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Yang, D, Sheng, Y and Green, M (2014) UCG: Where in the world? TCE The Chemical Engineer (872). 38 - 41. ISSN 0302-0797 tce

the chemical engineer | issue 872 | february 2014

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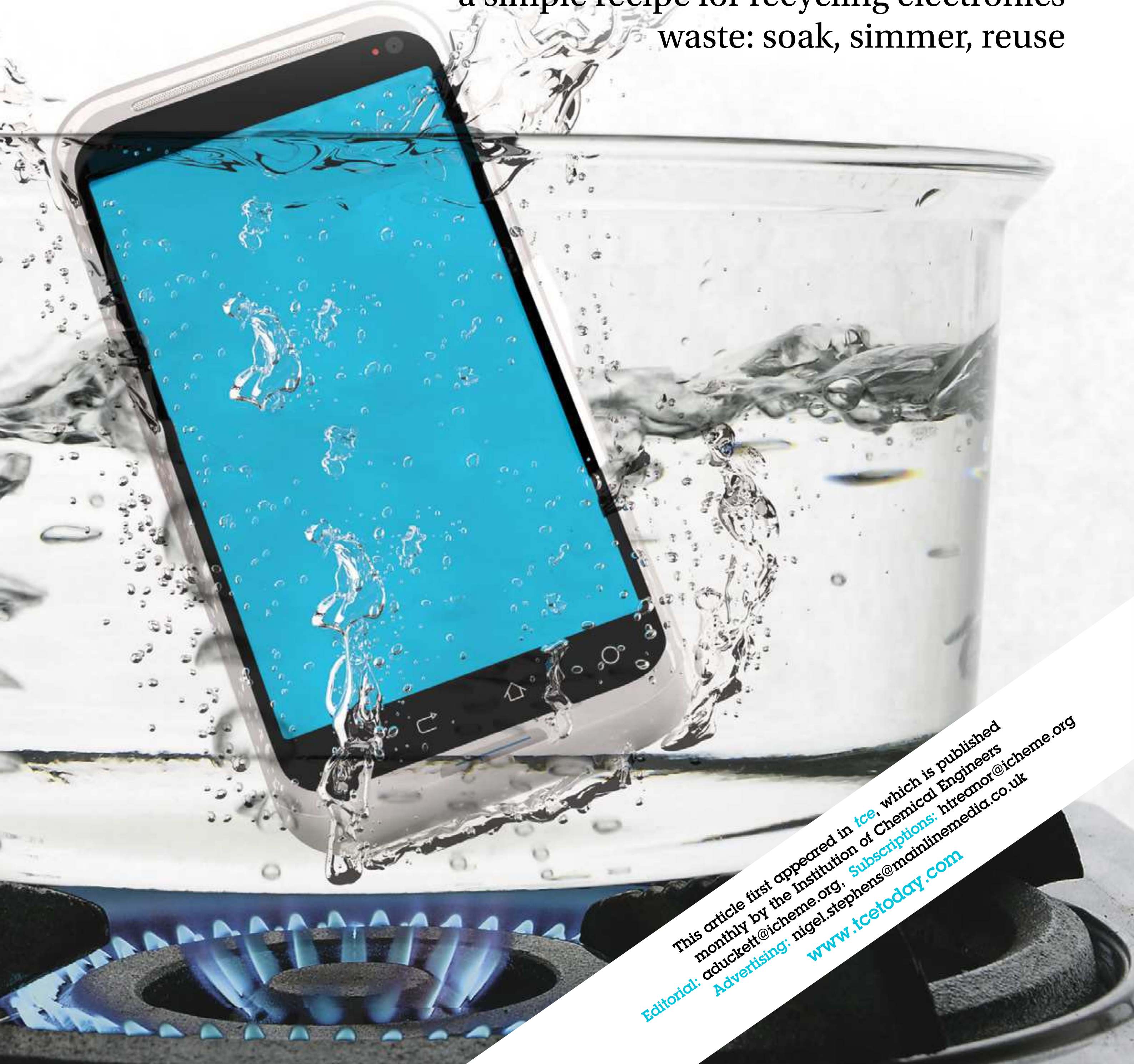

This article first appeared in *tce*, which is published monthly by the Institution of Chemical Engineers
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UCG: where in the world?

