

No. SN-01/20

The REJUVENATE Decision-Making Approach

- A Worked Example -

**Crop Based Systems for Sustainable Risk Based Land Management for
Economically Marginal Degraded Land**

Accompanying Volume to the Final Research Report

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Paul Bardos

Name of coordinator organisation:

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Abstract

This Rejuvenate project is a desk study carried out by four organisations from the United Kingdom, Sweden the Netherlands and Germany. Its goal is to highlight the potential opportunity for using marginal or degraded land, in particular brownfields and other previously developed or contaminated land, for producing biomass. This biomass could be used for energy, fuel production or as a feedstock. The use of marginal / degraded land may offer sustainability advantages in regions where it is present in significant amounts and cannot be readily used for built development. In addition, composts and other recycled organic matter may play an important role in the soil improvement and management necessary for the cultivation of these non-food crops.

This report provides a worked example of decision making for biomass production on marginal land.

Abstrakt

Projektet Rejuvenate är en skrivbordsstudie som utförts inom fyra organisationer från Storbritannien, Sverige, Nederländerna och Tyskland. Projektets mål är att belysa möjligheten att använda marginaliserad mark eller degraderad mark, framförallt gamla industriområden, andra tidigare utvecklade eller förorenade områden, för att producera biomassa. Denna biomassa kan användas för energi, bränsleproduktion eller som en råvara. Nyttjandet av marginaliserad mark för detta ändamål kan erbjuda fördelar ur ett hållbarhetsperspektiv, speciellt i områden där det finns stora sådana arealer som inte kan användas för bebyggelse. Dessutom kan kompost och annat återcirkulerat organiskt material spela en stor roll som markförbättring och för åtgärder som behöver vidtas för odling av denna typ av grödor.

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The Swedish Geotechnical Institute's project work began before the official SNOWMAN start date under Swedish funding. Work was also initiated by all partners from early in 2008 and was self funded.

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Executive Summary

The increasing use of biomass for energy has become an important facet of reducing the use of fossil fuels. The establishment of non-food crops for biomass utilisation can contribute to policy goals related to renewable energy and carbon management. However, the use of land to produce any type of biomass for feedstocks, fuels, and energy has become increasingly contentious, with a number of environmental, economic and social sustainability concerns raised (e.g. land use conflict between biomass for industrial food production versus energetic and material use of biomass). The use of marginal land is an emerging opportunity in this biomass debate. Marginal land includes previously developed land, under-utilised land and land affected by diffuse contamination (post industrial, mining and military areas, etc.). All across Europe there are areas of land that have been degraded by past use, and that are not possible to restore easily or sustainably using conventional methods. The Rejuvenate Project Final Research Report proposes a decision tool framework (or *decision support tool*) to support the use of biomass on marginal land and the recycling for organic matter for soil improvement. This report applies this decision support tool in a worked example for a fictional site. The decision making process addresses:

- What are the realistic possibilities for the sustainable re-use of marginal land for biomass for a particular site in a particular geographical area?
- How the site characteristics affect these possibilities and how a site might need to be managed to optimise biomass cultivation and manage any potential risks to human health and the wider environment?
- Of the available options which deliver the greatest value in terms of direct project returns and wider sustainability benefits?
- What project risks might exist, such as those relating to project financing, acceptability and technological reliability, and how these might be mitigated if necessary?

The worked example applies the decision support tool to a typical post industrial mining area. A real marginal land site, a UK colliery spoil heap, for which the Rejuvenate team had good access to information, and for which biomass had been considered, was used as a basis for the worked example. However, the context was shifted to a fictional location in Germany, which is where the researchers carrying out the worked example were based, and was shifted in time to the present day. The fictional location included a series of surrounding facilities which might supply organic matter to the site, and use the biomass that it produced. These changes were made to support illustrative economic modelling relating the delivery of value. This modelling used a German context in terms of crop performances and financial returns. The soil management and risk management processes discussed were also placed in a German regulatory and policy context.

The Rejuvenate decision-making framework comprises four stages.

1. Crop suitability: primarily considers from a range of possible biomass crops which crops are able to grow in a region with a potential local market. This will include an assessment of both climate and site topography. For convenience, this stage provides a biomass crop short list. Each subsequent stage is likely to reduce the length of this list as a more refined solution is found.
2. Site suitability: considers whether the site conditions are suitable for particular biomass crops in the short list and what the environmental risks of crop production might be; a site may be suitable already for some crops or can be made suitable by soil / risk management interventions. If an on-site conversion facility is being considered then the suitability of the site for this facility must also be considered and any necessary interventions (for example infrastructure) considered. Furthermore, the impacts arising from any site management activities for risk and soil management and facility development need to be properly considered.
3. Value: there is a direct cost benefit equation as to whether the benefits of using a site for biomass are worth the investment needed, but also a wider sustainability consideration, considering for example aspects such as improvement in biodiversity, carbon sequestration or local community enhancement. It may be appropriate to include other measures to increase overall project value, for example integrating other forms of renewable energy production with the site re-use, or combining biomass use with the re-use of agricultural residues.

4. Project risk: once a firm project concept has been elaborated whose value is attractive to its developers, the project planning needs to then ensure its viability as far as possible before any major investment takes place. Three broad considerations are important: technology status, detailed diligence (e.g. of financial partners and project partners) and developing a broad stakeholder consensus.

The worked example is based on a fictitious site, which is a closed colliery spoil heap in the western part of Germany. Currently, the surface is partly used for grazing. There are also a small number of visitors that pass through the site on the bike path. The intended use of the area will be a mixture of SRC, forestry and open fields amounting to an 80 ha size in total.

The example elaborates the four stages of the decision-making framework to identify the lowest risk alternative of crop cultivation on marginal land from environmental and economic viewpoints, taking into account regional and site conditions. Stage 1 (crop selection) provides a rationale for a shortlist of three crop types (poplar, willow, and *Miscanthus*).

Stage 2 considered site characteristics to identify, soil management and risk assessment needs and their impact on crop selection, along with the wider environmental impacts of biomass production. Stage 2 would in practice select only willow for further evaluation. Soil depth was insufficient for *Miscanthus* and costs of increasing soil depth would be prohibitive. Poplar was discounted as it is seen as too susceptible to disease. The soil management selected was based on the use of green compost and sewage sludge to improve the soil quality without degrading the risks. The estimated cost of management was found to be €1,510 per ha.

The key focus of Stage 3 is concerned with the selection of crop types providing the most attractive prospects in terms of revenue and sustainability. In this example Stage 3 compared maize, *Miscanthus*, poplar and willow for the purposes of illustration for Stages 3 and 4. On the basis of the economic modelling in Stage 3 *Miscanthus* and willow were taken forward to Stage 4. However in practice maize, *Miscanthus*, poplar would have been discounted at Stage 2.

Stage 3 found that, had it been possible to grow it, *Miscanthus* would have been the most the financially attractive crop, and maize had the poorest financial performance. In addition, supplementing on site energy generation using wind and/or solar energy could have been attractive as project enhancements. Both willow and *Miscanthus* were considered in Stage 4, for purposes of illustration.

Within Stage 4, broader feedback from stakeholders hitherto not involved with the project identified a difficulty with the economic model forecasting for *Miscanthus* and also a concern over biodiversity impacts for *Miscanthus*. This led to a requirement for pilot testing of *Miscanthus* production in comparison with willow, or proceeding with a full scale willow project. The uncertainties caused by this situation led to a demand for energy supply guarantees from the main bioenergy client, which placed a new liability on the site owner should they decide to proceed with the biomass project. Ultimately the site-owner took a pragmatic approach in decision-making to proceed with a willow based project immediately, and carry out *Miscanthus* pilot tests in parallel, given the possible benefits of *Miscanthus* for future restoration projects. The site owner found a potential collaboration with the green waste compost supplier was an attractive route to providing energy supply guarantees, that both limited liability and potentially created a new business opportunity for harvesting local wood waste as biomass (providing it was of suitable quality for use for bioenergy).

This worked example is an illustration only. It is intended to show the benefits of a staged approach in determining viable re-use options for biomass based restoration. The illustration shows how options should be refined as early as possible in decision-making, to minimise decision-making effort. In fact, in practice only one viable option remained after Stage 2. However a range of options were retained purely to show the functioning of the later decision-making stages of the framework. The value of this has been to show how economic analysis can support decision making, and how practical and commercial decisions are likely to have a major impact in managing project risks.

The conclusion of the worked example of the decision support tool at this (fictional) German mine site location was that use of willow short rotation coppice over most of the 60 ha of the site, supported by soil improvement using compost and sewage sludge. This would be accompanied by a test plot for ingoing *Miscanthus* trials.

The restoration to biomass approach suggested would also achieve adequate site risk management. Willow has a high environmental tolerance and good biomass productivity. Economic modelling predicted that the direct project returns from this cultivation of 60 ha Willow with a 20 year lifespan (based on a discounting factor of 4%, rate of interest by 4%, Earnings Before Taxation) would yield a Net Present Value of € 235,885 and an Internal Rate of Return of 10.98%. Amortisation of project investment would take place after 11 years, and the project would yield an annuity (see Annex 1) of € 17,357. This is an attractive opportunity for the sustainable transformation of marginal land into sustainable landscape development.

The decision-making framework developed by Rejuvenate can be adapted to country specific boundary conditions and the use of the set of common principles of crop, site, value and project risk management set out by Rejuvenate. This implies that this framework should have wider applicability across the European Union. Consequently, a real field site test and verification of the Rejuvenate procedure is a highly recommended next step in the decision making framework implementation.

The worked example is fictitious and strictly related to the spoil heap described. It is not intended to convey any general conclusions about the suitability of biomass crops for coalfield restoration outside this context. It is intended to illustrate a decision making process.

Sammanfattning

Den ökade användningen av biomassa till energiframställning har blivit en viktig faktor för att minska användningen av fossila bränslen. Etableringen av grödor för produktion av biomassa som inte skall användas som föda kan bidra till att uppnå politiska mål för energiproduktion och koldioxidutsläpp. Nyttjandet av mark till biomassaproduktion som sådan råvara, bränsle och energi, har emellertid blivit allt mer ifrågasatt avseende ett flertal miljömässiga, ekonomiska, och sociala hållbarhetsaspekter (t.ex. konflikten som rör markanvändning för industriell produktion av mat kontra bränsle eller energi). Nyttjandet av marginaliserad mark är en möjlighet som dykt upp i denna debatt. Marginaliserad mark innefattar tidigare utvecklade områden, underutnyttjad mark och mark som blivit utsatt för diffus förorening (gamla industriområden, gruvområden och militäranläggningar, etc.). Över hela Europa finns det områden som har degraderats genom tidigare nyttjande, och som inte är möjliga att restaurera på ett lätt eller hållbart sätt med konventionella metoder. Slutrapporten för *Rejuvenate*-projektet föreslår ett ramverk för beslutsverktyg (eller *beslutstödsverktyg*) för att stödja nyttjandet av biomassa på marginaliserad mark och återcirkulerat organiskt material som jordförbättring. Denna rapport applicerar beslutstödsverktyget på ett exempel för ett fiktivt område. Beslutsprocessen innefattar:

- Vad är realistiska möjligheter för hållbar återanvändning av marginaliserad mark för biomassa för ett specifikt område på en specifik geografisk plats?
- Hur påverkar platskaraktäristika dessa möjligheter och hur ett område kan behöva åtgärdas för att optimera odling av biomassa och för att hantera potentiella risker för hälsa och miljö?
- Bland de tillgängliga möjliga alternativen vilket ger störst värde i termer av direkt omsättning för projektet och i ett vidare hållbarhetsperspektiv?
- Vilka projektrisker kan finnas, såsom risker relaterade till projektfinansiering, accepterbarhet och teknisk tillförlitlighet, och hur kan dessa minskas om nödvändigt?

