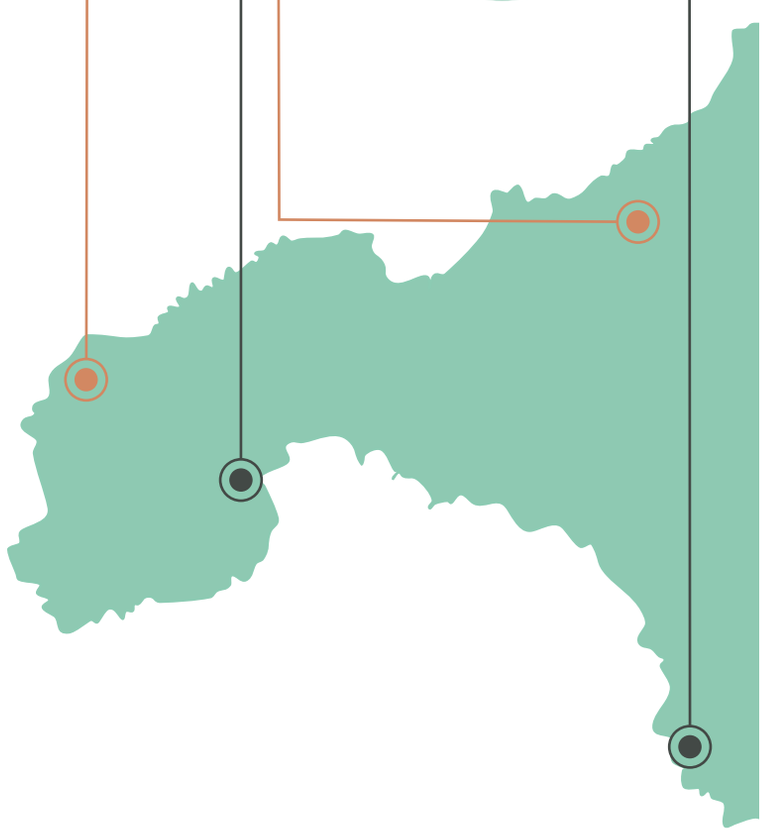
The historic tin mine is now home to a museum and heritage centre, as part of the UNESCO Cornwall and West Devon Mining Landscape World Heritage Site. p 6 - 7

ISLES OF SCILLY

Soils are an often overlooked georesource, and are a vital part of ecosystems and economies across Cornwall – and in the Isles of Scilly, where they have long underpinned the commercial cultivation of narcissi, pinks and other flowers. p 12 - 13





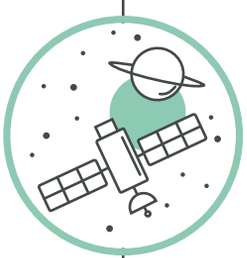


SPACEPORT CORNWALL

With the first launch planned for 2022, this is expected to be the UK's first launch site for satellites, which play an essential role in environmental intelligence gathering for many applications, including georesource exploration and global monitoring of mining impacts. p 16 - 17

DELABOLE SLATE QUARRY

Local building stones are vital to the character of Cornwall's built environment, and have been reused for centuries. p 6 - 7



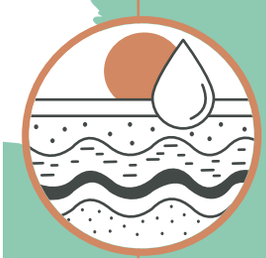
MILLOOK HAVEN

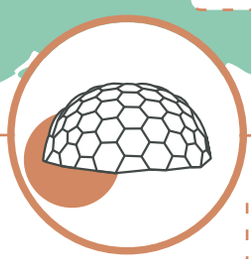
Cornwall's extraordinary and varied landscapes, on the coast and inland, are underpinned by their geology – they are essential to its tourism sector, promote physical and mental wellbeing, and provide leisure and enjoyment to local communities. p 14 - 15

IMERYS

UK KAOLIN PLATFORM

Cornwall's china clay industry remains one of the largest producers in the world, generating income and employment, while also producing resources from waste and leading the way in sustainable site remediation. p 8 - 9





EDEN PROJECT

The iconic tourist attraction is located in a former china clay pit, and promotes visitors' understanding of sustainability. p 14 - 15

PENRYN CAMPUS

Shared by the University of Exeter and the University of Falmouth, and home to the Camborne School of Mines, the campus is a hub for globally respected research and education in a wide range of fields essential to using and managing georesources sustainably, in Cornwall and around the world. p 16 - 17

UNITED DOWNS

Home to the UK's first planned deep geothermal power plant, this is also the test site for Cornish Lithium's innovative approach of extracting lithium needed for low-carbon energy technologies from the hot springs in and around the granite beneath the surface. p 10 - 11

THE PAST, PRESENT & FUTURE OF MINING IN CORNWALL

Minerals and metals have been fundamental to human societies for thousands of years, and their extraction in Cornwall dates back to antiquity. At its height, the Cornish mining sector provided some of the key resources that made the industrial revolution (see p 7), and this has left a complex and sometimes contested legacy.

