# Exploring our marine geological resources in the fifth dimension: About 3D voxels, 4D impact models and uncertainty

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Mineral and geological resources such as sand and gravel, ores and hydrocarbons can be considered to be non-renewable on time scales relevant for decision makers. Once exhausted by humans, they are not replenished rapidly enough by nature, meaning that truly sustainable management of these invaluable and sought-after resources is not possible. Using them wisely and sparingly requires a thorough and careful balancing of available quantity and quality *versus* rapidly changing societal and economical needs. The need for such an approach is recognized in the EU's Raw Materials Initiative, which highlights the optimization of the geological knowledge base as a key element in ensuring enduring supplies from within the EU borders. Comprehensive knowledge on the distribution, composition and dynamics of geological resources therefore is critical for developing long-term strategies for resource use in our changing world.

To help ensure the optimal use of finite quantities of sand and gravel in the Belgian and southern Dutch parts of the North Sea, the new Belspo Brain-be project TILES will develop cross-border and integrated strategies for their long-term extraction. TILES has the ambition of:

Developing a decision support system (DSS) for resource use. This DSS contains *tools* that link 3D geological models, knowledge and concepts, providing information on present-day resource quantities and distribution, to numerical models of extraction-related environmental impact through time. Together they quantify natural and man-made boundary conditions and changes to define exploitation thresholds that safeguard sustainability on a multi-decadal time scale. These thresholds need to be respected to ensure that geomorphological and habitat recovery from perturbations is rapid and secure, a prerequisite stated in Europe's Marine Strategy Framework Directive, the environmental pillar of Europe's Maritime Policy.
Providing long-term adaptive *management strategies* that have generic value and can be used for all non-hydrocarbon geological resources in the marine environment, locally and more globally.
Proposing legally binding *measures* to optimize and maximize long-term exploitation of aggregate resources within sustainable environmental limits. These proposed measures feed into policy and associated monitoring plans that are periodically evaluated and adapted (e.g. Marine Spatial Planning and the Marine Strategy Framework Directive).

Extensive analyses of data- and interpolation-related uncertainties, and of the propagation of these uncertainties in data products such as maps and GIS layers, form the backbone of the DSS. This is a necessary step in producing data products with confidence limits, and critical to detecting *'true'* seabed changes in environmental monitoring. Using a dedicated subsurface viewer, a suite of data products will be viewable online. They can be extracted on demand from an underlying voxel (3D pixel) model. Each voxel will be assigned with values for geological, environmental and decision-related parameters, including uncertainty. The flexible 3D interaction and querying, enabled by TILES, will be invaluable for professionals, but also for the public at large and for students in particular. It will herald a new age in assessing cross-border impacts of marine exploitation activities.