Det exempel som beslutstödsverktyget används till i denna rapport är ett typiskt postindustriellt gruvområde. Ett verkligt marginaliserat område, ett kolgruveavfallsområde, för vilket Rejuvenate hade bra tillgång till information och produktion av biomassa på området hade varit en av de möjligheter man beaktat utgjorde grunden för detta exempel. För det fiktiva fallet skiftades dock kontexten till Tyskland, eftersom det var där det huvudsakliga arbetet med själva exemplet utfördes. Det fiktiva området innefattade ett flertal omgivande nödvändiga verksamheter som kan förse området med organiskt material och ta tillvara på den producerade biomassan. Ändringarna gjordes för att stödja illustrativ ekonomisk modellering relaterad till leveransvärdet. Denna modellering använde tysk kontext för växtlighet och finansiell avkastning. Även diskussionerna kring mark- och jordhantering liksom riskhanteringsprocessen var också utförda för en tysk kontext.

Rejuvenates beslutsramverk består av fyra steg:

1. Lämpliga växter
2. Platslämplighet
3. Värde.
4. Projektrisk

Det exempel som presenteras i denna rapport är ett fiktivt område, med en avslutad kolgruveanläggning i de västra delarna av Tyskland. För närvarande används området för bete. Det finns också ett litet antal besökare som passerar området på cykelvägen. Den planerade markanvändningen är en blandning av rekreation, skog och öppna fält täckande tillsammans en yta av ca 80 hektar.

Exemplet behandlar de fyra stegen i beslutstödsramverket för att identifiera det lägsta riskalternativet för odling av biomassa på marginaliserad mark med hänsyn tagen till miljömässiga och ekonomiska aspekter med hänsyn tagen till regionala och platsspecifika förhållanden. Steg 1 (växtval) utgör en logisk grund för en kortlista med tre växtsorter (poppel, *Salix* och *Miscanthus*).

Steg 2 beaktar platsspecifika förhållanden för att identifiera behov av markåtgärder och riskbedömning och dessas inverkan på valet av gröda, liksom en bredare miljöpåverkan av produktionen av biomassa. I praktiken skulle steg 2 välja endast Salix för fortsatt bedömning eftersom markdjupet var otillräckligt för Miscanthus och poppel ansågs för mottaglig för sjukdomar. Vidare skulle ett ökat markdjup för att kunna odla Miscanthus vara alltför kostsamt. De markåtgärder som valdes baserades på nyttjande av grön kompost och avloppsslam för att förbättra markkvaliteten utan att påverka risken. Kostnaden för denna åtgärd bedömdes till € 1 510 per hektar.

Nyckelfrågan för steg 3 är att välja den växtsort som är mest attraktiv avseende intäkter och hållbarhet. I detta exempel valdes majs, Miscanthus, poppel och Salix för att kunna illustrera stegen 3 och 4. På basis av den ekonomiska modellen i steg 3 fördes därefter Miscanthus och Salix vidare till steg 4. I praktiken hade emellertid majs, Miscanthus, poppel varit bortsorterade redan i steg 2.

I steg 3 fann man dock att om det varit möjligt att odla Miscanthus så hade detta varit den finansiellt mest attraktiva grödan och att majs hade den svagaste finansiella kapaciteten. Vidare, en komplettering med platsgenererad energi i form av vind och/eller solenergi hade varit attraktiva projektförbättringar. Som illustration beaktades både Miscanthus och Salix beaktades i steg 4.

Inom steg 4, visade en bredare återkoppling från intressenter som hittills inte varit involverade i projektet på en svårighet med den ekonomiska prognosmodellen för Miscanthus liksom på problem med påverkan på biodiversitet för Miscanthus. Detta ledde till behovet av att pilottesta Miscanthusproduktion i jämförelse med Salix, eller att fortsätta med ett fullskale Salix-projekt. Osäkerheterna orsakade av denna situation ledde till krav på garantier på energitillförsel från huvudbioenergi-klienten, som därmed medförde ett nytt ansvar för markägaren inför valet av om man skulle fortgå med planerna med biomassaprojektet. Markägaren valde då en pragmatisk inställning i sitt beslutsfattande genom att starta ett Salix-baserat projekt direkt, och parallellt genomföra en pilotstudie med Miscanthus, för att på så sätt ändå kunna tillgodogöra sig de eventuella ekonomiska fördelarna med Miscanthus i framtida restaureringsprojekt. Markägaren fann att en potentiell samverkan med leverantören av grön kompost var ett sätt att garantera bioenergitillförseln, som både begränsade ansvaret och skapar möjligheter för en ny affärsverksamhet för att tillvarata lokal trädavfall som biomassa (förutsatt att det är av tillräcklig kvalitet för att användas som bioenergi).

Det exempel som presenteras här är endast ett illustrationsexempel. Det har för avsikt att visa på fördelarna med ett stegvis synsätt på livsdugliga återanvändningsalternativ för markrestaurering baserad på biomassaproduktion. Illustrationen visar på hur alternativa möjligheter kan förfinas så tidigt som möjligt i beslutsprocessen, för att underlätta beslutsarbetet. Faktum är att i praktiken hade det bara kvarstått ett alternativ redan efter steg 2. I detta exempel behölls fler alternativ enbart för att visa funktionen hos de senare stegen av ramverket. Värdet med detta har varit att visa hur ekonomiska analyser kan stödja beslutstagandet och hur praktiska och kommersiella beslut har en avgörande påverkan vid hantering av projektrisker.

Mest lämplig att odla, baserat på detta fiktiva exempel av en tysk tidigare gruvanläggning, var Salix-småskog med stöd av markförbättring med kompost och avloppsslam och parallellt testpilotförsök med odling av Miscanthus.

Beslutstödsramverket som utvecklats inom Rejuvenate kan anpassas till nationella och regionala specifika förhållanden genom att nyttja de generella principerna av växt, plats, värde och hantering av projektrisk som tagits fram av Rejuvenate. För implementering av beslutstödsramverket är en verklig fallstudietest och verifikation av Rejuvenateproceduren ett högt rekommenderat nästa steg.

Det exempel som presenteras här är ett fiktivt exempel och strikt relaterat till det avfallsområde som utgör exemplet. Det har inte för avsikt att peka på generella slutsatser på kolgruveområden generellt utan exemplets avsikt är att illustrera beslutsprocessen.

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List of Abbreviations

atro	Measurement for dry material
BBodSchG	Bundes Bodenschutz Gesetz (Federal Ground Protection Law)
BimSchG	Bundes Immissionsschutz Gesetz (Federal Immission Protection Law)
BMELV	Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz (Federal Ministry of Sustention, Agriculture, and Consumer Protection)
BMJ	Bundesministerium für Justiz (Federal Ministry of Justice)
BMVBS	Bundesministerium für Verkehr, Bau und Stadtentwicklung (Federal Ministry of Transport, Buildings, and Urban Development)
CO ₂	Carbon Dioxide
CO ₂ Eq.	Carbon Dioxide Equivalent
DF	Discounting Factor
DCF	Discounted Cash Flow
EU	European Union
EU SDS	EU Sustainable Development Strategy
€	Euro (currency)
FAME	Fatty Acid Methyl Esther
FNR	Fachagentur für Nachwachsende Rohstoffe (Agency of Renewable Primary Products)
ha	Hectare
i	Interest
IRR	Internal Rate of Return
kWh Eq.	Kilo Watt Hour Equivalent
l	Litre
MSP	Municipal Sewage Plant
NPV	Net Present Value
Oil Eq.	Oil Equivalents in l
p.a.	Per Annum
%	Percent
SCR	Short Rotation Copies
t	Ton
UBA	Umweltbundesamt (Federal Environmental Agency)
UNFCCC	United Nation Convention on Climate Change
VER	Voluntary Emission Reduction
WRAP	Waste and Resources Action Programme

1 Introduction

On the one hand, there are significant amounts of degraded land which are not in beneficial use and significant amounts of organic wastes which could be used for restoration, soil improvement and as a fertiliser substitute. On the other hand, there is an increasing demand for land and biomass (for energy, fuel and feedstock) and an increasing interest in carbon management opportunities. The Rejuvenate project has identified that the use of marginal land for biomass production could be an important opportunity in some areas, and has developed a decision making framework as a decision support tool, to facilitate this re-use of marginal land (Bardos *et al.* 2009, Andersson-Sköld *et al.* 2009, Suer *et al.* 2009), shown in Figure 1. This type of land re-use has benefits for a range of sustainability targets, such as those identified by (ISCC 2008):

- preservation of resources
- climate protection
- extension of renewable sources of energy
- downsizing the surface demand for society
- increasing biodiversity
- providing economic welfare.

This report provides a worked example of the decision support tool, applied to a fictional site in Germany. The decision making process addresses:

- What are the realistic possibilities for the sustainable re-use of marginal land for biomass for a particular site in a particular geographical area?
- How the site characteristics affect these possibilities and how a site might need to be managed to optimise biomass cultivation and manage any risks to human health and the wider environment?
- Of the available options which deliver the greatest value in terms of direct project returns and wider sustainability benefits?
- What project risks might exist, such as those relating to project financing, acceptability and technological reliability, and how these might be mitigated if necessary?

The worked example applies the decision support tool to a typical post industrial mining area. A real marginal land site, a UK colliery spoil heap, for which the Rejuvenate team had good access to information, and for which biomass cultivation has been considered, was used as a basis for the worked example. However, the context was shifted to a fictional location in Germany, which is where the researchers carrying out the worked example were based, and was shifted in time to the present day. The fictional location included a series of surrounding facilities which might supply organic matter to the site, and use the biomass that it produced. These changes were made to support illustrative economic modelling relating the delivery of value. This modelling used a German context in terms of crop performances and financial returns. The soil management and risk management processes discussed were also placed in a German regulatory and policy context.