Our need for a wide range of mineral resources is greater than ever. They underpin modern society in a multitude of ways, being used in everything from building construction to complex new technology applications. Their use often goes unrecognised, despite their presence being essential to tackling the energy transition and other sustainable development goals. Yet, as well as providing vital resources, employment opportunities and potential economic benefits, mining has in many cases caused great harm to the environment and communities where it has been undertaken. Despite considerable progress by the mining sector in addressing these challenges, the legacy is often still felt today.

While metalliferous mining in Cornwall largely ceased in the late 20th century, mining and quarrying still make a significant contribution to the county's economy, through the china clay industry and the extraction of high quality building stone. Increasing demand for technology materials such as those used in batteries is once again stimulating exploration for minerals. Together with technical advances in mining and improved approaches to addressing its social and environmental impacts, this offers the prospect of reviving mining production in Cornwall, and placing it at the forefront of sustainable mining best practice internationally.

THE LEGACY OF METAL MINING IN CORNWALL

Significant tin mining took place in Cornwall throughout the medieval period. However, by the mid-18th century, a mining revolution was underway. From around 1750, Cornwall led the world supply of tin and copper for over a century, and between 1800 and 1830 it is estimated to have provided two thirds of global copper supply, along with significant amounts of other metals. Not only did this play a fundamental role in resourcing the industrial revolution, first in Britain and then across much of the world – it also transformed mining technology, especially in the application and improvement of steam power (vital for water pumping), drilling, digging and ore refinement techniques. By the late 1800s, Cornish mining technology and expertise was exported around the world. Mining became a defining and enduring element of Cornish identity, at home and globally.

Despite the significant wealth that Cornwall's mining revolution generated, this was not equitably shared at the time, and the rapid decline of metal mining together with lack of economic regeneration left behind extensive poverty and deprivation. The industry also shaped today's Cornish landscape, in ways as immediately recognisable as its natural characteristics. It features over 200 engine houses, other disused or repurposed infrastructure, waste tips and remains of mineral processing, as well as hidden aspects such as thousands of underground mine shafts and tunnels. The designation of the UNESCO Cornwall and West Devon Mining Landscape World Heritage Site in 2006 recognised this unique landscape, together with its contribution to the industrial revolution. Some of the physical legacies of mining have competing environmental and social dimensions – they may require careful remediation or ongoing environmental management, as well as providing scope for economic and social regeneration, sustainable tourism, biodiversity growth and future resource extraction. These drivers may not be easy to reconcile, and require sensitive management in partnership with local communities.

MORE INFO:

- **Cornwall and West Devon Mining Landscape World Heritage Site**
  - https://www.cornishmining.org.uk
- **REMIX Report - Georesources Cornwall**
  - https://emps.exeter.ac.uk/csm/research/environment/remix
- **Cornwall Council - Guide to Cornwall's Building Stones** - https://www.tinyurl.com/cornwallstones

CORNISH BUILDING STONES

In addition to its history of mining for metals and china clay, Cornwall is home to an exceptional variety of igneous and sedimentary rocks that have been quarried throughout history as building stones, decorative stones and aggregates. These range from granite and slate to more exotic materials like luxullianite and serpentine. They contribute enormously to the character and richness of Cornwall's built environment, and are highly prized further afield, with Cornish granite being used in the construction of iconic landmarks such as London's Tower Bridge.

Geomaterials that are well suited to their function and environment can last for many centuries. The slate seen in 5th-6th century buildings on Tintagel Island has proved highly resistant to weathering, and stone and slate from old buildings has been recycled over the centuries – the original circular economy! A distinctive human-made part of the Cornish landscape are the thousands of miles of 'Cornish hedges', made up of stone, earth and vegetation. They are stable and long-lasting, as long as they are maintained by refurbishing them every 150 years or so. Some are thought to date from 2000-4000 years ago, when they were made from stone cleared from fields.

The quarrying of building stone in Cornwall continues, and some of the oldest granite and slate quarries still operate. Delabole quarry, noted for its distinctive silvery grey slate, has been continuously operating since the 15th century at least – possibly much longer – and is one of the oldest slate quarries in the world. Locally sourced stone is gaining in importance once again with increased attention to sustainable building materials with a low carbon footprint, and restoration and conservation of historical buildings using sympathetic materials.

