ENHANCED LANDFILL MINING – A FUTURE PERSPECTIVE FOR LANDFILLING

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SUMMARY: Governments and co-operations are aware of the fact that more sustainable consumption and production practices are required. Efforts are being made to produce less waste while increasing the recycling ratio. Concurrently, it is of importance to place landfilling in a sustainable context. The present paper discusses a novel concept where a landfill is no longer considered as a final solution but rather as a ‘temporary storage place, awaiting future valorisation’. Enhanced Landfill Mining (ELFM) offers the opportunity to select the most suitable moment to recycle certain waste streams, depending for instance on the state of the technology. Recently, a transdisciplinary consortium was established. The first, embryonic elements of this new vision are presented in this paper. To make matters more tangible, the ‘Closing the Circle’ case-study is used to illustrate the ELFM concept. The economics are influenced by technical and society driven parameters. In order to successfully transitionise this novel view on waste management, a multi-actor approach is of paramount importance.

1. INTRODUCTION

Recently, a consortium of people with varying expertise was established in Flanders (Belgium) in order to explore potential pathways to develop an enhanced landfill mining approach and to integrate landfilling in a more sustainable waste management practice (Enhanced Waste Management: EWM). The authors of this paper are members of this consortium..The initiative was initiated through a first landfill mining feasibility study, Closing the Circle, of Group Machiels. The landfill site in the east of Flanders has been operational since the beginning of the 1970s. At present it contains more than 15 million tons of waste. Roughly half of this material is household waste, while the other half comprises industrial wastes such as shredder material from the car industry, metallurgical slags, pyrite containing slags, dried sludge and so on.
Several of the industrial processes that produced these wastes are still in operation. In contrast

with the regular practice in the past, the valuable materials from these waste streams (e.g. metal from steel slags) can presently be recovered in the respective industrial plants. Hence, the landfill operator concluded from this that the technologies are available to also recover these materials from the previously landfilled waste. Unfortunately, due to several barriers, the start of the mining of specific wastes could not take place. Further studies indicated that many additional waste types from the landfill can be recycled or used as an energy source. Beside, society demands for a more integrated and sustainable approach of waste management. This new opportunity and long term vision of Group Machiels was developed into a business plan. Only sustainable technologies were selected in the plan, to comply as much as possible with the concept of ‘closing the materials loop’. The approach is clearly distinct from traditional landfill mining (for a literature review, see van der Zee et al., 2004), where the mining is often limited to reclamation of methane, a limited number of valuable metals such as copper or alumina, and reclamation of land (Jones, 2008; Prechthai et al., 2008). Likewise, it is also distinct from the concept of so-called ‘sustainable landfills’, which partially refer to the bioreactor concept (Read et al., 2001). In the latter only organic matter is allowed, which is kept moist in aerobic conditions. The material subsequently degrades and becomes stable (Rich et al., 2007). Emissions of leachate and landfill gas are reduced. After completion of the biodegradation, the internal body of the landfill should match that of the surroundings to prevent movement of pollutants (Stichting Duurzaam Storten, 2006).

In our novel ELFM vision, the goal is not to stabilise the materials but rather to valorise the various waste streams either as material or as energy. Concurrently, the function of the reclaimed land use will be designated for nature purposes. The economic profits are thus only based on the valorisation of the mined materials from the landfill. Therefore, an integrated approach using different and highly efficient techniques for valorisation is required. As part of the sustainable approach, also CO_2 neutrality is envisaged. This can be achieved by using Carbon Sequestration and Storage (CCS) techniques and/or mineral carbonation, in which the potential of some alkaline waste materials will be exploited (Van Gerven et al., 2009).