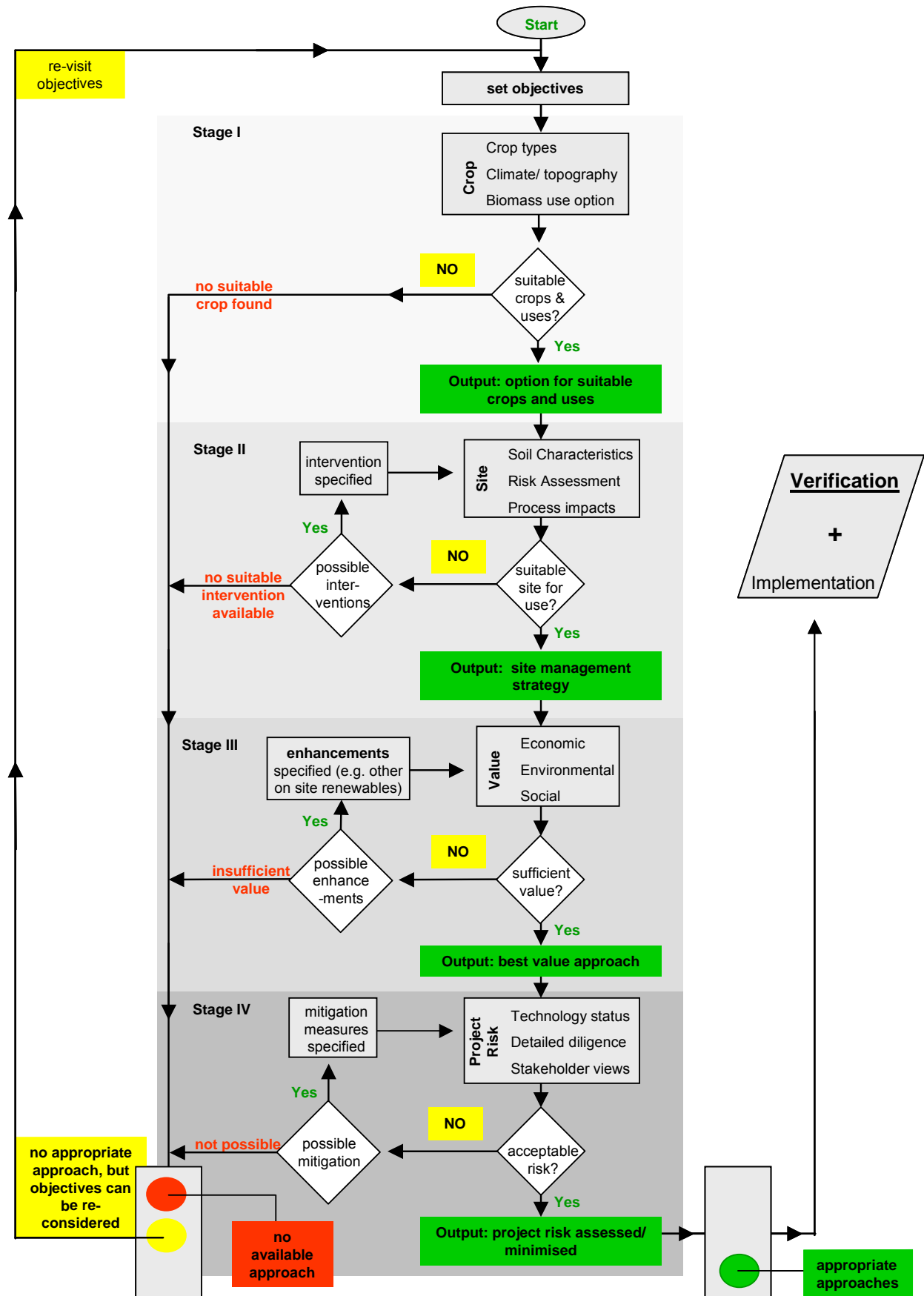


Figure 1: Decision Support Tool Overview

2 Description of the Example Used

2.1 Description of the Site and its Surroundings

Figure 2 provides a plan view of the site and its surroundings. The site is declared as a closed colliery spoil heap in the Western part of Germany. The surface has been grassed over for some years and currently, is partly used for grazing by sheep and horses. There are also a small number of visitors that pass along the site on a bike path, which is next to a brook that runs past the spoil heap. The intended use of the area will be a mixture of short rotation coppice, forestry, open fields amounting to a 80ha size in total. The aim is to provide a mosaic of land use, rather than a single biomass-based re-use.

2.1.1 Former and Current Uses

The spoil heap rises up to 35m above the surrounding natural area and contains well in excess of 1 million cubic metres of man-made spoil. Construction of the colliery spoil heap commenced before 1945 (by aerial ropeway) and continued until about 1990, after which a cover of about 0.3 m of soil was spread over most of the spoil heap. Elevated concentrations of PTEs in some areas are likely to be due to erosion of the surface soil cover on steep-sloping sides of the spoil heap. No other potential sources of on site contamination have been recorded.

2.1.2 Ownership Structure

The site is owned by one company, who have now relocated to another region of Germany where it has new sites in operation. German Law provides a driver for site development, as it is required that contaminated, former colliery sites receive aftercare (§1 BBodSchG 2004). The term 'aftercare' implies a range of management activities. At this site the company was required to carry out restoration work to improve its appearance and reduce dust blow, to maintain that vegetation cover over time. The company is also required to monitor surface water runoff / leachate from the site at a number of measuring points, including regular analyses for a number of dissolved compounds, pH, and turbidity. This has created an annual aftercare cost for the company since the late 1980s, when the area was exhausted for economic purposes. The entire area has been out of use since 1991 and remains abandoned today. A feasibility study for the future use of the brownfield has been offered by the local government and a private consultancy investigating its use as a regional renewable energy source through biomass production.

2.1.3 Detailed Site Description

The overall colliery area is approximately 500ha in total size and includes a central processing and pit head location and two spoil heaps to the North and South of this. The feasibility study is examining the re-use of one of these spoil heaps. This has an area of approximately 80 ha, of which 60 ha is suitable for biomass re-use. The remaining 20ha is not directly suitable or accessible (e.g. where steepness of slope $\geq 5\%$). The processing area is flat has good road links and consequently is being redeveloped for light industrial commercial purposes.

The spoil heap was revegetated as part of earlier restoration work in 1990s. A 0.3 m layer of what was referred to as "topsoil" was spread across the site as far as possible and was then seeded with grass. Close to the spoil heap is a small former depot building (200 m²). A track used by agricultural vehicles runs across the spoil heap, and there is a reed bed located in the south-western part of the site, which is contiguous with the brook (small river) which runs past the site. The area is surrounded by three areas of housing. A municipal sewage plant (MSP) is close by and a "green waste" composting facility is located 8 km away. A cement plant is located about 15km away. These facilities have been included in the worked example to demonstrate how synergies between connecting site re-use and local facilities producing organic matter, and others potentially able to use biomass.

The composting plant and the municipal sewage plant (MSP) are both sources of organic matter for soil improvement on site, with available capacity to supply organic matter (see Section 3.3). The cement production facility has an interest in substitution of biomass for fossil fuel energy.

The scenario includes local availability of compost and sewage sludge for restoration purposes, and local availability of an energy market (the cement works). This is a realistic scenario given the density of green waste compost production and sewage treatment plants in Germany. The cement facility is a “trigger” for the biomass use of this site. For other sites the triggers might be different, for example: including wood heat in a municipal heating scheme, or a boiler replacement programme; heat requirements in local manufacturing for a variety of products; substitution of fossil fuel in local power plant; or a new on site combined heat and power facility – depending on scale. There are a wide range of possible triggers, but for this example a cement facility has been used.

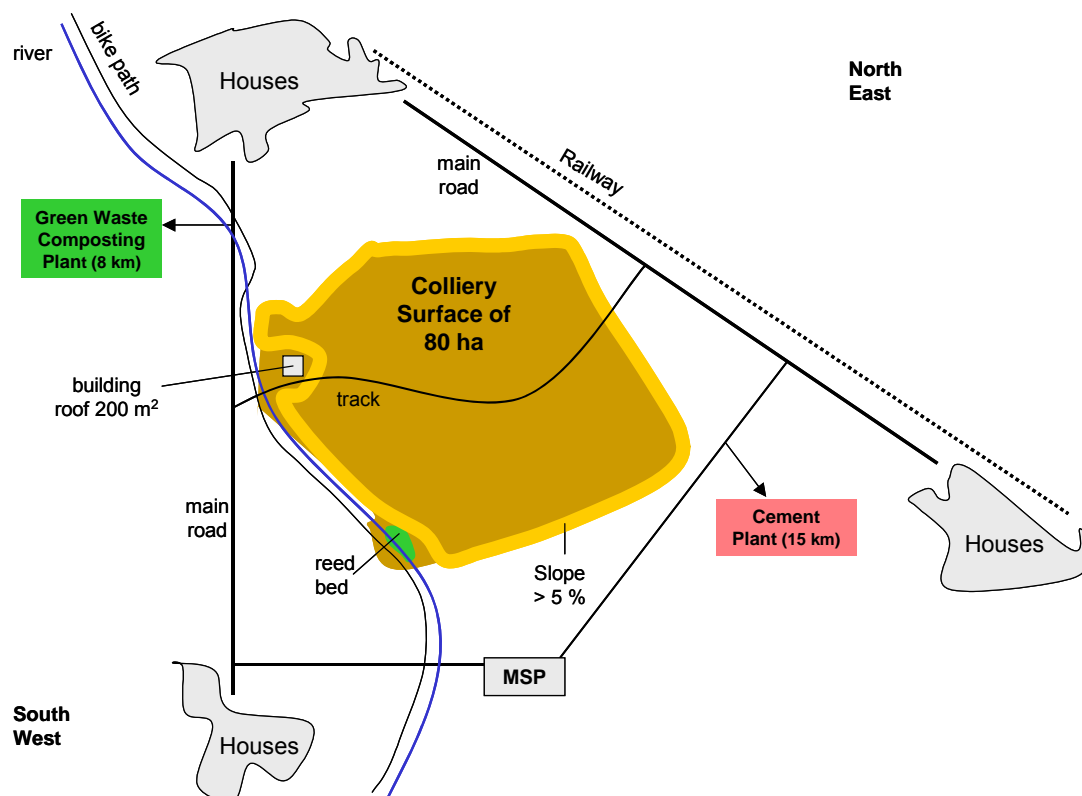


Figure 2: Plan view of colliery spoil heap and its surroundings

2.1.4 Dominating Climatic Conditions

The colliery surface is located in the western part of Germany, where the average annual climate conditions meet crop requirements like the average annual temperature, rainfall, sun hours, frost days, and wind level. A detailed description is provided in Table 2.

2.1.5 Dominating Topographical Condition

The site altitude averages approximately 150m above sea level. The majority of the spoil heap surface is relatively flat. The edges have an average slope angle of greater than 5%, and cover an area of 16 ha.

2.1.6 Contamination Characteristics

Although the spoil heap has been covered by “topsoil” as part of earlier restoration work, the uneven nature of this application, and processes of erosion since this work was carried out, mean that elevated levels of arsenic, chloride, sulphates and potentially toxic elements (PTEs) have been found at the spoil heap surface. Beneath the topsoil the pyritic spoil materials contain high levels of sulphides, and elevated levels of PTEs. Consequently risk assessment has been carried out to determine risks from contamination to future users, ground and surface water, and possibly, ecological receptors (see Section 3.2.2).

2.2 Hydrology, Geology, and Hydrogeology

2.2.1 Hydrology

A small river runs along the western edge of the site flowing from the south - west to north - west. Surface water reaches the river via open ditches and subsurface drains, and also through the reedbed. Run-off from the site passes through subsidence lagoons before discharging to the river.

2.2.2 Geology

The natural strata beneath the spoil heap consist of bands of mudstone, siltstones, sandstone, and coal. Bands or nodules of ironstone may be present within the mudstone. The strata dip gently SE. The top of the Coal Measures (geological coal-bearing part of the Upper Carboniferous System) is likely to be weathered and cryoturbated (mixing of materials due to freezing and thawing) with soils less than 1 m thick over the sandstones and up to 5 m thick over the mudstones. There are alluvial deposits beneath the river. These can be up to 5 m thick and comprise soft silty clays with peaty lenses. Clay bound gravel is common at or near the base of the alluvium. The natural deposits are covered with the northern spoil heap, which comprises colliery spoil and other waste as described above. A cross-sectional view of the soil structure is provided in Figure 3.