Dongmin Yang, **Yong Sheng** and **Michael Green** take a global look at how underground coal gasification is developing

DESPITE the ongoing trend towards renewable energy sources, fossil fuels, particularly coal, will continue to be a major source of energy for many decades – a 20% increase in coal demand is predicted between 2008–2035. However, coal is one of the primary environmental polluters and its use is contributing to the rising CO_2 concentration in the atmosphere. Furthermore, many of the world's coal reserves are too deep to exploit by conventional methods (such as surface mining or underground mining).

Underground coal gasification (UCG) provides access to coal deposits that would otherwise remain unused and an attractive route to carbon capture and storage (CCS). However, in spite of the concept being a relatively simple one, putting it into practice isn't so easy. Here we take a look at efforts around the world to keep the momentum going.

a simple concept

UCG involves a minimum of two wells (injection well and production well) partly drilled into the coal seam some distance apart, and connected by a channel through which gases can flow (see Figure 1). During the UCG process, the gasifying agent (air, oxygen enriched air, or oxygen, possibly with added steam) is supplied via the injection well to the underground gasification chamber, and the product gases (also called syngas) are extracted via the production well to the surface for treatment and use. Commercial-scale operations using UCG would involve multiple boreholes/wells to produce sufficient quantities of syngas. UCG offers the potential for using the energy stored in coal in an economic and environmentally sensitive way, particularly from deposits which are unmineable by conventional methods. If UCG is to be successfully developed and widely deployed, then the world's coal reserves are likely to be revised upwards by a substantial amount. Also, site selection is critical to any development since the geology and hydrogeology must be appropriate.

practicalities of UCG

UCG is conceptually very simple but the development of a working system has proved more difficult in practice. The main problems are accurate in-seam drilling, controlling the reaction within the seam and producing a consistent, high quality gas. Meaningful experiments cannot be carried out in the laboratory, so trials must be undertaken at pilot scale, which is both costly and time consuming. More research on site evaluations, economic studies and safety are generally required to convince financial institutions, permitting authorities and investors to support the commercial projects. As most of the existing UCG projects and trials were carried out in separate countries and regions, converting the knowledge gained into commercial practice and sharing experience would significantly increase the economic viability of UCG. Few are currently looking at UCG in preference to conventional mining where the coal can be extracted economically using well proven methods, but there are signs that if the technology becomes established during the next ten years or so, the situation might change.