RESPONSIBLE MINING & SUSTAINABILITY

Achieving carbon targets will require rapid increase in the use of low-carbon energy technologies such as wind turbines, solar panels and electric vehicles. The volume of these technologies required will need huge quantities of metals, including some which have not previously been mined in significant quantities. The World Bank estimates that production of lithium, cobalt and graphite may need to increase by nearly 500% by 2050 to meet these requirements, for example. However successful we are in reducing our energy consumption, and implementing recycling and other circular economy approaches, mining will continue to be necessary for the foreseeable future.

Cornwall's rocks are still home to potentially significant mineral wealth – lithium offers the greatest immediate prospects, but tungsten and remaining deposits of tin may also be economically worthwhile to extract. Other metals such as copper, zinc, lead, cobalt and indium are known to be present in the ground too, and may become viable if prices increase or mining technologies develop sufficiently. There is also potential to extract metals from materials discarded as mine waste in the past, or even from the waters that have filled old mine workings. Mining the resources needed for a sustainable future must be done in a socially and environmentally responsible way – minimising waste, maximising co-production of resources, and listening to communities to sensitively address tensions between economic and environmental priorities at the planning stage, among other considerations. Cornwall's mining expertise and heritage positions it ideally to lead the way in this.

LITHIUM IN CORNWALL

Lithium was detected in Cornish hot springs as early as the 1860s, but was not considered a useful or economically viable resource. But demand for lithium is now growing rapidly, and new technologies are being developed to extract it sustainably. These innovations make Cornwall's lithium a potentially world-class resource, and help point the way towards a rejuvenated, socially and environmentally responsible Cornish mining sector, providing sustainable economic opportunity to the county while contributing to the global imperative to decarbonise our energy systems. Companies exploring for lithium include Cornish Lithium Ltd and British Lithium Ltd, both of which are developing novel low-energy approaches to extracting lithium from mica minerals in the near-surface granites that also host Cornwall's china clay resources.

Cornish Lithium also plans to extract dissolved lithium directly from the geothermal waters that circulate deep beneath Cornwall's surface. Lithium-rich brine will be pumped to the surface via boreholes to extract the lithium, and the heat it contains potentially used to generate geothermal energy, before returning it safely to the subsurface. This novel, low-impact extraction approach will minimise or eliminate many of the environmental challenges often associated with mining. There will be no need to remove ore from the ground and crush it for processing – activities that use huge amounts of energy and create extensive waste materials requiring careful long-term management. Nor will evaporation ponds be required, as happens on a large scale when extracting lithium from salar brines in South America.

Exploration to locate and evaluate the most promising lithium resources is now underway, combining historical mining archives, data from satellite imaging, field mapping by geologists, and digital mapping using drones – minimising the need for exploratory drilling. Results so far are highly promising, and also suggest the future possibility of other technology metals as potential by-products. A pilot-scale extraction plant is also under development, in collaboration with Geothermal Engineering Ltd's United Downs deep geothermal power plant (see pages 10-11), to demonstrate that lithium hydroxide can be produced from geothermal waters with a net zero carbon footprint by using the geothermal energy to power the lithium extraction plant. In future, it is hoped that as well as providing the energy needed for lithium extraction, it will be possible to co-produce lithium, heat and electricity for external use.

IMERYS - RESOURCES FROM WASTE

Cornwall's historic china clay (or kaolin) industry continues to be globally significant, making the UK the third largest producer of kaolin globally. Imerys Minerals Ltd is the current operator, employing about 650 people across 20 quarrying and industrial sites in the UK, mostly in Cornwall.

Imerys leads the way in addressing the sustainability impacts of its activities and playing a positive role in local communities. Its programme of post-mining restoration and regeneration has resulted in the creation of over 1500 hectares of varied biodiverse habitats over the past decade, including heathland, woodland and pasture, and 40km of public access trails. The Enterprise Space for Advanced Manufacturing, developed in partnership between Cornwall Council and private companies to house new high tech businesses, is also built on former mining land, and a garden village is planned at West Carclaze to provide sustainable homes and community spaces. Imerys has also installed wind turbines and solar panels on redundant land to generate renewable energy, reducing its carbon footprint.

Imerys has made particular progress with sustainable waste management. In common with other mining, china clay extraction has historically produced vast amounts of waste material, giving rise to the distinctive white spoil heaps sometimes colloquially known as the 'Cornish Alps'. As well as finding ways to reduce the amount of waste produced, Imerys works in partnership with others to reuse waste materials and generate resources from them. At Littlejohns Pit, for example, Brookland Sand and Aggregates Ltd produces sand and aggregates from 'stent' – rock produced as a by-product of kaolin extraction. Imerys is also among the partners from industry, academia and government in the EU INTERREG North West funded UrbCon project, which is exploring how by-products can be used to produce sustainable concrete.