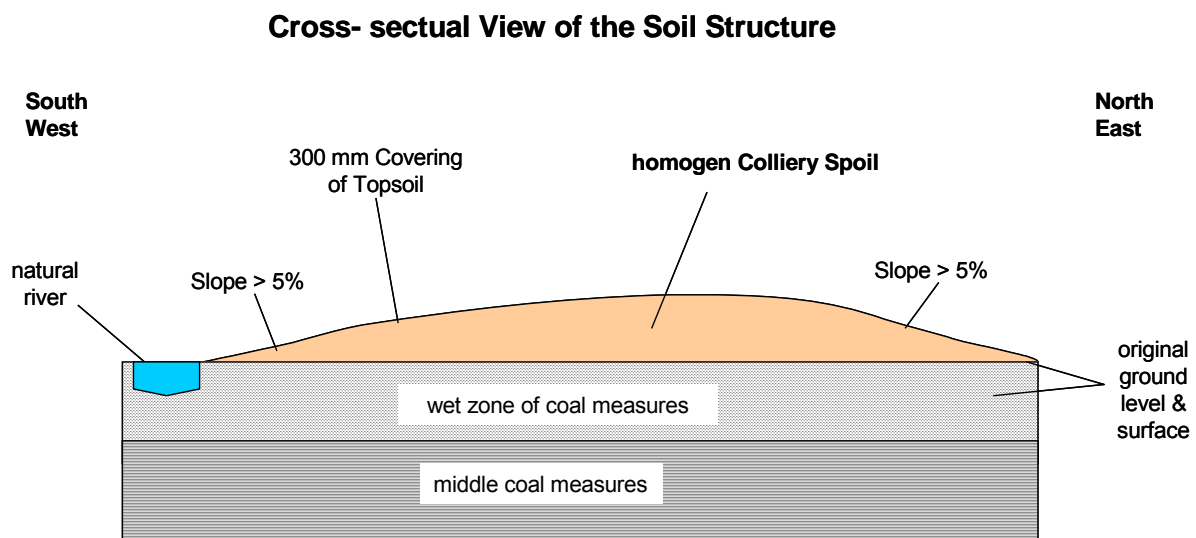


Figure 3: Cross - sectional View of the marginal Land

2.2.3 Hydrogeology

The middle coal measures are a minor aquifer. The spoil heap is not within a groundwater source protection zone. The soils over most of the area are classified as ‘Soils of High Leaching Potential’, with a small area on the western edge being of low leaching potential. Site investigation at the colliery

surface indicated that the water level was at the level of the river in the west and rising gently in the east. In addition, there may also be perched groundwater within the made ground.

2.3 Initial Risk Assessment –

An initial risk assessment of the site has been carried out to identify linkages between sources, pathways and receptors. The risk assessment at this stage excluded the possibility of biomass production and focused on the current (abandoned) use of the site.

2.3.1 Sources

The sources of contamination on the spoil heap derive from the colliery spoil. Contaminants detected include arsenic, chromium, cadmium, sulphate, sulphide. The spoil is also acidic and some samples were found with relatively high calorific value.

2.3.2 Pathways

Pathway 1 (P1): Unsaturated zone and Saturated zone i.e. groundwater

- Downward migration of contaminants to underlying coal measures which is a minor aquifer
- Subsurface materials are colliery spoil, weathered coal measures and coal measures. The permeability of these materials is likely to be heterogeneous and therefore the pathway of subsurface migration is difficult to predict. Sandstone bands within the coal measure are shown to outcrop at the surface, forming potential contaminant pathways.
- Subsurface materials could also act as a pathway to surface water receptors (some of which may also be ecological receptors e.g. flora and fauna) and adjacent sites.
- Groundwater could be a pathway to adjacent sites and to surface water bodies.

P2: Drainage Features and Surface water

- Migration of soil contaminants via drainage features (e.g. erosion gullies, drainage ditches) and migrate off the spoil heap (Federal Ministry of Environment 2008).

P3: Ingestion (soil and dust ingestion) Dermal Contact and Inhalation

- Contaminants may be ingested (for example via hand to mouth contact) or inhaled by the current livestock users of the site, as well as trespassers on the site, or they may come into direct skin contact with contaminated materials. Users of the bike path may be affected by dust blow from the site, which in certain circumstances may also pose a risk to residents in surrounding housing. Direct contact with contaminated materials (other than dust blow) via the bike path is not expected as it was sealed with asphalt when it was constructed five years ago.

2.3.3 Potential Receptors

Human receptors

- Cyclists and walkers on track and bike path
- Residents in adjacent housing

- Agricultural workers on site

Controlled Waters

- Surface Water (the small river)
- Groundwater (middle coal measure aquifer)
- Drainage liquids

2.4 The Decision Makers

The industrial company is the major decision maker in this worked example, supported by a technical consultancy. Their decisions will be affected by local authorities and regulators supported by Federal authorities. The intention of these “core stakeholders” is described in more detail in Table 1. In addition the project needs to gain public acceptance in the local area.

Table 1: Core Stakeholders

Industrial Company	Consultancy	Local Government	Federal Government
- decrease of aftercare cost	- commission for consultancy	- improvement of untreated contamination in soil	- substitution of fossil sources of energy
- decrease of the companies taxation in favour of investments	- increase of regional market share of renewable projects	- revitalisation of marginal land	- decrease of national cash outflow for the purchase of energy from abroad
- search for new sources of cash inflow	- further reference for consultative activity	- upgrading quality of the surrounded natural scenery	- support of the compliance of EU targets
- Public Relation (participation on voluntary emission rights trading)		- stabilisation of local attractiveness/ competitive business location	

2.5 Project Objectives

The guiding principles for re-use of this site are:

1. to bring the land back into beneficial use
2. whilst preserving the heritage of the area
3. and managing potential risks from contamination

Given the site conditions and supporting infrastructure, the use of land for biomass production was taken forward for detailed consideration. The re-use by biomass project is aimed to manage the contamination risks of the colliery site and bring productive use to the majority of the area of the spoil heap. The overall project activity aims to secure a long term economically viable solution for a sustainable use of marginal land. Sustainability requires a balanced consideration of environmental economic and social benefits and impacts.

The extent of the biomass production area is currently limited to available area on the spoil heap under investigation. The type of biomass produced, and the productivity of the biomass crop, will depend on

climate, soil, and topographic factors.. Box 1 provides a calculation of cultivatable surfaces (see Section 3.3.2).

In parallel with the development of a soil management strategy for biomass production, the project team has been master-planning the layout of the site. The key factors underlying this master-planning (shown in Figure 4) are:

- creation of a maintenance track with public use across the site in recognition of its amenity value to the local population and to link to an existing maintenance track.
- the maintenance track will also provide access for site management machinery for biomass cultivation.
- the fringes of the maintenance track will be landscaped. Woodland specimen trees and bushes will be used to screen the steep slope areas to protect them against erosion and to limit surface run off in these areas.
- maintaining the natural reed bed in the south western corner.

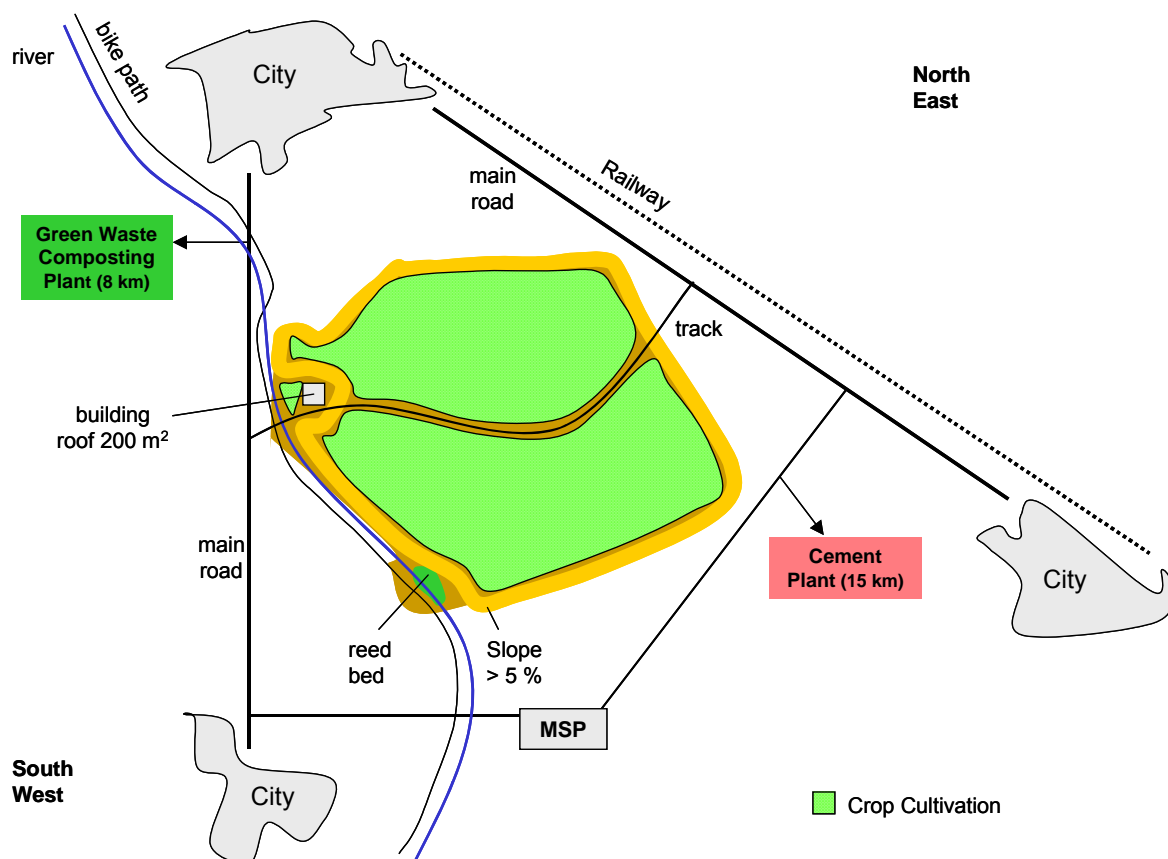


Figure 4: Completed Site Concept

3 Application of Decision Support Tool according to the Worked Example

The Rejuvenate decision making framework encompasses four stages (shown in Figure 1 above):

Crop suitability: primarily considers from a range of possible biomass crops which crops are able to grow in a region with a potential local market. This will include an assessment of both climate and site topography. For convenience, this stage provides a biomass crop short list. Each subsequent stage is likely to reduce the length of this list as a more refined solution is found.

Site suitability: considers whether the site conditions are suitable for particular biomass crops in the short list and what the environmental risks of crop production might be; a site may be suitable already for some crops or can be made suitable by soil / risk management interventions. If an on-site conversion facility is being considered then the suitability of the site for this facility must also be considered and any necessary interventions (for example infrastructure considered. Furthermore, the impacts arising from any site management activities for risk and soil management and facility development need to be properly considered.

Value: there is a direct cost benefit equation as to whether the benefits of using a site for biomass are worth the investment needed, but also a wider sustainability consideration, considering for example aspects such as improvement in biodiversity, carbon sequestration or local community enhancement. It may be appropriate to include other measures to increase overall project value, for example integrating other forms of renewable energy production with the site re-use, or combining biomass use with the re-use of agricultural residues.