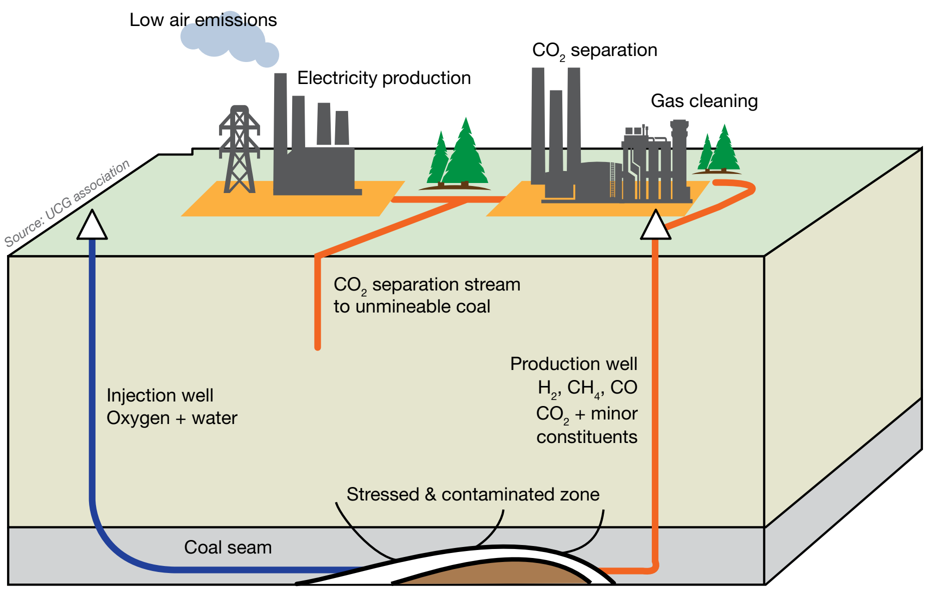
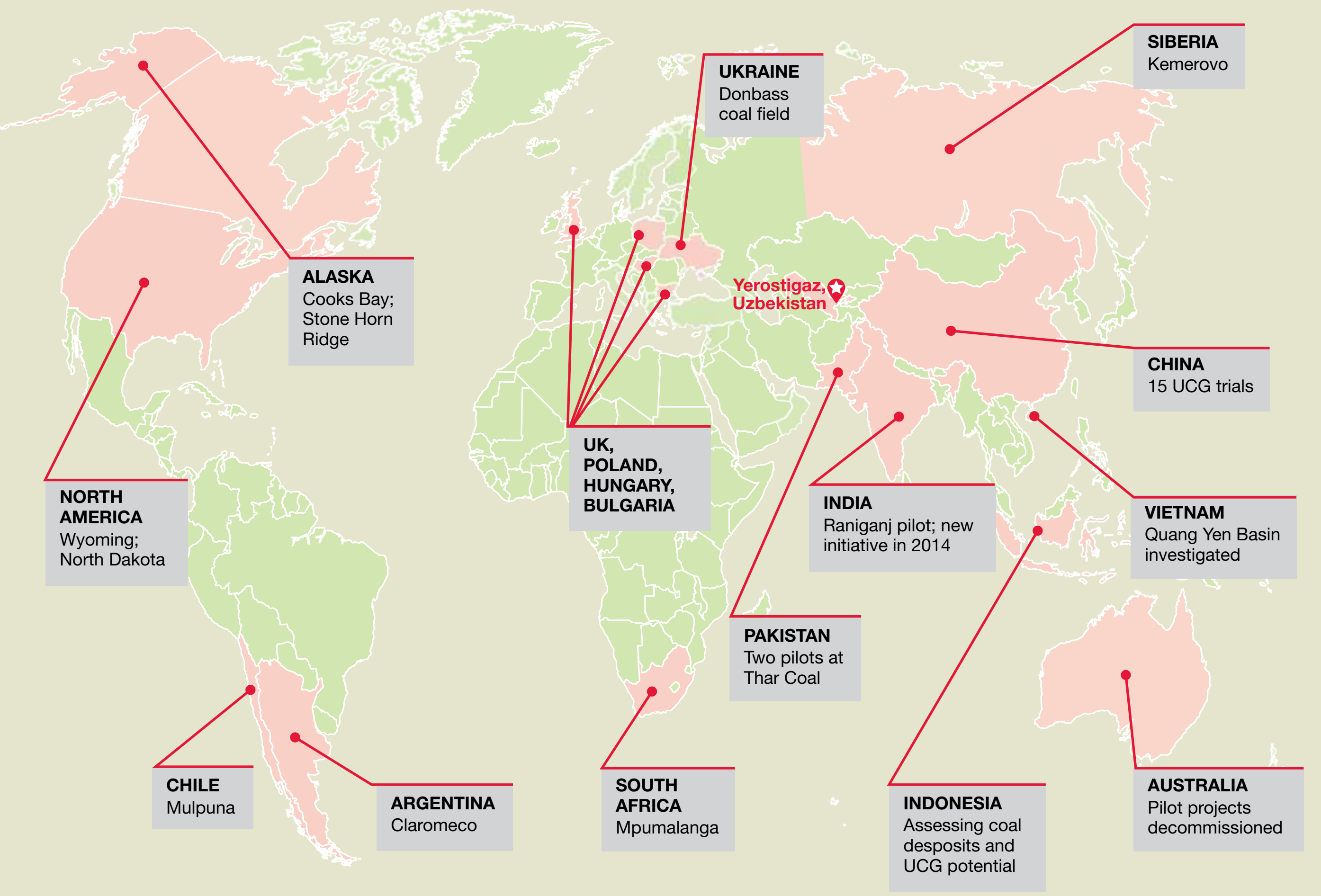


Figure 1: Schematic diagram of UCG process

UCG is conceptually very simple but the development of a working system has proved more difficult in practice. The main problems are accurate in-seam drilling, controlling the reaction within the seam and producing a consistent, high quality gas.