To emphasise the novel, distinct approach with respect to traditional landfill mining, we propose to use the concept ‘enhanced landfill mining’ (ELFM). The sustainable approach, the alternative energy perspectives and various job opportunities have already convinced several stakeholders in Flanders about the attractiveness of ELFM. The region of Flanders counts more than 2000 closed landfills and several major, still active sites. A successful ELFM project will certainly result in the start up of new projects. Furthermore, ELFM is considered by the consortium to be an integral part of a more general novel view on waste management. The latter is described as Enhanced Waste Management (EWM). The consortium is developing both concepts – EWM and ELFM – based on discussions with varying actors and similar developments in other countries. An important aspect of EWM is that, as a last option after optimised re-use, recycling and recovery of materials, the landfill or storage place also becomes part of the closed materials loop. In this case the material loop has a prolonged time span. An extended producer responsibility should make sure that in the future more materials are recycled or valorised as energy.

The ELFM consortium is well aware that this study envisages a major shift in both waste management technology and waste management vision, and is well aware of the conflict between this vision and existing European and national regulations concerning waste management and landfilling. It, therefore, developed several research lines. One of the crucial issues here constitutes an economic and societal assessment of the ELFM concept. In order for ELFM to become a success, apart from technological improvements and breakthroughs, a multitude of socio-economic barriers need to be overcome. These barriers include: regulations, societal acceptance, economic uncertainty and feasibility.

The present paper discusses the first, embryonic results of the assessment by the ELFM consortium and is mainly focussed on the development of a new vision on waste policy, being the combination of Enhanced Waste Management (EWM) and Enhanced Landfill Mining (ELFM) as a future perspective for landfilling.

2. CONCEPT

2.1 Towards Enhanced Waste Management (EWM)

During the past 50 years, major paradigm shifts have occurred in waste management in Flanders as well as in the rest of Europe, both for municipal solid waste (MSW) and industrial waste (IW). Fig. 1 provides an overview of the main shifts. The first shift was the phasing out of uncontrolled landfilling. Since the 1980s, all landfills have to obey a number of regulations. A landfill constitutes an environment, which is entirely closed to the outside and is meant to be isolated for ever. However, it is clear that the applied protection layers will not last that long. A major drawback is that the after care period for a closed landfill is limited to 30 years. Likewise, it is doubtful that all wastes are stabilised in that period. Stabilisation implies that the waste will undergo no chemical or physical changes anymore and that it has become safe for the environment even after ruptures in the protection layer. Furthermore, landfills require enormous amounts of land space. Landfilling as 'a final solution' is thus a suboptimal choice. It is, therefore, not surprising that a following step in waste management included the use of incinerators to radically reduce the amount of material to be landfilled. Nevertheless, in an energy (exergy) restrained world, incineration without energy recovery is a completely unacceptable practice. The next step in waste management policy, therefore, consisted of combining landfill practices with a waste-to-energy approach. In Flanders, landfilling for MSW was gradually replaced by incineration. Apart from some exceptions, mainly due to limited incineration capacity, landfilling of MSW is currently almost phased out. Following Lansink's stepladder – which sets the following priority for waste management: prevention > recycling > incineration with energy recovery > incineration > landfilling – waste management has also evolved to a stronger focus on material recuperation and recycling (e.g. glass, paper etc.) and waste prevention. Nevertheless, despite increasing attention for sustainability, total MSW generation in the EU25 has increased from about 150 million tonnes in 1980 to more than 250 million tonnes in 2005 and is forecasted to reach 300 million tonnes by 2015 (ETC/RWM, 2007). With respect to industrial waste (IW) it is clear that the landfilling/incineration ratio is much higher compared to MSW. On the positive side, a major shift has been made from dumping or incinerating waste towards increased recycling and re-use of materials. Moreover, new concepts in waste and material management such as cradle-to-cradle and industrial ecology are receiving a lot of attention (Kollikkathara, 2009).

On the one hand, it is clear that we still need landfilling as a waste management tool and it will probably be the case for quite a long time. The main reasons are due to the limited capacity of other techniques such as incineration combined with the still growing amount of municipal solid waste (MSW); a lack of suitable techniques to treat all kinds of wastes; and no sound economic balance. On the other hand, it is also clear that it will become increasingly difficult to find new space for new landfills and to get the permission for their construction. Some local authorities not only charge a tax for every tonne of waste that is landfilled but also for surface area that is occupied by a landfill because this space is not available anymore for new industrial development. As a consequence, also old landfills will be charged.