Project risk: once a firm project concept has been elaborated whose value is attractive to its developers, the project planning needs to then ensure its viability as far as possible before any major investment takes place. Three broad considerations are important: technology status, detailed diligence (e.g. of financial partners and project partners) and developing a broad stakeholder consensus.

The worked example progresses through each stage in turn.

3.1 Decision Tool Framework - Stage 1 Crop Suitability

Stage 1 primarily considers from a range of possible biomass crops which crops are able to grow and find a market in a region. Site topography is also considered at this stage for convenience. The output is a short list of biomass of crops that fit local conditions and have an outlet. Each subsequent stage is likely to reduce the length of this list as a more refined solution is found. This can be divided into substages (as shown in Figure 5):

- Stage 1.1: range of crops meeting site objectives.
- Stage 1.2: range of crops meeting local climate conditions.
- Stage 1.3: range of crops that can be cultivated on the sites topography.
- Stage 1.4: available uses.

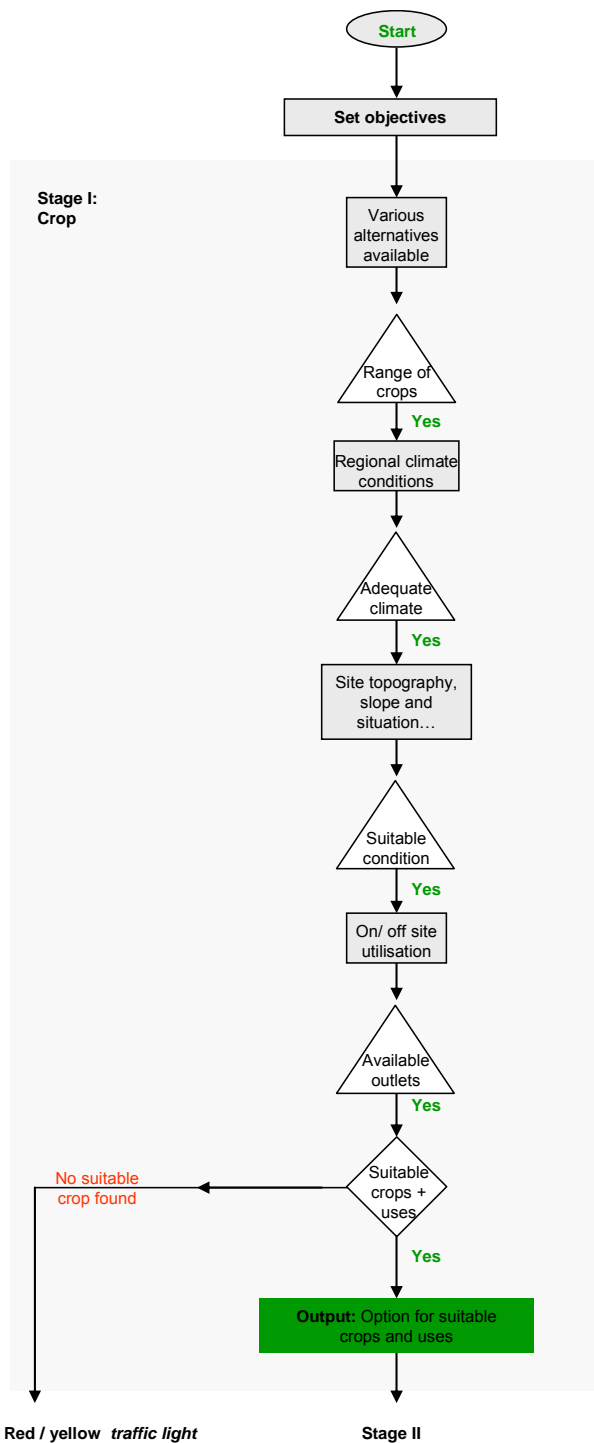


Figure 5 Decision Support Tool - Stage 1

3.1.1 Biomass Options Meeting Project Objectives

One factor in developing a short list is the availability of uses or markets for the biomass. However a fundamental influence is that crop types have to be compatible to a region's climatic conditions and major features of the site such as its topography and water availability (UBA 2008). Further influences will be the prevailing soil conditions at the site which are considered in Stage 2. Crops suitable for biomass cultivation include woody types (such as willow and poplar), annual lignocellulosic crops such as Miscanthus and food crops such as maize, wheat, sugar beet and oil seed rape. An overview of crop requirements is provided in Table 2 (FNR 2007b, Defra 2004).

The nature of the site was seen as ruling out the use of food crops as biomass sources because of concerns that the commodities produced on site might enter the food chain. The biomass crops for which greatest expertise exists in Germany are willow, poplar and Miscanthus, so these were taken forward for consideration. Maize has been included in this worked example to provide a comparison. These four crops were seen as potentially meeting project objectives and were taken forward for more detailed scrutiny.

Table 2: Biomass Crop requirements

"Growth Requirement Overview"		Wood Plantation		Halm based Cultures	
		Poplar	Willow	Miscanthus	Maize
Crop specific Measurements	Seeds/ bags per ha	10,000	10,000	10,000	2
	Deepness of Roots	1 - 3 m	1 - 3 m	< 2,5 m	< 2m
	Vegetation Time	> 20 years	> 20 years	> 20 years	< 1 year
	Growing Period	March - Oct.	March - Oct.	April - Oct.	March - Sept.
	Harvest	Dec. - Febr.	Dec. - Febr.	Dec. - Febr.	Sept.
	Crop Rotation Possibilities	no	no	no	no
	Bending Property	no	no	medium	medium
	Labour intensity/ skilled	low	low	medium	medium
Utilisation Duration (years)	20	20	20	1	
Harvest Rythm (year)	4	4	1	1	
"required" Climate Condition	Temperature "stress resistance"	high	high	> 8°C	> 8°C
	Rainfall "stress resistance"	high	high	> 500 mm	> 500 mm
	Sun Hours "stress resistance"	high	high	high	high
	Dryness "stress resistance"	medium	medium	medium	medium
	Topographic "stress resistance"	< 700 m	< 700 m	< 700 m	medium
	Wind Level "stress resistance"	high	high	medium	medium

3.1.2 Climate/ Topography

Regional climate and topography conditions will influence the range of crop types that can be considered. Table 3 summarises the annual conditions predominating in Western Germany. The average elevation of the site is approximately 150m above sea level (DWD 2009). All four crops were cultivable under the prevailing climatic and topographical conditions.

A problem with the spoil heap is water supply: excessive rainfall and run-off (surface erosion) in the winter, with the site being very dry in the summer because of its exposure above surrounding ground level. Both effects can be attenuated to some extent by increasing the moisture retention and plant availability potential in soil by improving soil structure with organic matter (Federal Ministry of Environment 2006b). Longer term opportunities for providing additional water supply might be storage of winter rainfall, or use of grey water. However, these have not been considered further in this worked example.

Table 3: Annual predominating climate conditions in western Germany

Annual pre-dominating climate conditions in the west of Germany	
Categories:	Measurements:
Temperature <small>average</small>	ca. 9°C
Rainfall <small>average</small>	ca. 800 mm
Sun Hours <small>average</small>	ca. 1.500 h
Frost Days <small>average</small>	40 d
Wind Level <small>average</small>	15 km/h

3.1.3 Biomass Utilisation Opportunities

The nearby cement plant may provide a potential opportunity as an end user for biomass energy. On site conversion of biomass to energy was discounted at an early stage as uneconomic because of the limited planting area (discussed in more detail in Annex 1 – Box 2). An alternative application of biomass is as a feedstock for industrial processes as illustrated in Figure 6 (Heck, P./ Bemman U., 2002/ 2003). However, no available biofeedstock opportunities for wood chip, Miscanthus or maize were readily available for production from the site.

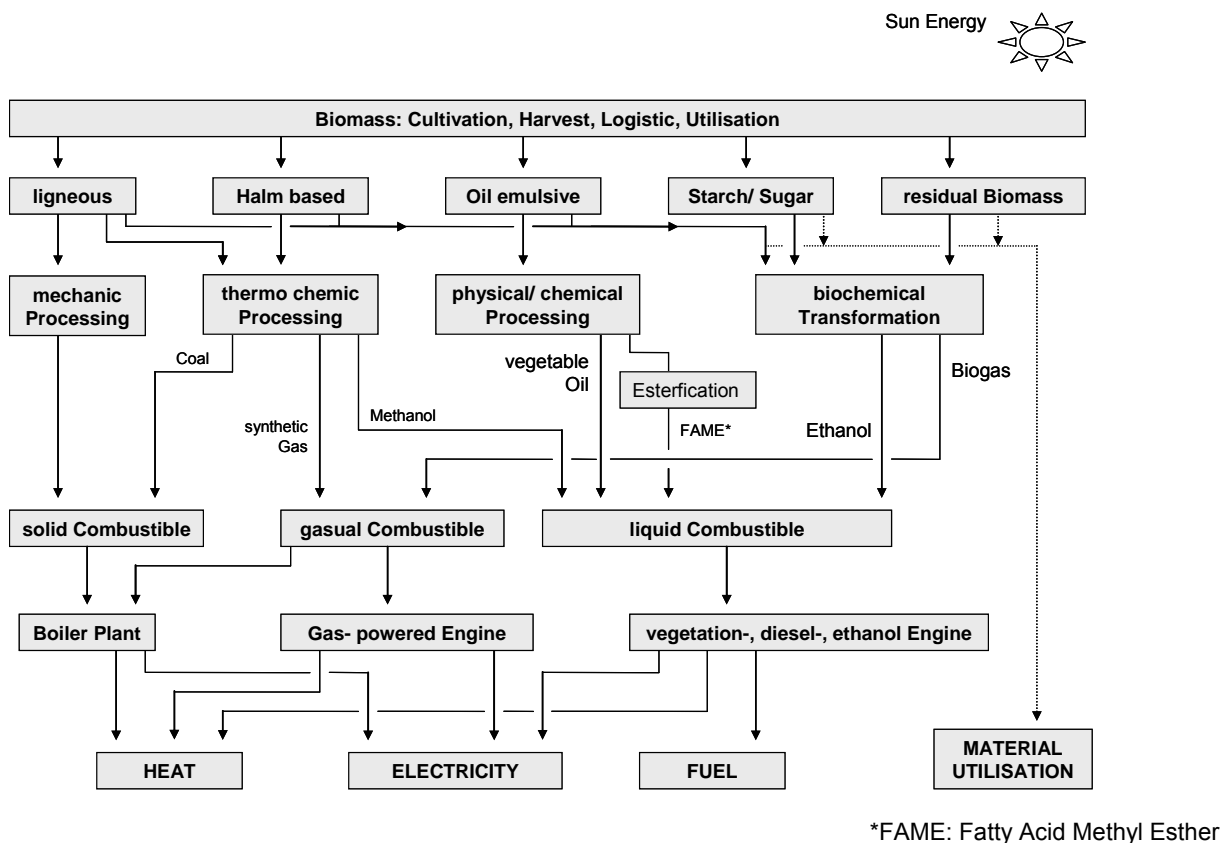


Figure 6: Biomass Use Opportunities

3.1.4 Output of Stage 1

The order of considerations of Stage 1 approach is important, because it is intended to simplify the next step by eliminating possible options on the basis of the least needed information to do this. Consequently, only crops will be considered who have a chance to meet the users' objectives. The output of Stage 1 provides a suitable range of crop type possibilities, where the presumption of crop growth in relation to the climate/ topography/ use condition is optimal.