One particularly innovative sustainable product made from china clay waste is Green&Blue's BeeBrick. The waste constitutes 75% of the concrete mix from which they are made. The BeeBrick is designed to provide a habitat for non-swarming solitary bees, repurposing locally sourced waste to provide a sustainable building material, while also supporting biodiversity.

MORE INFO:

- **Cornish Lithium** - https://www.cornishlithium.com
- **REMIX Report - Georesources Cornwall** - https://emps.exeter.ac.uk/csm/research/environment / remix
- **World Bank report - Minerals for Climate Action** - https://www.tinyurl.com/minerals-for-climate

ENERGY FROM BENEATH OUR FEET

As well as minerals for low-carbon energy technologies, the subsurface can provide us with sustainable energy more directly. The temperature of the Earth's crust increases with depth, due to heat from its interior, and in Cornwall additional heat is generated by the decay of radioactive elements that occur naturally at low levels in the granite. This results in heat gradients more than double the UK average, making Cornwall the most promising area for deep geothermal energy production anywhere in the country.

Geothermal energy is renewable as it draws its heat from the very slow cooling of the Earth. It is a consistent energy source that complements other more intermittent renewable sources like wind and solar power, as it is unaffected by the weather.

In settings such as Cornwall, water can be pumped through rocks at depth (typically several kilometres), where it is heated before being returned to the surface, via enclosed boreholes. If it is sufficiently hot, this water can be used to generate electricity, with heat for local commercial or domestic use as a co-product. The UK's first deep geothermal power plant, at United Downs, is at an advanced stage of development, and a further project at the Eden Project site is soon to get underway. There is potential for many more sites across Cornwall, providing low-carbon heat and electricity to local communities, and generating income by contributing to the UK's electricity supply via the national grid.

The community-run Jubilee Pool in Penzance, the UK's largest art deco seawater lido, already uses geothermal energy (though from shallower depths and at lower temperatures) to heat its unique Geo Pool, making it an attractive place for locals and visitors to swim throughout the year. A further potential energy source is water that has filled former mine workings, which is slightly warmed by the subsurface even at fairly shallow depths – this can be used for both heating and cooling. While the waters associated with coal mining are well mapped across the UK, metal mines are often overlooked in this regard. There is also considerable scope for domestic and commercial use of ground source heat pumps that can use solar energy stored near the Earth's surface to warm buildings in the winter – some of these can also transfer heat to the subsurface to provide cooling in the summer.

EDEN GEOTHERMAL

Eden's geothermal plant is planned to be developed in two phases. The first phase has been approved and drilling is due to start in 2021. This will consist of a single well around 25cm wide, reaching about 4.5km underground, and should produce enough heat for the Eden Project's biomes, offices and nursery greenhouses. A second phase is expected to follow, with the construction of a second well and a binary power plant at the site, which like the United Downs project will have low impact on the landscape. It is hoped that by 2023, enough renewable electricity will be exported from the site to completely neutralise the Eden Project's carbon footprint.

UNITED DOWNS DEEP GEOTHERMAL POWER PLANT

Construction of two directional wells for geothermal power production at the United Downs Industrial Site near Redruth was completed in 2019. Water will be pumped through the injection well to a depth of 2393m, and will then be heated as it passes through fractures in the hot rocks below, before being returned to the surface via the 5275m-deep production well. Final stages of testing have continued in 2020, and the power plant to generate electricity from the superheated water is expected to be commissioned in 2021. The binary design of the plant will keep geothermal brines physically separate from the secondary fluid that will drive the turbine. Buildings will be low-rise, and the plant will not produce vapour plumes, meaning that once completed it will have very little visual impact.

MORE INFO:

- **United Downs Deep Geothermal Project**
  - https://geothermalengineering.co.uk/united-downs
- **Eden Geothermal Project**
  - https://www.edengeothermal.com
- **Jubilee Pool, Penzance**
  - https://jubileepool.co.uk

HIDDEN VALUE IN THE GROUND

Some georesources are frequently overlooked, but are nonetheless fundamental to environmental growth, human wellbeing and sustainable economic development. If their importance is not recognised, they are at greater risk of not being protected or managed appropriately. These 'hidden' georesources include groundwater, soils, and less tangible ecosystem services.