The consortium investigates the development of a more sustainable waste management vision, which we call Enhanced Waste Management (EWM). In this new concept, prevention and re-use/recycling become even more important, while the idea of landfills as 'a final solution' is discarded. In our view, landfills can become part of EWM, provided they are considered as 'temporary storage places awaiting further treatment'. In this approach, indicated in figure 2, landfills become future mines for materials, which could not be recycled with existing technologies or show a clear potential to be recycled in a more effective way in the near future. Extended producer responsibility for the materials stored in such temporary storage places becomes part of this EWM view. This idea is related to the fact that today's practice of incineration eliminates the possibility for reuse of materials resulting in increased material costs and decreased welfare. (In fact, some authors claim that, using a social cost minimising model, landfilling with energy recovery is to be preferred over WTE plants (Dijkgraaf et al., 2004)). An approach based on improved recycling and storage in view of recycling is a possible answer in order to increase re-use rates. This is the first pillar of EWM.

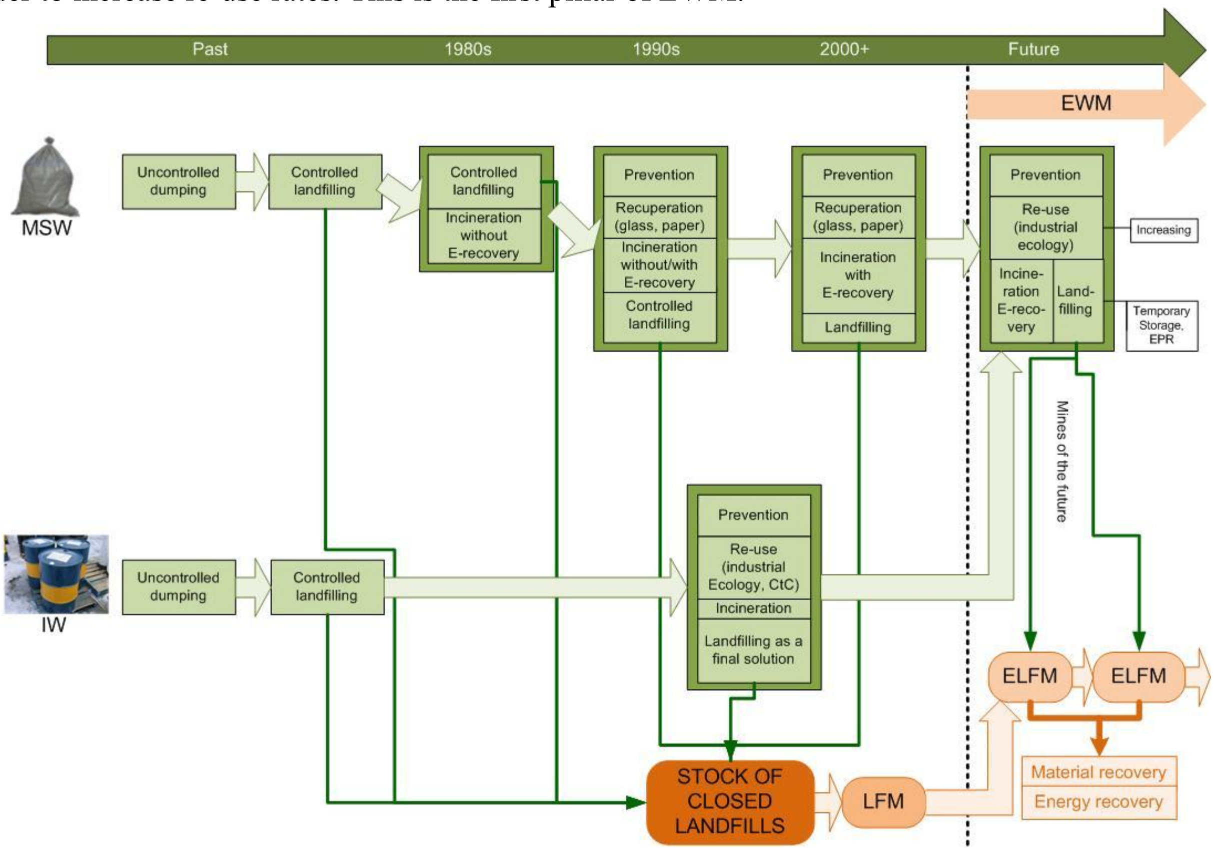

Figure 1: Schematic overview of the historic and (potential) future evolution of waste management.