3.2 Decision Tool Framework - Stage 2 Site suitability and interventions

Stage 2 (illustrated in Figure 7) considers whether the site conditions are suitable for particular biomass crops in the short list and what the environmental risks of crop production might be. A site may be suitable already for some crops or can be made suitable by soil / risk management interventions. If an on-site conversion facility is being considered then the suitability of the site for this facility must also be considered and any necessary interventions considered (for example infrastructure). Furthermore, the impacts arising from any site management activities for risk and soil management and facility development need to be properly considered. The output is a shortened list of crops that could be grown on-site and specification of the management interventions needed to achieve this.

- **Stage 2.1: range of crops that can be grown on the site under its prevailing soil conditions.** The soil may already be suitable for a biomass crop, in which case perhaps only soil maintenance for the crop need be considered. Alternatively some form of soil improvement may be required. In some cases a crop may need to be discounted because no feasible intervention exists.
- **Stage 2.2: environmental risk management.** Where the site is suspected as being contaminated (or organic matter inputs may contain contaminants), risk assessment will be necessary. The effects of biomass production and use will need to be included in a conceptual site model that reviews all of the pollutant linkages that need to be considered for a site. Risk assessment may determine that some of these pollutant linkages are not significant, whereas others will require a risk management intervention. In some cases it may be determined that a particular biomass type cannot be grown on a site with acceptable risks.
- **Stage 2.3: impact of interventions.** Soil management and risk management interventions may themselves have environmental impacts. The purpose of this step is to ensure that the crop, soil and risk interventions on-site are compliant with wider environmental protection needs, for example considering the water environment and the local ecology.
- **Stage 2.4: facility development.** This stage is only necessary if on-site conversion of the biomass is envisaged. It considers the feasibility of the various on-site bioconversion alternatives available. (On site biomass conversion was discounted for this site at an early stage)
- **Stage 2.5: facility development impacts.** This stage considers the impacts of the facility development on the marginal land and its surroundings.

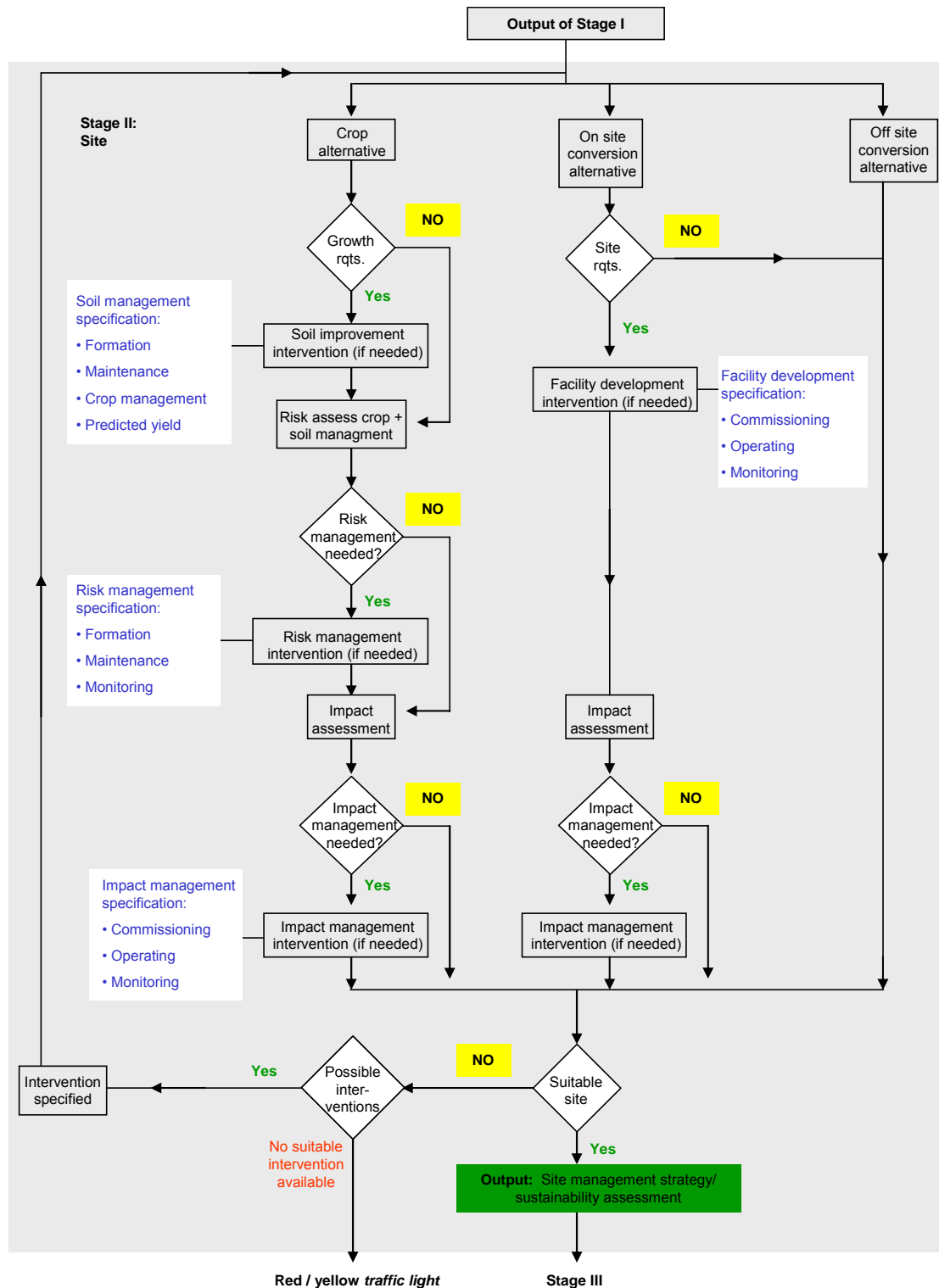


Figure 7: Decision Support Tool - Stage 2

3.2.1 Soil Characteristics, Management and Crops

The spoil heap was covered with soil materials of unknown quality in 1990 and sowed with robust perennial rye grass cultivars in the 1990s. The soil came from the construction of a new suburb and road infrastructure in one of the nearby cities. The top soil from the excavated material was mostly reserved for local landscaping or sold for residential use, so the soil materials used on the spoil heap were likely to have been largely subsoils with some construction debris.

Since then trees have spontaneously regenerated on the steep slopes of the spoil heap. The flatter areas (slope < 5%) have been used as rough grazing. The impacts of grazing and the poor quality of the soil used have led to significant erosion of top soil over parts of the site. Water runoff is also problematic as it has led to significant erosion of topsoil. Low pH has also caused acidic scorching of grass in some of the areas. There are also problems from an uneven application of topsoil, with original spoil materials remaining at the surface in several locations.

The average soil depth across the site is 30cm and has a low organic matter content and very low plant nutrient status. The soil structure is poorly developed with little in the way of recognisable soil horizons, except for the discontinuity between soil and weathered spoil material.

Although food crops had been discounted at an early stage because of concerns over the possibility of their entry into the food chain, had they been considered further, many would likely have been discounted at this stage because of their typical rooting depth. For example the rooting depth for sugar beet is in the region of 120cm. While it is feasible to bring on soil improvement materials to render the soil more productive for shallow rooted biomass crops such as willow; it was not considered feasible to bring on the enormous soil volumes that would be needed to render the site usable by crops such as wheat and sugar beet¹.

This consideration would also likely exclude Miscanthus and maize from further consideration in practical circumstances. They have been retained in this worked example to provide a wider range of crop types for the economic assessments illustrating Stage 3.

The existing soil characteristics indicate that improvement measures are needed in order to provide favourable conditions for successful plant growth. Recycled organic matter can provide a cost effective soil improvement for this site, given the proximity of green waste compost and sewage sludge (Federal Ministry of Environment 2007, WRAP 2006). The cost of transportation of organic matter is a major factor in determining the economic viability of any such intervention measure (discussed further in Stage 3). Low pH is potentially a problem on the soil heap soil. Applications of green waste compost have the further benefit of a liming effect to improve soil pH.

Soil improvement, from organic matter addition, is planned to take place before planting, and after each successive harvesting (e.g. annually for maize, or after cutback for short rotation coppice). Initial soil improvement work is to take place over the autumn to allow planting in the spring. It is important that planting takes place as soon as weather conditions permit each spring to allow crop establishment before the relatively dry summer. Soil formation and planting as well as the timing of harvesting depends on the crop types selected (see Table 3: Suitable Crop Type). Figure 8 provides a cross-sectional view of the soil structure under consideration of the soil preparation by sewage sludge and green compost.

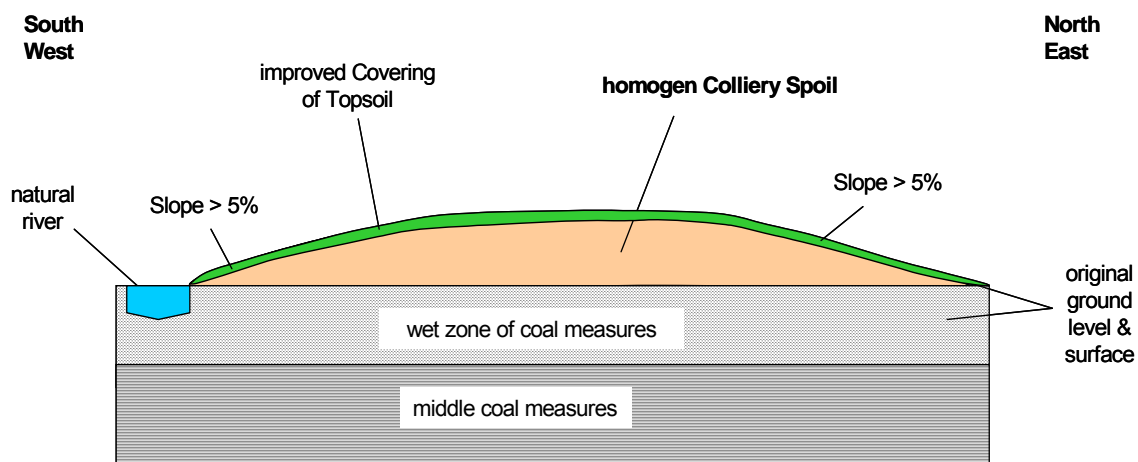


Figure 8 Cross-sectional View of the Soil Structure Envisaged

¹ Willow rooting depth is typically comparable with a cereal crop, but experience on restoration projects indicates it will tolerate a thinner soil cover, although productivity is then reduced

Applications of green waste compost and sewage sludge for the on-site restoration are restricted by German regulations to 100t ha⁻¹ and 5t ha⁻¹ per year respectively (Federal Ministry of Agriculture, Environment and Nature Conservation of Thüringen 2009; Federal Ministry of Environment 2006a). So the maximum organic matter addition rate for this site from locally available sources is 105 tonnes per hectare per year. Pot trials were used to show that the establishment of willow, poplar, and Miscanthus was generally optimised by the same soil improvement strategy which was to amend site soil with a mixture of sewage sludge and green waste compost. These pot trials also showed that the allowable rate of use of organic matter meant that soil organic matter input and plant nutrient supply from this input is less than would be required to maximise biomass crop yields on site for the four crops under consideration. Mineral fertiliser addition could therefore support further yield improvement, and may be considered after crop establishment.

