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EUROPEAN UNION CO-FUNDED PROJECT

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Horizon 2020

COMPETITIVE LOW-CARBON ENERGY

Project acronym:

ShaleXenvironmenT

Maximizing the EU shale gas potential by minimizing its environmental footprint

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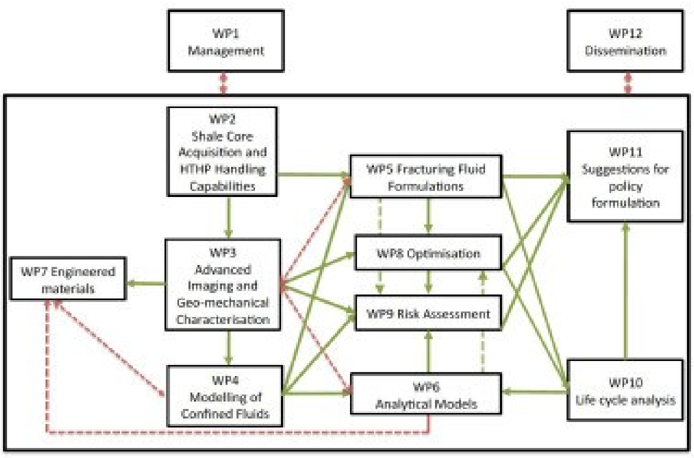
1. *SUMMARY*

Securing abundant, affordable, and clean energy remains a critical challenge. In an ever-changing geo-political climate, European shale gas could become a practical necessity for the next 50 years. However, the exploitation of shale gas remains challenging, in part because its environmental footprint is at present poorly quantified, and in part because several technological challenges remain to be overcome. Great care is needed to assess and pursue this energy resource in the safest possible way for the long-term future of Europe whilst protecting the European diverse natural environment. ShaleXenvironmenT assembled a multi-disciplinary academic team, with relevant industrial connections. A comprehensive approach has been implemented towards ensuring that the future development of shale gas in Europe will safeguard the public with the best environmental data suitable for governmental appraisal, and ultimately for encouraging industrial best practice. This document is prepared at the mid-point stage.

2. *PROJECT SCOPE*

ShaleXenvironmenT, SXT, implements a holistic approach to determine the environmental impact, risks, and economic potentials associated with each shale play, while maintaining complete and transparent communication with all stakeholders. The workflow planned for SXT is summarised as follows: (a) shale core samples are extracted from formations of interest across Europe when possible, and overseas for comparison; (b) the samples are characterised implementing state-of-the-art techniques, including, but not limited to in situ synchrotron tomography, dual beam focussed ion beam 3D microscopy, electron tomography, permeability measurements, mechanical properties; (c) the fluid behaviour in the rocks is studied from a fundamental point of view – this includes using the experimental information regarding chemical composition and pore structure to understand the flow of fluids in the rock, the design of green fracturing fluids that reduce the amount of naturally occurring radioactive materials extracted, and the quantification of the amount of gas stored and recoverable from the rock sample; (d) predict the well productivity – this very demanding task requires the combination of geological information regarding the sub-surface formation, the position of the well, the number of fracturing stages, the presence of natural fractures in the sub-surface, the operation of shale gas production, etc., given the state of shale gas exploration in Europe, this can only be a thought experiment at the moment; (e) quantify the life-cycle environmental impact related to the production of shale gas, inclusive of well construction, fracturing stages, natural gas production, reclamation of flow-back and produced water, possible risk related to micro-seismicity, fugitive emission, and even wellbore blowout; (f) by combining the predictions regarding economical benefits related to the production of shale gas, and the environmental 'costs' quantified by the life cycle analysis approach, SXT will be able to provide to all stakeholders scientific-based tools to decide whether it will be worth producing a specific well/formation.

Deliverables have been and will continue to be in the form of reports, scientific publications, fracturing fluid formulations, procedures for shale rock characterization, prediction of the natural gas produced, limitations of the environmental impact of the technology, etc. The deliverables are public and available on the SXT website. The published manuscripts describe the procedures implemented, which allow others to use SXT's results. Impact can be measured by common bibliographic information such as the citations for the various articles, the number of downloads, etc. New technologies are being developed in the form of the application of X-ray tomography to visualize the pore network (paper just accepted in Scientific Reports), implementation of techniques for high-P and high-T quantification of the gas in place, algorithms for the meso-scale description of gas transport in pore networks, and improvement of the commercial software roxol, owned by SME partner Geomecon.



3. *PROJECT TECHNICAL DESCRIPTION & IMPLEMENTATION*

The project develops along 11 Work Packages, WPs. WP 1 is responsible for managing the consortium. It is led by UCL. Its key tasks include financial, legal and administrative management of the consortium and liaison with the European Commission (sponsor). In the figure we show the synergistic intellectual connections among WPs.