In order to prevent that waste materials will be given an application that is far from the optimal valorisation and to make sure that more materials find their way to recycling instead of incineration or dumping, the 'temporary storage' concept (instead of a permanent landfill) may become acceptable. This temporary storage is of course not simply another name for a traditional landfill. The landfill owner, the landfill operator and/or the waste producer will have to take into account that the landfill needs to be mined after a short, intermediate or long period. This extended producer responsibility for the materials stored in such temporary storage places becomes part of the EWM view. For small producers of waste streams who are probably not able to invest in novel valorisation methods and applications, the extended producer responsibility approach can be modified to better suit these companies. Instead of paying a high landfill fee that is transferred to the state treasury, a (small) producer of residues can pay the landfill operator to take over its responsibility and to develop future valorisation solutions. The operator of the temporary storage facility will be responsible for finding sound applications and will invest to increase the value of the applications. It will induce another way of landfill engineering and landfill operation. The concept of temporary storage facility is not new, considering it is standard practice for low to moderate polluted soils (with limited applications). Bringing together a much greater amount of soil or waste material will improve the economic balance when looking for an application.

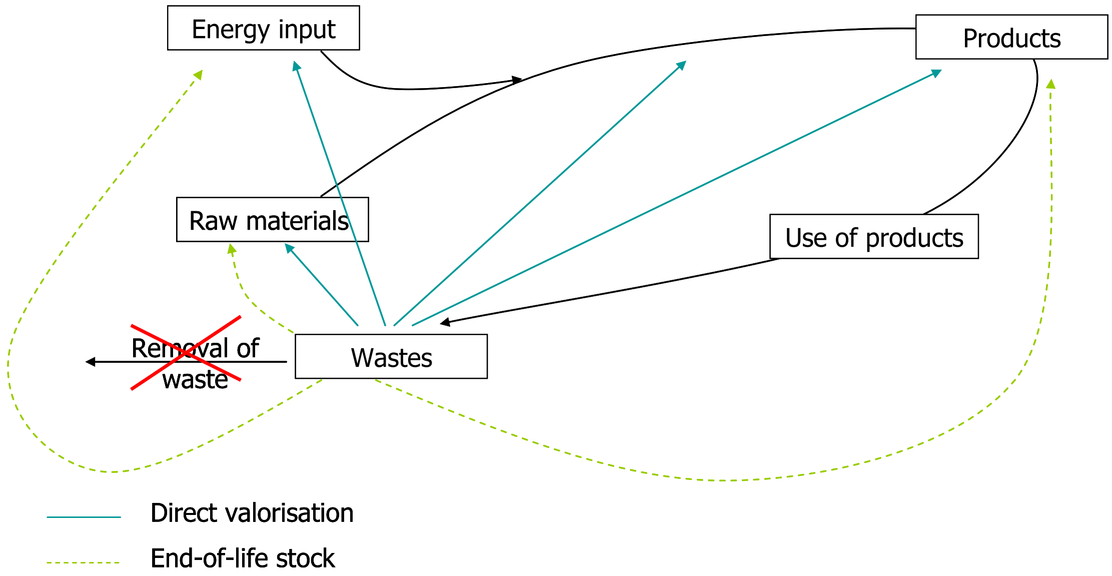

Figure 2: The production cycle with end-of-life stock (temporary storage).