Worldwide underground coal gasification: a snapshot

The only commercial UCG facility is In Yerostigaz in Uzbekistan, which has produced 1m m^3/d of syngas since 1961. Despite this, development work continues elsewhere in the world.



a global snapshot

Australia, Europe, Canada and more recently South Africa have been leading the development of UCG technology since 2000. Australian Company Linc Energy now owns the world's only commercial UCG facility, Yerostigaz in Uzbekistan, which has consistently produced 1m m^3/d of syngas since 1961, and has also constructed and commissioned a UCG demonstration facility in Chinchilla, Australia to produce syngas for gas-to-liquid production (GTL). Other companies such as Carbon Energy and Cougar have tried to pursue their own UCG projects, but all the Queensland projects are currently being decommissioned. The future of commercial UCG in Queensland will depend on satisfactory closure and restoration of the pilot tests, and a stage-by-stage approval of the environmental processes. Solid Energy in New Zealand carried out a UCG pilot in Huntly West in February 2012, but the project has been shut down and the commercial plant suspended for internal financial reasons.

However, there has been some progress in Asia, particularly in China. China has run around 15 UCG trials to date. ENN Group, which is part of the Hebei based XinAo Group, is working closely with corporations in Uzbekistan, the US, Australia, South Africa and the EU, with the aim of using UCG syngas for chemical manufacture. In 2011,

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a US$1.5bn commercial partnership was launched between UK and China to gasify 6m t/y of buried coal in Inner Mongolia's Yi He coal field to generate 1,000 MW of power.

In addition, Australian-based Carbon Energy has a technology licence agreement with Shanxi Coal to commercialise its proprietary 'keyseam' UCG technology in Shanxi Province, and India started a UCG pilot project in Raniganj coalfield in 2005 which reached the stage of borehole exploration drilling.

Several attempts have been made in India to launch commercial UCG in designated UCG blocks, and a new initiative in 2014 is planned. In 2010, Pakistan started a UCG project in the Thar Coal deposit, aiming to set up two pilot 5 MW power plants and to generate 8,000 MW from Thar Coal by 2015. Indonesia has assessed a range of coal deposits and UCG project development opportunities at one area in South Sumatra, and two other areas in East Kalimantan. Duong Do Company in Vietnam is collaborating with Gazprom to investigate the prospect of UCG in the Quang Yen Basin.

Meanwhile, back in the West, the US and Canada have conducted field trials and modelling work on UCG for decades in both industry and research establishments. The US has been undertaking the commercial development of UCG in Wyoming, Cooks bay Alaska and North Dakota. The lead project in Wyoming, again led by Linc Energy, is close to gaining approval for a pilot test. The Canadian Company Laurus Energy plans to develop a UCG project at Stone Horn Ridge near the Beluga River in southern Alaska. The project will be designed and developed with the capability for carbon capture and storage. Currently, Swan Hills Synfuels with Synergia Polygen have successfully completed a UCG trial at 1,400 m and are seeking financial support to commercialise the project.

Over in Europe an important and recent project undertaken by GIG in Poland is the hydrogen oriented underground coal gasification for Europe (or 'HUGE') project (2007–2010), and its successor HUGE2 (2012–2015) funded under the Research Fund for Coal and Steel (RFCS) programme and bringing together collaborating partners from seven Member States.

In Hungary, Wildhorse Energy completed the pre-feasibility study of a UCG project at Mecsek Hills (in 2012), which concluded that the project was attractive economically and technically. The project is currently at the bankable feasibility study phase. Red Mountain Energy in Russia launched a UCG project in the Kemerovo region in Siberia in 2011, currently at the feasibility study stage.

Initially the syngas from UCG will be used to generate power for a local town.

Ukraine has continued to work on UCG and sites in the Donbass coal field are again being evaluated. The UK has large reserves of indigenous coal both onshore and offshore in the southern North Sea. An initiative on UCG (2000–2005) led by the UK Coal Authority and supported by the then UK Department of Trade and Industry (DTI) investigated the feasibility of UCG in the UK. The main conclusion was that UCG should be seen primarily as a near-shore and estuary technology and a site was identified in the Firth of Forth as a possible field trial location. Since 2008, more than 20 licences have been issued for UCG exploration in offshore locations. The key players have been Clean Coal (Swansea, Cromer, Humberside, Canonbie and Sunderland), BCG (Firth of Forth), Five quarters (Newcastle) and the Welsh government (N Wales, Irish Sea). Cluff Natural Resources has recently joined the efforts, with exploration licences for five offshore sites in Scotland, Wales and Cumbria in England.