Groundwater passes through the ground to the 'saturated zone' below the water table, where it resides in porous rocks, moving through the subsurface (often very slowly) until it is eventually discharged into body of surface water such as a spring, a river or the sea. The geology of Cornwall is not suitable to sustain the extraction of groundwater for public water supply, as happens in some other parts of the UK. However, it is appropriate for private water supply to homes, farms and some other businesses, which may come from springs, wells, boreholes and even adits (see p 13). As much of Cornwall is rural, connecting to the mains can be impractical, and many people rely on private supply for drinking water (estimated at 5% of the population across the county, and as much as 16% of inhabitants in hamlets and small villages). Cornwall Council currently monitors the quality of nearly 4000 private supplies. Water can be naturally contaminated, but is also at risk of pollution from human activities, including agriculture and mining. Arsenic is the most significant pollutant in Cornwall – most is natural, but some comes from old mining and arsenic processing works.

Groundwater provides base flow to rivers, keeping them flowing in the summer, and in turn sustaining ecosystems. Environmental change and increased drought risk may put groundwater levels and quality at risk. Groundwater circulating at much greater depths is also the basis for generating geothermal energy (see pages 10-11) – this happens far below the depths from which drinking water is extracted, and proper casing of wells ensures that contamination does not arise.

Soils, composed of geological and biological matter, are vital for agriculture and as a part of ecosystems. They are also valuable carbon sinks, and their role in providing other environmental buffering functions is becoming increasingly apparent. Understanding, preventing and remediating soil contamination is essential to sustaining these functions. Preserving soil quality is equally important, especially given the potential environmental consequences of reliance on artificial fertilisers. One initiative in this area, the Soil Carbon Project, is developing a methodology to test the amount of organic matter and carbon in soil, and investigating the impacts of farming practices on soil health. It is a collaboration between Duchy College, Farm Carbon Toolkit, Rothamsted Research North Wyke and the University of Plymouth, funded by Agri-Tech Cornwall and the Esmeé Fairbairn Charitable Trust.

SOILS & FLORICULTURE ON THE ISLES OF SCILLY

The Isles of Scilly have long been renowned for their flowers, especially narcissi and pinks. Their cultivation depends on protecting the islands' mostly sandy soils from salt spray and wind erosion, notably by growing hedges known locally as 'fences', and on preventing degradation of soil quality which has sometimes resulted from unsustainable agricultural practices. Nitrate fertilisers applied to supplement soil quality have leached into groundwater and caused problems with the quality of drinking water, which comes mostly from boreholes and shallow wells, supplemented by a reverse osmosis desalination plant on St Mary's. The islands' richer soils are manmade humus soils, resulting from the historical application of natural fertilisers such as seaweed – an instance of sustainable integrated management of bioresources and georesources where the land meets the sea.

GROUNDWATER & MINING IN CORNWALL

Mining has interacted with Cornwall's groundwater for centuries. A hidden legacy of Cornwall's mining history is its many adits – long, slightly sloping tunnels that were dug to drain water from mines by lowering the natural water table, thus reducing the amount of pumping that was needed to keep mines from filling with water. The greatest of these, known as the Great County Adit, was started in 1748, and by the 19th century had reached a length of over 40 miles, draining over 100 mines into the Carnon River. Some adits move water from one catchment into another, and if they are not maintained they can become blocked and rebound, causing 'new' springs to appear – in fact, these probably represent the reappearance of historical springs, potentially affecting rows of cottages that were often originally built along lines of springs.

After the Wheal Jane mine ceased operating in 1991, pumping of groundwater at the site also stopped, causing groundwater levels to rise. In January 1992, this resulted in the discharge of red ochreous acid mine drainage from an adit, causing major contamination of the Carnon River and Fal Estuary. As well as a very visible orange plume and the impact of the low pH of the contaminated water, there was concern over dissolved metals including toxic cadmium. Fortunately the impact of the incident on wildlife seems to have been limited, although it is thought that it killed some fish and may have contaminated wild fowl. Following short-term remedial action, a high-quality water treatment system was put in place. The former mine site is now an exemplar of mine site regeneration, and is home to the Wheal Jane Earth Science Park, which provides services and jobs in fields such as sustainable energy, water treatment, geological and mining consultancy, jewellery making, and post-mining land use.

MORE INFO:

- **British Geological Survey & Environment Agency groundwater report - Granites of SW England**
  - https://www.tinyurl.com/SWEngland-groundwater
- **Natural England National Character Area profile - Isles of Scilly**
  - https://www.tinyurl.com/NCA-Scilly
- **Soil Carbon Project**
  - https://www.farmcarbontoolkit.org.uk/soil-carbon-project

LANDSCAPE & RECREATION

Natural environments, human communities and sustainable economic development are inextricably linked. Cornwall's extraordinary and varied landscapes are underpinned by their geology, shaped over millions of years by natural processes – from the chevron folds of Millook Haven to the granite tors of Bodmin Moor – and more recently by human processes so evident in historic mining districts, for instance. They have huge economic value for the tourism sector, but they also promote and sustain the physical and mental wellbeing of all who spend time in them, from near and far. Cornwall's landscapes and places provide opportunities for leisure, amenity and enjoyment to local communities, and contribute immeasurably to their sense of identity.