2.2 Towards Enhanced Landfill Mining (ELFM)

The second pillar of EWM is the concept of Enhanced Landfill Mining (ELFM). As indicated above, the waste brought to new storage facilities needs to be mined after a limited time. The storage operation will be performed in such a way to make mining and valorisation as efficient as possible. For example, in case high caloric values are required for energetic valorisation, it is better to keep the waste dry by preventing water to enter the storage facility. The non-recyclable fraction needs to be stored again at that particular moment in such a way that future mining is possible. Valorisation will continue in an iterative way.

Next to new landfills, taking into account the iterative valorisation approach, ELFM is also applicable to old landfills (see Figure 1: 'Stock of closed landfills'). This is essential to deal with the (waste) legacy of the past. Historically, billions of tonnes of waste have already been dumped and stored in landfills worldwide. Given the fact that recycling and energy technologies have sharply improved (and are still improving), and given the volatile but steadily increasing prices of commodities and carbon emissions, new opportunities are arising. Past and present landfill mining (LFM) practices (i.e. opening up old landfills to recover some of the materials and/or CH4) are not suited to valorise these opportunities in a sustainable and integrated way (for a review, see van der Zee et al., 2004). Therefore, an enhanced landfill mining (ELFM) practice is urgently required. ELFM includes the valorisation of the historic waste streams as both materials (Waste-to-product, WTP) and energy (Waste-to-energy, WTE), with the ratio being dependent on the type of waste streams and the state-of-the-art technology for material recuperation and energy production. Material recuperation can be either direct or indirect (i.e. when an additional step is required). Enhanced landfill mining also incorporates the goal to prevent that CO_2 arising during the energy valorisation process is emitted in the atmosphere. ELFM becomes part of the transition towards a fully closed loop material system. The ideas generated through ELFM become directly relevant for the future development of EWM with respect to the mining of the temporary storage places mentioned above. The consortium will perform Life Cycle Analyses (LCA) of this concept and compare the results with that of others (Cherubini et al., 2008; De Feo et al., 2009; Liamsanguan et al., 2008).

3. INNOVATIVE TECHNOLOGIES FOR ELFM

Fig. 3 shows a general picture of the different technological innovations required to realise ELFM at the case study landfill site. It consists of separation, further treatment and recycling, energetic valorisation, mineral carbonation, carbon sequestration and storage (CCS) and the use of the recycled materials in or as construction materials. The detailed analyses of possible techniques are not described here. Pilot testing of different techniques still needs to be done and is planned to happen by the end of 2010. Besides literature reviews and discussions with technology suppliers, waste will be collected from several spots of the landfill and treated with available technologies. Technology providers will be invited to show the possibilities of their techniques and international meetings will be organised to attract parties that can provide promising technologies. Separation, material recycling as well as energy recovery should be as efficient as possible to maximise the return. In case of 'Closing the Circle', the location of different waste types is well described in a log book of the landfill. Sampling waste at different spots showed good correspondence with the information of the log book. The combination of log book information and sampling made it possible to develop a detailed business plan as will be discussed further.