3.2.2 Risk Assessment and Management

3.2.2.1 Risk Assessment

Three groups of potential contaminant receptors have been identified: human receptors, aquatic receptors (e.g. river) and biomass receptors (see chapter 2.3.3). Pathways to human receptors are via ingestion or inhalation. (It is understood that public access will be restricted permanently to the trail system running over and across the spoil heap.) Water movements are considered by both through drains and surface water as well as soil water and groundwater as the principal pathways to controlled water. For risk assessment of the different pathways the S-P-R linkage conceptual models were identified for the site in its envisaged end use, shown in Figures 9 - 11, and the pollutant linkages identified were prioritised (as shown in Table 4). This risk assessment encompasses the effect of the soil management interventions and biomass crop production. Based on the three S-P-R Conceptual Models a prioritisation of potential risks can be made as shown in Table 4.

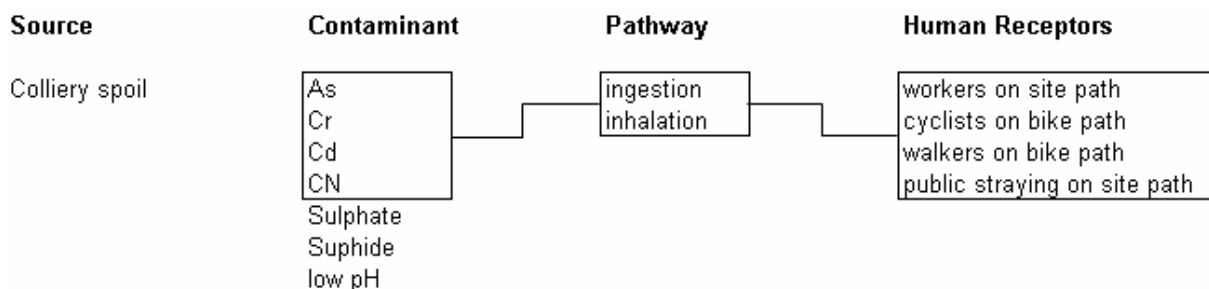


Figure 9: Human Receptor S-P-R Conceptual Model

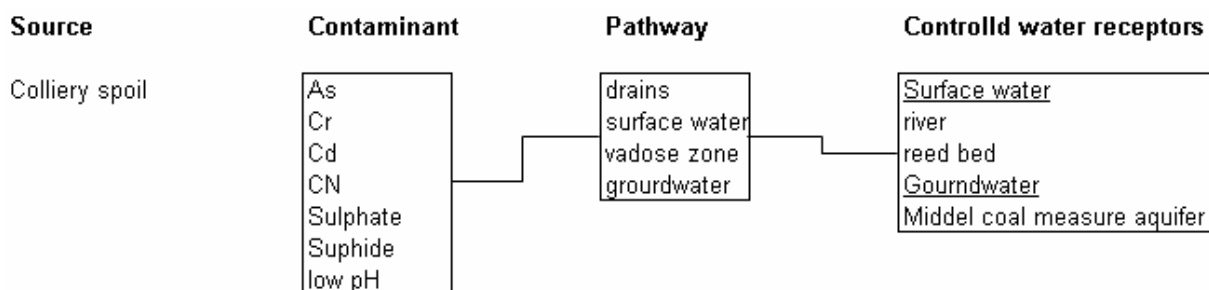


Figure 10: Aquatic Receptor S-P-R Conceptual Model

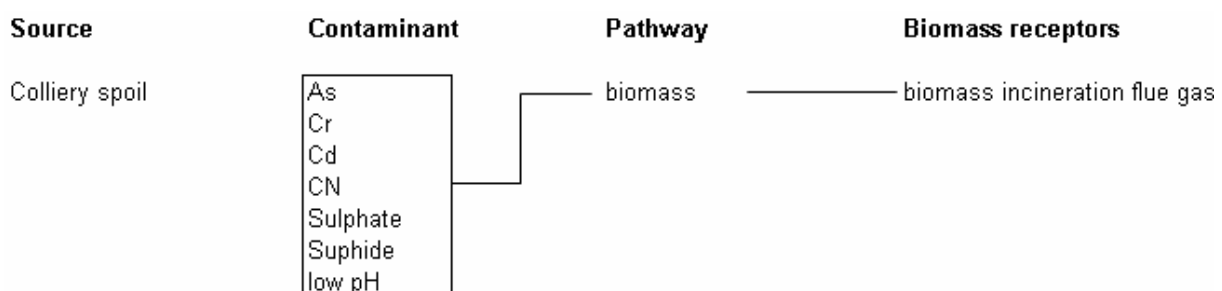


Figure 11: Biomass Receptor S-P-R Conceptual Model

Table 4: Prioritisation of Potential Linkages Identified in the Site Conceptual Model

Priority	ID	Potential Linkage	Comment
Medium	1	- workers on path - ingestion/ inhalation	Elevated contaminant levels indicate a potential erosion of the soil cover at the tracks on site
Low	2	- cyclists on bike path - ingestion/ inhalation	No elevated contaminant levels were found around the bike path, but dust inhalation might theoretically be possible
Low	3	- walkers on bike path - ingestion/ inhalation	No elevated contaminant levels were found around the bike path, but dust inhalation might theoretically be possible
Medium	4	- public straying on site path - ingestion/ inhalation	Elevated contaminant levels indicate a potential crack of the soil cover at the tracks on site
Medium	5	- nearby river - drains & surface water	Elevated contaminant levels in surface run-off indicate a potential pollutant linkage
Medium	6	- reed bed - drains & surface water	Elevated contaminant levels in surface run-off indicate a potential pollutant linkage
Low	7	- middle coal measure aquifer - vadose zone & ground water	No elevated contaminant levels were found in groundwater but there might be a long term potential pollutant linkage via the vadose zone.
Medium	8	- biomass incineration flue gas - biomass cultivation	Even so pot trials showed low levels of PTEs in harvestable plant segments, a potential pollutant linkage is given by root uptake.

The key outputs of the applied risk assessment according to the decision tool framework are:

- the potential pollutant linkages identified based on the development of the conceptual model, the criteria used to assess risks, the unacceptable risks identified, and the proposed next steps in relation to the site.
- an explanation of the development of the conceptual model (in particular the results of site investigation); the selection of criteria and assumptions; the evaluation of the potential risks; and the basis for the decision on what happens next.

3.2.2.2 Risk Management Strategy

For the worked example it is assumed that there are structural funds available for utilising marginal land for biomass production. Prerequisites for these funds are:

- Only land not suitable for food production can be used
- The use of biomass has to substitute fossil energy resources and must not be just an addition to the use of fossil fuels
- Evaluation of significance for pilot test cultivation of selected crops after Stage 2 in order to further minimise project risks of non-growing biomass types
- Demonstration that the site utilisation concept is self funding within 12 years.

There are two broad groups of risk: risks from existing site contamination and risks from contamination introduced by organic matter brought on to the site. In addition the site management processes themselves may pose risks to human health and the environment, which are discussed in Section 3.2.3. The input of contaminants from the organic matter used for soil improvement is not considered high, both on the basis of its analytical composition (which is below regulatory limits for use) and because of the relatively low addition rate. Management of potential pollutant linkages arising from the mine spoil is summarised in Table 5.

Table 5: Risk Management Approach

Possible Pollutant Linkages	Remedial Objectives	Remedial Options
Subsurface and surface contaminants Ingestion / inhalation / dermal contact Workers and public not on paths	Prevent workers and public not on footpaths being exposed to hazardous levels of contaminants	Hotspot removal then vegetation based containment (pathway management), linked to a comparison of surface contamination levels with suitable criteria.
Subsurface and surface contaminants Ingestion / inhalation / dermal contact Footpath users	Prevent path users being exposed to hazardous levels of contaminants	Hotspot removal for path areas, followed by a conventional cover system for containment (pathway management), in turn protected by a wearing surface
Colliery spoil, waste deposits, surface deposits (various contaminants) Surface water / drainage / vadose zone / groundwater Adjacent small river	Prevent unacceptable deterioration of the river	The effect of biomass revegetation and management should alleviate inputs to the small river. However, river quality adjacent to the spoil heap will be monitored. Some form of permeable reactive barriers may be installed if impacts are significant
Contaminants in harvested biomass	Biomass content of PTEs must be within tolerable limits for the cement facility	Site trials are recommended to assess likely biomass quality, and any mitigation measures that might be need (for example appropriate clone selection and addition of <i>in situ</i> stabilisation amendments such as biochar. However, previous experience from other sites indicates that the biomass will be suitable for use.
Mine gas Explosion All users	Prevent mine gas explosions	No buildings will be constructed on the spoil heap

3.2.3 Process Impacts

Human health receptors will be those undertaking site management, and residents in nearby housing. Risks that may occur are from bioaerosols released by organic matter spreading on site and dust caused by soil disturbance. There may also be a nuisance from odour emissions. Risks from compost use will need to be managed by compliance with prevailing regulations for organic matter re-use and the mitigation of odour and bioaerosol use, in particular taking care to carry out operations when weather conditions are suitable, and for composts ensuring that mature and well stabilised compost only is used. For sewage sludge risks will be managed by following best practice for rapid sewage sludge incorporation. In addition, a site hygiene plan will be operated to minimise risks of exposure to pathogens. An additional human health risk is from the operation of machinery on site, and traffic which bring materials to the site; these will be managed by the execution of a safe working plan for the site.

Environmental impacts from the site that have been considered include the migration of soluble compounds to the nearby brook. However, the limited amounts of organic material being used indicate that these impacts will be negligible. A more significant impact may be from the traffic required to move organic matter on site (estimated to be an initial 6,300 tonnes or 12,600 m³).

3.2.4 Output of Stage 2

The Stage 2 finding is that willow and poplar SRC remain as viable biomass options for the spoil heap, but that a soil management strategy is needed to support their cultivation. Interventions for risk management have also been identified, along with discussion of any impacts of the soil and risk management processes themselves.

Of the remaining crop options: willow and poplar, it is likely that a project would not consider poplar further as available cultivars tend to be susceptible to fungal rust diseases. Stages 3 and 4 would then focus on determining if a willow coppice approach was viable for the site in question.

However, in order to have a more interesting illustration for the Stage 3 the worked example includes a consideration of four crop types: willow, poplar, maize and Miscanthus.

3.3 Decision Tool Framework - Stage 3 Value

There are two components to value in the Rejuvenate decision framework. There is a direct cost benefit equation as to whether the benefits of using a site for biomass are worth the investment needed, and also a wider sustainability consideration, for example aspects such as carbon sequestration or local community or biodiversity enhancement. It may be appropriate to include other interventions to increase overall project value, for example integrating other forms of renewable energy production with the site re-use, or combining biomass use with the re-use of agricultural residues. There are three steps in Stage 3, illustrated in Figure 12.

Stage 3.1: financial feasibility. The direct costs for each biomass option (including soil and other site management interventions and any on-site conversion) are compared with its revenue earning potential.

Stage 3.2: financial viability. This stage develops a more detailed financial model and compares it against investment thresholds set for the project, such as requirements for return on capital set by investors and other funders.

Stage 3.3: Sustainability appraisal. This stage uses a sustainability appraisal based on a series of indicators of sustainability representative of economic, environmental and social factors identified as important by the project team and the other stakeholders involved in the project.