The Cornwall Geoconservation Group is a voluntary body that aims to identify, conserve and raise awareness of the rich and diverse geological and geomorphological heritage of Cornwall and the Isles of Scilly. It is linked to the Cornwall Wildlife Trust, and works to ensure that geoconservation is fully integrated into the work of the Trust, recognising that geodiversity and biodiversity are intertwined.

THE EDEN PROJECT

The Eden Project's iconic domed biomes and botanical gardens are located in a reclaimed china clay pit which was mined for over 160 years. It exemplifies how the sustainable management of multiple georesources, biodiversity and communities can come together to stimulate environmental growth, human wellbeing and economic activity. As a vital part of Cornwall's tourism sector, it provides employment opportunities, and engages and informs visitors about ecosystems and sustainability – over a million of them in 2019. It demonstrates how post-mining landscapes can be transformed, and is a showcase for site remediation. Groundwater is continually pumped to prevent the site from flooding, as it sits below the water table. A geothermal energy project at the site is soon to get underway, and is expected to generate enough electricity to power the Eden Project together with 7,000 houses, as well as commercial and community heating (see p 11).

MORE INFO:

- **The Eden Project** - https://www.edenproject.com
- **Geological Society: 100 Great Geosites** - https://www.geolsoc.org.uk/100geosites
- **Cornwall Geoconservation Group Facebook page** - https://www.tinyurl.com/Cornwall-GCG

GREAT GEOSITES IN CORNWALL

The diversity of the UK's geology, spanning nearly three billion years, is second to none. As well as enriching people's lives through their enjoyment of beautiful and fascinating places, and providing myriad goods and services in often overlooked ways, this geological heritage has been fundamental to advancing our understanding of our planet, and how we can live sustainably on it. In 2014, the Geological Society of London, partner organisations and members of the geoscience community across the UK and Ireland celebrated 100 Great Geosites that exemplify aspects of this rich scientific, cultural and communal heritage.

There were three Cornish sites on the list:

1 MILLOOK HAVEN

The amazing 'chevron folds' in the cliffs were formed when layers of sandstone and shale, originally deposited underwater, deformed and buckled under huge pressures. As well as being strikingly beautiful to visit, they illustrate the Earth's dynamic nature and the extraordinary changes that Earth processes can cause over time.

2 KYNANCE COVE

The rocks of the Lizard record an ancient ocean – formed in the Earth's crust beneath this nascent ocean, they were subsequently forced to the surface by the collision of two continental plates 300 million years ago. At Kynance Cove, distinctive red and green serpentinite, in amongst dark grey igneous rocks and striped metamorphic ones, have been polished by the waves over thousands of years to give them a shiny snakeskin appearance. Further round the Lizard, at Coverack, is one of the few places in the world where you can walk across the 'Moho' boundary between the Earth's crust and mantle!

3 GEEVOR TIN MINE

The mine at Geevor operated from 1911 until 1990, although tin and copper were mined in this area for hundreds of years. It is now part of the UNESCO Cornwall and West Devon Mining Landscape World Heritage Site, and is home to a museum and heritage centre showing visitors how the metals that underpinned the industrial revolution were mined in Cornwall, and what life was like for those who worked there.

HUMAN & INSTITUTIONAL GEORESOURCES FOR SUSTAINABILITY

Cornwall benefits from close-knit but welcoming business and academic communities; local government bodies that are engaged and knowledgeable about georesources, environmental growth and sustainable economic development; and local communities with close connections to Cornwall's environment as well as its mining heritage.

A key part of the business community is the Cornwall Mining Alliance, launched in October 2016. This business and innovation cluster of over 100 organisations is the only one of its kind in the UK, and brings together SMEs and local branches of larger companies. Most of its members export goods or services, and between them they have connections to 155 countries, continuing Cornwall's tradition of engagement in the global mining sector, and providing a network through which high standards of environmental and social responsibility can be promulgated.

A much anticipated addition to Cornwall's infrastructural capabilities is Spaceport Cornwall. This is expected to offer horizontal launch of satellites from 2022, and will be the UK's first satellite launch site. It will make a significant contribution to sustainable georesources, both in Cornwall and far beyond its borders, given the vital and growing role of satellites in providing environmental intelligence data, including for environmental monitoring of mining and its impacts. Satellite imaging can also complement other techniques in innovative approaches to environmentally and socially sensitive mineral exploration, such as that currently being carried out by Cornish Lithium.