4. RESULTS ACHIEVED

WP02 – This WP provides rock samples. The original plan was to use the Core Vault technology, owned by partner Halliburton, to access rock samples containing >90% of the formation fluids. Because of the recent drop in oil price, and because of the lack of significant activity related to shale gas in Europe, SXT has instead secured 11 samples from the well 'Preese Hall 1' in the Bowland formation in the UK; access to rock samples from the Marcellus formation in North America, and a repository has been established; access to 5-10 core samples from a commercial well in the European continent. Additional rock samples from EU formations are available. Samples are distributed to partners within SXT, and also to collaborators and other scientists upon request. A repository has been established.

WP03 – This WP provides detailed experimental characterisation of the rock samples. Characterization include X-ray tomography, OM, (E)SEM, TEM, mechanical properties, chemical composition, etc. Resolutions of the order of 20 nm have been achieved, giving SXT the opportunity of observing, in a rock sample, the pore network and the presence of natural micro-fractures that extend for 100 microns or less. Results obtained and published by SXT show that shale rock properties (microstructure, mechanical properties) are significantly heterogeneous even within mm-size samples. A number of papers have been published in high-impact journal. The difficulty is to correlate the various measurements (e.g., the mechanical properties vs. the pore connectivity and permeability), but some excellent results have been achieved. For example, permeability has been correlated with pore network tortuosity in commercial shale samples (paper just published), and mineral characterization has been correlated with gas adsorption at pressure and temperature conditions relevant for the formation (paper in preparation). In collaboration with Dr Paul Ashby, who is part of the External Advisory Board, SXT is now attempting to extend the experimental capabilities towards better characterising the kerogen-clay interface in shale samples with resolution of the order of ~ 1-2 nm, which would allow better synergism with WP04. To achieve this new objective we are submitting proposals to other agencies, as this task was not originally part of the SXT proposal.

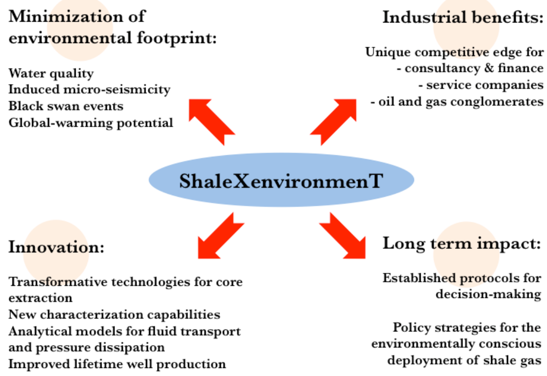
WP04 – The task of this WP is to develop a fundamental understanding of the behaviour of the fluids (incl. water, methane, higher molecular weight hydrocarbons, carbon dioxide, surfactants, salt) confined in the heterogeneous narrow pores present in shale rocks. Many results have been obtained and published. For example, SXT has contributed to developing new computer models to simulate clays, SXT has demonstrated the effect of CO2 on the equilibrium pore size in clays, SXT has developed new models for kerogen that are consistent with experimental characterization, SXT has simulated has adsorption in pores that are consistent, sometimes quantitatively, with experiments, SXT has quantified the transport of hydrocarbons in narrow pores filled with water, etc. The papers are reported on the SXT website, including a recent review article published in Energy & Fuels. The goal is to maintain strong connection with experimental characterization of both rocks and fluids.

WP05 – This WP seeks to design 'green' hydraulic fracturing fluids. The obstacle was that the fluids formulation is highly protected by industry, so SXT had to start from scratch in its studies. Impressive fundamental results have been obtained using aqueous solutions containing polysaccharides and natural surfactants, for example. The data are in the form of viscosity as a function of the shear rate and as a function of system composition. SXT reported that the viscosity can change by 1-2 orders of magnitude depending on the salt type present. Fluids whose properties can be changed in response to an external stimulus have also been designed, and tested. Preliminary data are being collected for fluids containing zeolites (from WP7). Now the focus is on designing strategies to precipitate selectively NORM, so that to minimise the environmental impact. Following recommendations from the mid-term review we have established new connections with Innospec and with Anadarko, industrial companies, to accelerate the impact of these studies. We have also identified a new collaborator, from the University of Huelva, to conduct characterization experiments at conditions relevant for sub-surface applications. SXT is ensuring that this is a new partner before the experiments can be conducted.