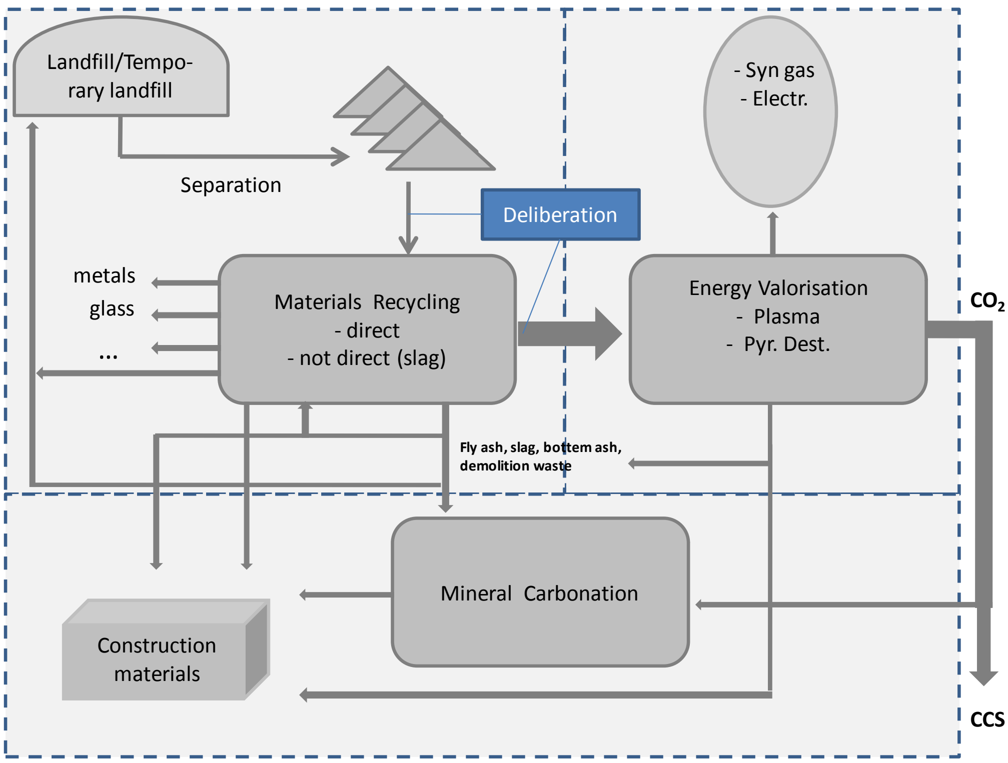

Figure 3. General picture of the different technological innovations required.

The separation technology that is to be applied will depend on the waste type. Soil, glass and stones should be removed in the case of household waste. As regards to stainless steel slags, the separation and sieving will intend to recover metal (iron, nickel and chromium) and create a slag residue suitable for the asphalt industry.

A large part of the waste of the selected landfill case-study is of organic nature and can be used for energetic valorisation. The power plant to treat this amount will be constructed on site to minimise transportation costs. Waste of different caloric value needs to be mined in order to optimise the caloric value of the feed of the power plant. The landfill will, therefore, be opened at several spots. A grate furnace that treats 100.000 ton annually operates at an installed electrical power of typically 5 MW. Fluidised bed burning will be more efficient but the high amount of fly ash and slag production results in high process costs of these wastes. Besides, both technologies produce a lot of CO_2. Peter Jones (Jones et al., 2008) indicated that plasma technology has the lowest CO_2 impact due to the production of syngas. Syngas can be used as such or burnt in a second combustion chamber delivering the energy output. Although the viability of this technology is not completely established on a large scale, it is promising and clearly shows major advantages. Its disadvantage is the use of electrical power as energy source (Gomez, 2009). Plasma technology works at low gas flow rates, thereby reducing the requirements for off-gas treatment. However, the high temperature of the plasma (temperatures higher than 6000°C can be reached) will vaporise volatile metals. Metals can be collected afterwards as a melt or condensed from the vapour phase. Slags with low leachabilities can be obtained by applying the appropriate additives to obtain a glassy matrix in which contaminants such as metals are trapped. The ability to recover metals is of interest for the treatment of automotive shredder waste that still contains a lot of copper. Also cold plasma technology can be applied with temperatures below 2000°C (Huang, 2009).

The Chartherm process is an improved gasifier that operates at much lower temperatures (Helsen, 2009). However, it is not clear yet whether such an installation can be scaled up to treat almost 100.000 ton a year. Existing plants treat 1500 kg/hour. The main output of the process is very pure carbon powder and syngas, which is used to maintain the process. Pure carbon powder is highly valuable. As new carbon fiber and carbon nanotube applications are being developed, the value of pure carbon powder will even increase.

The emitted CO_2 from, for example, the second combustion chamber of the plasma process can be injected and stored in the soil. Carbon sequestration and storage still costs over 40 €/ton. An alternative is the use of alkaline waste materials to react with CO_2 to form $CaCO_3$. Fly ashes and slags from metallurgical processes and waste incineration are all present in the landfill and can be used for mineral carbonation (for an overview, see Van Gerven et al., 2009).