In 2007 Eskom commissioned a UCG pilot plant (3 MW) next to Majuba Power Station in Mpumalanga in South Africa and in 2010 the syngas produced was used for co-firing with coal in the power station. Eskom has since joined forces with Sasol in a ZAR1bn (US$92m) development project. In South America, in June 2013, Carbon Energy signed a memorandum of understanding (MoU) with the Delmo Group to provide UCG technology and related services for commercial-scale UCG at Claromeco coal basin in Argentina. Previously, Carbon Energy announced a joint project with Antofagasta Minerals in Mulpuna in Chile. The pre-feasibility study for power generation has been completed, and the project aims to supply syngas to a minimum 250 MW power station.

More and more potential UCG sites (such as Ukraine's Donbass coal field) are being investigated and evaluated for pilot tests.

While conventional mining technologies exploit most of the world's coal resources, UCG technology brings new life for the vast coal deposits deep underground.

UCG combined with CCS?

UCG, when combined with carbon capture and storage (CCS), has the potential to provide the energy needed without the offending greenhouse gases and other emissions. The UCG syngas can be processed to partially or completely remove CO_2 before it is passed on for end users (industrial heating and power generation), thereby providing a source of cleaner energy while minimising greenhouse gas emissions (see Figure 1). In today's world, managing carbon and controlling CO_2 emissions are likely to become subjects which may determine the future of individual UCG developments. However, combining UCG with CCS is still under desk study and no trial project has yet been conducted.

challenges in the future

Though licensing policies for UCG are already being formed in some countries (eg Australia, UK, Canada, New Zealand and the US), the lack of specific regulations in other countries could be slowing down progress.

The challenge to ensure the commercial viability of UCG technology is significant, but these hurdles could be overcome by deploying the right policies and arguments to convince public opinion. While government support of the technology is needed to produce a reliable technical knowledge and expertise base, more projects need to be implemented to test possible UCG approaches. Additionally, some commercial

> **China, South Africa and Canada are the countries probably closest to commercialisation outside of the EU.**

field projects could serve as possible locations to develop and test novel monitoring, simulation, advanced drilling techniques, and tools and approaches to confirm the environmental viability of UCG.

Collaborating and sharing expertise and knowledge between projects and governments is key to commercialising and growing the UCG industry. The countries with the greatest interest and most active R&D programmes in UCG are China, India, South Africa, the US, Canada, Australia and certain Member States of the EU. China, South Africa and Canada are the countries probably closest to commercialisation outside of the EU.

Within the EU, the countries showing the most progress are Poland, Hungary and the UK. CCS research and development is active and demonstration-scale projects of both capture and CO_2 storage are under way in most countries; lead countries including the US, Canada and the EU Member States. China is increasingly interested in this field. EU RFCS supported works in Bulgaria and Poland, and the recent FP7 study of UCG and CCS offers the opportunity to produce low carbon UCG at a competitive price.

Although the majority of the environmental impacts of UCG are positive ones, such as the significant reduction of the surface damage and solid waste discharge as well as sulphur dioxide (SO_2) and nitrogen oxide (NOx) emissions, there are a few potential environmental concerns associated with the UCG operation, for example aquifer contamination. Organic and often toxic materials (such as phenol) remain in the underground chamber after gasification and, therefore, are likely to leach into groundwater. However, some research has shown that the persistence of such substances in the water is short and that groundwater recovers within a few years. Rigorous site selection procedures with regard to the hydrological conditions can also reduce the risk of the groundwater contamination.

Modern UCG is a new industry to the public and the media. Public acceptance of this green technology will depend on more successful research and trials to demonstrate its advantages in terms of both financial and environmental impacts over the traditional mining methods. **tce**

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Chemical Engineering Matters

The topics discussed in this article refer to the following lines on the vistas of IChemE's technical strategy document *Chemical Engineering Matters*:

Energy *Lines 2, 3, 15, 21, 24*

Water *Lines 2–3, 13–14*

Health and wellbeing *Lines 1–2, 6–7, 11, 13*

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