PENRYN CAMPUS

The Penryn Campus opened in 2004, and was financed by the EU and UK government. It is shared by the University of Exeter and Falmouth University, and is home to several departments and initiatives that are making a vital contribution to georesources for sustainability, in Cornwall and globally.

The Camborne School of Mines (CSM) was founded in 1888, coinciding with the export of Cornish mining technology and expertise around the world, and soon developed an international reputation. It has been part of the University of Exeter since 1993, and provides research and training across the core geology and mining disciplines, which now include social and environmental sustainability – a field in which it has globally recognised expertise. CSM has played an active role in many EU-funded research projects relating to georesources and sustainability, which bring together universities and other partner organisations from across Europe. Two recent examples are the MIREU project, which established a network of European mining and metallurgy regions to help ensure the sustained and sustainable supply of mineral raw materials, and the REMIX Interreg project, which produced the Georesources Cornwall working paper in 2019, proposing an integrated approach to Cornwall's minerals, geothermal energy, and industrial and natural heritage.

The Exeter Centre for Circular Economy (ECCE), part of the University of Exeter Business School, has rapidly established itself as a national and international focus for circular economy research and education, and leads the UKRI National Circular Economy Hub. New areas of collaboration between ECCE and CSM, as well as with the university's Environment and Sustainability Institute and others, are mobilising circular economy thinking and expertise for responsible mining and sustainable resource management, and are key to delivering the University of Exeter's climate emergency plan. Together with the European Centre for Environment and Human Health hosted at the university's medical school site in Truro, they help put Cornwall at the forefront of holistic approaches to the urgent challenges of sustainability.

Falmouth University is renowned for its expertise in design, gaming, and virtual and augmented reality – all of which can make a valuable contribution to georesources for sustainability. Its Design Centre seeks to facilitate research and innovation projects to realise novel low-carbon technologies, products and services, and aims to integrate smart technologies, digital platforms and sustainable design principles, including in areas such as the built environment, energy and transport.

TEVI

Tevi (Cornish for 'grow') has the twin aims of promoting environmental growth and economic growth throughout Cornwall and the Isles of Scilly. Its work to date has been funded by the EU's European Regional Development Fund. Tevi is led by a team from the University of Exeter based at the Penryn Campus, in partnership with the Cornwall Wildlife Trust, Cornwall Council and the Cornwall Development Company. It brings together a community of SMEs from across Cornwall and the Isles of Scilly, and supports these enterprises in delivering a variety of sustainability and circular economy objectives, drawing on the expertise of its full-time specialist staff and academic researchers from a range of relevant disciplines. Tevi has drawn on its growing community of stakeholders from business, academia and civil society to establish several challenge networks, including one on georesources that focuses on the role they can play in delivering environmental growth and a circular economy.

Tevi has also launched Lagas (www.lagas.co.uk), an environmental intelligence hub for Cornwall incorporating mapping tools, live video feeds and other information resources. As Lagas develops further, the resources it contains will complement other projects and data sets relating to Cornwall's georesources and their sustainable management and use, One such complementary initiative is the Deep Digital Cornwall project, which will bring together researchers and specialists from the University of Exeter, the South West Centre of Excellence in Satellite Applications, and companies from across Cornwall. It will create a Cornwall and Isles of Scilly data hub and visualisation suite for 3D spatial data sets relating to the georesources and subsurface of Cornwall, and their relation to surface information such as that contained in Lagas.

MORE INFO:

- **Tevi** - https://www.tevi.co.uk
- **Camborne School of Mines** - https://emps.exeter.ac.uk/csm
- **Exeter Centre for Circular Economy** - https://business-school.exeter.ac.uk/research/centres/circular

DELIVERING SUSTAINABLE GROWTH FOR CORNWALL IN A CHANGING WORLD

Conducted in 2020 during the global Covid-19 pandemic, against the backdrop of a mounting climate emergency, 'The Cornwall We Want' was Cornwall's biggest ever listening campaign, involving thousands of residents. It shaped the vision put forward in 'Gyllyn Warbarth, Together We Can: The Cornwall Plan 2020-2050'. Over 75% of participants wanted things to be different after the pandemic, with many calling for a fairer, more inclusive and greener Cornwall. 70% said they would be happy to change the way they work and travel to address climate change and other environmental challenges – a resolve that seems to have strengthened during the pandemic.