4. ECONOMIC APPROACH

In the end, the main incentive for private companies to initiate an enhanced landfill mining project is the expected economic return. Previous experiences with traditional landfill mining projects indicate that the economic costs and benefits are in many cases not in balance. An economic assessment of landfill mining is often not straightforward. The economic balance is strongly affected by time constraints (energy costs, available technology, value of land…) and by several factors related to contemporary environmental concerns such as climate change.

William Hogland (Hogland et al., 2008) discussed the financial aspects of landfill mining, indicated the case-by-case approach, the need for comprehensive accounting of the economic benefits and the need for new tools to facilitate the financial reviewing. Apart from costs and clear benefits, also various other sources of revenue can be obtained, such as emission credits for reducing methane or carbon dioxide emissions (in case of capture and storage) and an increased value of the reclaimed land. The majority of the examples from the literature concerning economic assessment is, however, related to sanitation or restoration of sites and not to cases of enhanced landfill mining.

The business plan of the landfill mining case in this paper (Closing the Circle) uses the methodology of the Internal Rate of Return (IRR), the Net Present Value (NPV) and pay-back time to assess the economic return. The IRR is compared with a benchmark IRR of 15% for private activities with public participation. An extensive sensitivity analysis of the business plan for variations in the exogenous parameters showed that the electrical efficiency of the waste-to-energy plant is the most important technical parameter with an elasticity of 2.7. Other important economic parameters are the share and value of green certificates (which are used by the local authorities to promote renewable energy) and the investment costs. Variations in the value of recovered metals hardly influence the IRR. On the other hand, the way the CO_2 emissions of the waste-to-energy plant will be treated in the European Emission Trading Scheme is a major parameter. In fact, this is a crucial element in the business plan for the ELFM project. If the plant is to be considered as a waste incineration plant, it will probably be exempted from the ETS obligations after 2012. If, in the other case, it is included in ETS, the installation should buy all required emission allowances at auctions. Although this would imply a high additional cost for the project, it also gives incentives to explore alternative ways of dealing with CO_2 such as mineral CO_2 sequestration or CCS.

In the case that landfill mining becomes part of an Enhanced Waste Management vision, other supporting policy instruments can be developed, such as a raw material saving credits that promotes the conversion of waste to materials, a time dependent tax reduction scheme for temporay storage compared to landfilling, CO_2-credits for indirect CO_2 reductions. It is important that policy makers clarify to what extent the waste from the landfill can be considered as renewable and what kind of supporting mechanism can be used.

5. SOCIATAL APPROACH

As indicated above, the possibility of the government to use several instruments to either support enhanced landfill mining or to maintain the status quo renders the economics strongly dependent on the societal acceptance (Jones, 2008). Besides the authorities, several local actors and stakeholders need to be convinced about the sustainability and desirability of the novel approach. It is clear that during this process one has to take into account that all stakeholders have distinct barriers in mind, which can only be solved if long term, visionary thinking is guiding the discussions. It is acknowledged that a long term approach is not always straightforward for all actors involved. Profit in the long run, which implies major changes today, is like a step into the unknown. The consortium fully recognises the major difficulties in guiding the transition from the present landfill concepts to the more sustainable, enhanced landfill mining view. The societal part of the consortium activities is set up according to the principles of transition management, with its five different phases: contextual analysis; vision development; strategy development; operationalisation and progress measurement. This paper is a first contribution to the development of a vision with respect to a novel (enhanced) landfill mining concept.

6. CONCLUSIONS

ELFM is a concept that intends to place the landfilling of waste in a sustainable context. The implementation of ELFM can be regarded as a transition within the regime of waste management, which will require a lot of deliberation with all stakeholders. The economics of ELFM are strongly influenced by several technical parameters (such as the energetic output) and by more society driven parameters (such as carbon taxes and green certificates). In order to successfully transitionise this novel view on waste management, a multi-actor approach is of paramount importance.

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