WP06 – This WP has led to the application of a stochastic approach (kinetic Monte Carlo) to predict the permeability of a formation depending on mineral composition. The first paper has been published, and now SXT is extending the approach. Partner Geomecon has enhanced the proprietary software roxol to describe fracture propagation. The next hurdle will be to combine fluid-transport properties with fracture propagation. This WP is a bit delayed because of the problems encountered in hiring suitable personnel, problem that is now overcome.

WP07 – This WP develops synthetic porous materials with features similar to those of the narrowest pores found in shale formations. New zeolites have been prepared and SXT has been able to manipulate the chemistry and the pore size of the materials produced. The progress has been excellent, with materials synthesized and characterized. The papers have already ben published. The next hurdle is to produce monoliths, and to integrate these materials in the other WPs. We are using the zeolites in WP03 (to measure adsorption isotherms) and in WP5 (to control the properties of hydraulic fracturing fluids.

WP08 – This WP focuses on the reclamation of flow-back and production water. The WP has identified several technologies that can allow SXT to recycle the water either in new fracturing jobs, or in various human activities on the surface. Several papers have been published. The next task is to connect these results with the geo-political landscape in Europe to make the results more applicable, and to include synergistically results from WP5, WP10, and WP11 in the optimisation strategy implemented here. We made connections with Anadarko, an oil and gas company that has successfully employed optimization strategies to reduce the environmental impact of its operations. For example, Anadarko is trying to use renewable energy to operate oil and gas wells. WP08 is exploring whether this is a suitable scenario for the shale gas operation in Europe.
WP09 – This WP quantifies the risks associated with the production of shale gas along two lines: (a) induced micro-seismicity and (b) wellbore blowout. We developed software to describe the flow of natural gas, water, and eventually other fluids from a shale formation up to a production well. The results have been integrated with a model, which will allow us to quantify how far from a well it will be possible that a possible blowout will have strong environmental effects. We also developed a framework to assess the risk of induced seismicity when a rock is hydraulically fractured. The model needs to be adapted to the properties of European shale formations, and tested against experimental data obtained from the literature (no new well will be drilled within this project). Following recommendations from the mid-term report we have allocated some resources to this WP to enhance its impact.
WP10 – This WP applies the Life Cycle Assessment methodology to quantify all possible environmental impacts of shale gas production. SXT has developed a LCA model, and has used it to compare and contrast the environmental impact of a hypothetical shale gas production in the UK inland, against the current natural gas used within the country, as well as other sources of energy. The approach followed recommendations from the mid-term review, and all deliverables from this WP are about to be submitted.
WP11 – This WP is tasked with the overview of the current legislation regarding shale gas exploration and production. The goal is to compare the EU framework to those available in other localities (e.g., Australia and North America) to identify governance conditions that could promote a more transparent engagement with both the wide public and the industrial sector. After initial delay, the activities are now entering the production phase.
WP12 – This WP is tasked with the dissemination of our results. During the first period of the project, 11 scientific papers have been published. Since the beginning of the project, SXT members have contributed to numerous national and international conferences. Two Summer Challenge events, targeting Year-12 students, were offered, once in 2016 and once in 2017. The 1st Shaleology Forum, a public dissemination event, was organised in December 2016 and gathered about 50 participants from academia, industry and government. The event was recorded and the videos are available on YouTube. The 2nd Shaleology forum took place on October 6th, 2017, and attracted ~60 participants, including 20 post-graduate masters-level students enrolled in the MSc 'Global management of Natural Resources', a program that was launched in 2016 at UCL as part of the SXT educational and training activities. One public presentation was offered to the public during the SXT 2nd Annual Meeting in Florence, in June 2017. One other dissemination event will take place in Doha, Qatar, in March 2018.



5. IMPACT

The positive impacts expected from SXT are summarised in the figure. Impact will be tangible at the end of the project:
Replicability. SXT is developing experimental and computational protocols to carefully characterise shale rock samples and predict with accuracy the productivity of a sub-surface formation. These tools will provide reliable testing methods in this sector.
Socio-Economics. SXT maintains a transparent communication with all stakeholders, as summarised in WP12. This wide dissemination will be instrumental for regulating the implementation of shale gas in the EU.
Environment. SXT is identifying technologies to minimise the environmental impact of shale gas production, ranging form the design of 'green' hydraulic fracturing formulations, reclaiming waste water, enhancing the ultimate recovery of a formation, and tools for quantifying the life cycle impact of shale gas.
Market Transformation. By combining innovative core samples characterisation tools, green formulations, and computations, SXT will positively transform the shale gas process reducing its environmental impact.
Policy. SXT is comparing policies in EU, USA and Australia. SXT will provide recommendation on which protocols secure the inclusion of all stakeholders in the decision-making regarding shale gas production. This impact will be enhanced by a close collaboration with the other 3 Horizon 2020 in the area of shale gas.