The Cornwall Plan and other roadmap documents developed over the past few years recognise the enormous natural assets that Cornwall possesses, many arising from or dependent on the geosphere, from mineral and energy resources to landscape and sense of place. But they also recognise that these assets must be used differently in future from how they have been in the past, in pursuit of environmental growth, equitable and inclusive communities, and sustainable economic development. Sectors from mining to tourism must develop not just with public consent, but with the active participation of communities that feel they are listened to and have agency in decisions about the places where they live. Understanding and engaging with public perceptions of the world beneath our feet, as research at the University of Plymouth relating to geothermal power in Cornwall has done, for example, can play a valuable role in enabling meaningful participation.

Unleashing Cornwall's potential to use its georesources for sustainability, locally, nationally and globally, will require action from UK government, in addition to the commitment and work of local bodies and communities. Smarter and more resilient energy infrastructure must be developed at a national level, including extension of the national electricity grid which currently ends at Indian Queens, to facilitate efficient deployment of multiple renewable energy sources and stimulate innovation in energy storage. Government has previously paid little attention to the mineral resources that will be required for decarbonisation and other aspects of national industrial strategy – this is starting to change, but greater coordination is needed across departments. Improved digital connectivity is essential to Cornwall's low-carbon, high-tech future. It remains unclear how the Shared Prosperity Fund (replacing EU structural funding such as the European Regional Development Fund) will work, and the impact of the UK no longer participating in Interreg is not yet known – Cornwall has benefitted significantly from these, and risks losing both funding and international influence if such uncertainties are not urgently addressed.

When Cornish policy and planning documents refer to georesources, it is usually in the narrow sense of minerals and geothermal energy. But a more holistic view is called for if Cornwall's georesources are to used and managed sustainably, encompassing the broader variety of interconnected georesources outlined in this report. A useful way of framing these, in the context of environmental and sustainability policy-making, may be as **geosystem services** – that is, the full range of ecosystem services that depend on the geosphere. These include provisioning services such as the supply of energy, water and mineral resources; regulating services including subsurface storage, carbon sinks and other natural buffering capacities; supporting services that underpin ecosystems, including geochemical cycles; and cultural services such as enjoyment and appreciation of landscape, minerals and fossils. Non-living aspects of natural capital such as rocks and minerals are often overlooked, and the provision of subsurface resources is rarely recognised as an ecosystem service, unlike food crops for instance.

CORNWALL & THE UN SUSTAINABLE DEVELOPMENT GOALS

Climate change is just one of the interconnected global challenges set out in the UN Sustainable Development Goals (SDGs). Georesources, used and managed responsibly, have the potential to contribute directly or indirectly to all 17 goals. A key principle of the SDGs is to leave nobody behind, and they apply in all nations and regions – not only in poorer countries most likely to bear the brunt of environmental change and unsustainable resource use. Cornwall can play an important role in delivering the SDGs globally, providing raw materials needed for low-carbon technologies while leading the way in sustainable mining. The G7 meeting to be held in Cornwall in June 2021 promises to focus on building back better from the Covid-19 pandemic to create a greener, more prosperous future, providing an ideal showcase for these Cornish strengths, and setting the scene for the COP26 UN Climate Change Conference in Glasgow in November 2021. The SDGs are also a useful external framework for Cornwall's own sustainable development plans – the Cornwall Plan 2020-2050, for example, sets out indicators of progress towards a greener and more inclusive Cornwall, and maps these to the SDGs.

MINING IN CORNWALL - BUILDING BACK BETTER

Economic research carried out for the REMIX project estimates that exploration, production and refining of Cornwall's lithium, tin and tungsten resources could generate £1 billion GVA (gross value added) over the next 20 years. This opportunity could also be the springboard for Cornwall to lead the way in responsible extraction and use of such resources. Cornish Lithium Ltd and British Lithium Ltd, for instance, are developing innovative technologies to minimise social and environmental impacts of lithium extraction (from hard rock settings as well as brines). With other partners, they are also exploring the potential for lithium processing in the UK, capturing more of the value chain, shortening the global journeys that mineral resources pass through, and maximising the sustainability benefits that responsible use of technology metals can deliver.

REMIX's Georesources Cornwall working paper also included a detailed set of policy recommendations. For example, it is vital that local and national policy makers facilitate the development of a sustainable 'industrial ecosystem' while mining is going on, to ensure ongoing economic productivity and positive legacies for communities and environments when it ceases. The Enterprise Space for Advanced Manufacturing developed on former kaolin mining land is a good example of this - in contrast to the legacy of poverty, deprivation and ecological damage following the closure of Cornwall's metal mines, in the absence of effective planning and regeneration.

MORE INFO:

- **The Cornwall We Want consultation** - https://tinyurl.com/cornwall-we-want
- **Geological Society - Geology and the UN SDGs** - https://www.geolsoc.org.uk/sustainabledevelopment
- **REMIX Report - Georesources Cornwall** - https://emps.exeter.ac.uk/csm/research/environment/remix

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