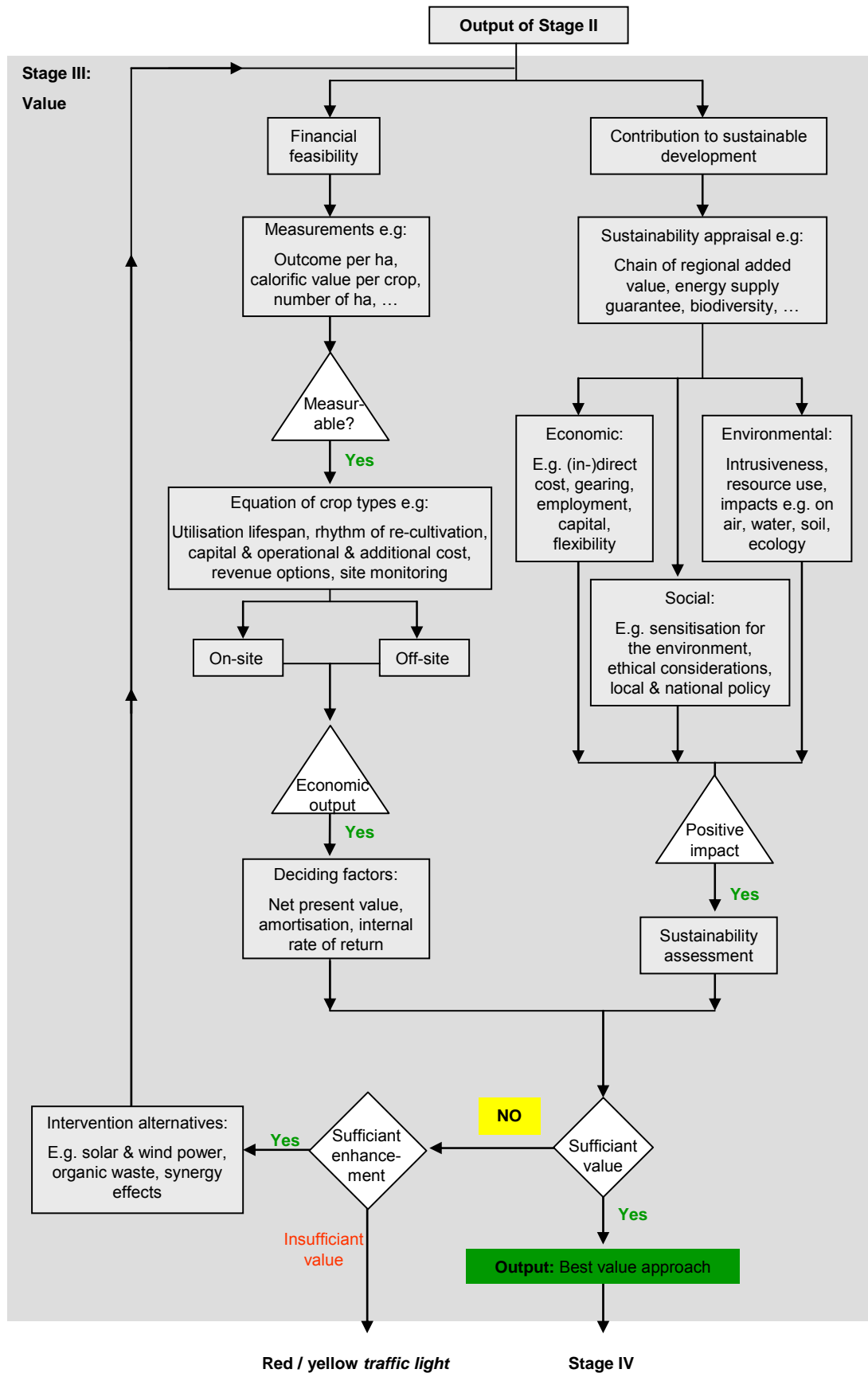


Figure 12: Decision Support Tool - Stage 3

3.3.1 Initial Approach

Four options are compared for the purposes of illustration: maize, poplar, willow and Miscanthus. The maize re-use scenario is the thermal conversion of all harvested biomass (and not solely re-use of grain). Poplar, willow, and Miscanthus are long term crops with a cultivation lifespan of ~20 years. Hence a project duration of 20 years has been used for this worked example, based on typical working lifetimes for coppice and Miscanthus plantation. The crop rotation plan is based on three subsequent planting periods for poplar and willow to allow annual harvesting of biomass, assuming a three year production period for biomass rather than three given the nature of the production site. The general approach to direct financial feasibility is based on the estimation of direct expenses per ha, the maximum number of ha available, and the subsequent yield. Wider sustainability appraisal considers these economic factors, but also a range of other indicators that the project stakeholders might be interested in such as the CO₂ saving potential, the potential for substitution of fossil fuels, and environmental and social impacts of production.

3.3.2 Direct Expenses

Tables 6 to 9 provide examples of direct expenses related to this worked example.

Table 6 presents the worked example costs for crop establishment, using the following scenarios. 10,000 Miscanthus rhizomes or willow / poplar rods have been chosen to represent an appropriate number of crops per ha. These crops will be established once over the 20 year period. Maize will be planted annually, and a seeding density of two bags of maize corn per ha has been used to represent a realistic harvest, based on advice from growers. Table 7 also includes a rudimentary assessment of the cost of working hours based on the views of typical producers².

Table 7 provides a projection of soil management intervention costs, based on the approach concluded by Stage 2 of the decision making process. Unit costs for sewage sludge and green compost are based on typical costs in Germany and include transportation from the local production facilities noted in the worked example. The compost for sewage sludge is nominal.

Table 8 provides estimates of establishment and ongoing cultivation costs. The cost structure is distinguished in terms of capital (long term) and operational (short term) costs. Ongoing (operational) costs anticipate ongoing soil amendment with sewage sludge and compost to maintain crop productivity. Poplar, willow, and Miscanthus have lower operational costs as a result of the crops' longevity (e.g. 20 years) compared to with maize which is an annual crop.

Table 9 provides tentative estimates for business preparation costs including business planning and test cultivation of different crops. The cultivation testing relates to a suggestion made in Stage 4 for using trials to reduce project risks (see Section 3.4.3).

Table 10 projects these costs to the 60ha of the site (i.e. the maximum land available for plantation). Table 10 includes rows to consider the possibility of supplementing on site energy production by wind power of photo-voltaics. Using brownfields to site both of these renewable energy options is being considered at a number of locations, and detailed guidance has been published in the USA (US EPA 2008). Annex 2 explores several scenarios for the inclusion of photo-voltaics and wind power in a cost model for developing the worked example site.

Table 10 also includes a tentative scenario for funding, based on 20% of the project being fundable by grant income from various sources and an 80% loan of the total investment would be required. Interest expenditure is calculated by an interest rate of 5% of the loan sum. (The cost model indicates that it will be possible to pay back the annuity loan as a result of the 20 year project duration.) The grant plus investment funding scenario is not meant to be indicative of any particular funding regime, its purpose is to show how investments costs and interest can be included in an overall cost model for this worked example.

This Stage 3 discussion also revisits the conclusion reached in Stage 1 that the project would not encompass on site energy conversion because the close proximity of the cement plant provides

² Personal Communications 2009: Wenzelidis, M., administrator Waldagentur Münster - 26.02.2009; and Heitmann, C., energy crop farmer - 20.02.2009.

adequate capacity for the project's biomass. For even a small scale energy conversion facility for electricity, for example an arbitrary (350 kW), the area needed for biomass production exceeds the area available for planting on the site (as shown in Box 1). More effective use of the biomass (without energy supply losses) can be made at the nearby cement production plant.

Table 6: Crop Establishment Costs

Direct Expenses per ha	Wood Platantion		Halm based Cultures	
	Poplar	Willow	Miscanthus	Maize
Plant Material (Cion & Bags)	10,000	10,000	10,000	2
Cost per Plant Material	0.22 €	0.20 €	0.27 €	90 €
Plant Protection	150 €	150 €	150 €	150 €
Labour Hours	3	3	4	7
Cost per Labour Hour	20 €	20 €	20 €	20 €
Machinery Hours	3	3	4	7
Cost per Machinery Hours	20 €	20 €	20 €	20 €
Logistics	10 €	10 €	20 €	20 €

Table 7: Intervention Costs

Additional Intervention Cost of Stage 2 per ha			
Categories	supply in m ³ / ha	€/ t	€/ ha
MSP	5	2 €	10 €
Compost	100	15 €	1,500 €
Sum	105		1,510 €

Table 8: Cultivation Cost per ha

Cultivation Cost Structure per ha		Wood Plantation		Halm based Cultures	
		Poplar	Willow	Miscanthus	Maize
Capital Cost	Plant Material	2,200 €	2,000 €	2,700 €	0 €
	Plant Protection	150 €	150 €	150 €	0 €
	Fertilizer	100 €	100 €	100 €	0 €
	additional Intervention Cost Stage II	1,510 €	1,510 €	1,510 €	1,610 €
Sum		3,960 €	3,760 €	4,460 €	1,610 €
Operative Cost	Plant Material	0 €	0 €	0 €	180 €
	Plant Protection	0 €	0 €	0 €	150 €
	Fertilizer	20 €	20 €	30 €	300 €
	total Labour cost	60 €	60 €	80 €	140 €
	total Machinery cost	60 €	60 €	80 €	140 €
	Logistics	10 €	10 €	20 €	30 €
Sum		150 €	150 €	210 €	940 €
Cost Structure along Utilisation		348 €	338 €	433 €	1,021 €
Cost Structure per t		31.64 €	30.73 €	28.87 €	25.51 €

Table 9: Business Preparation Cost

Upstreamed Business Preparation Cost	
Measurements	Euro
Business Planning Cost	25,000 €
Test Crop Cultivation	1,000 €
Sum	26,000 €

Table 10: Cultivation Cost Model for 60ha

Cultivation Cost Structure for 60 ha		Wood Plantation		Halm based Cultures	
		Poplar	Willow	Miscanthus	Maize
Capital Cost	Plant Material	132,000 €	120,000 €	162,000 €	0 €
	Plant Protection	9,000 €	9,000 €	9,000 €	0 €
	Fertilizer	6,000 €	6,000 €	6,000 €	0 €
	additional Invervention Cost Stage II	90,600 €	90,600 €	90,600 €	96,600 €
	Sum Biomass	237,600 €	225,600 €	267,600 €	96,600 €
	Wind Power	0 €	0 €	0 €	0 €
	Photo Voltaic	0 €	0 €	0 €	0 €
Sum Non-Organics	0 €	0 €	0 €	0 €	
Business Planning Cost	25,000 €	25,000 €	25,000 €	25,000 €	
Test Cultivation	1,000 €	1,000 €	1,000 €	1,000 €	
Sum Initial Cost	26,000 €	26,000 €	26,000 €	26,000 €	
Sum Capital Cost		263,600 €	251,600 €	293,600 €	122,600 €
Operative Cost	Plant Material	0 €	0 €	0 €	10,800 €
	Plant Protection	0 €	0 €	0 €	9,000 €
	Fertilizer	1,200 €	1,200 €	1,800 €	18,000 €
	total Labour cost	3,600 €	3,600 €	4,800 €	8,400 €
	total Machinery cost	3,600 €	3,600 €	4,800 €	8,400 €
	Logistics	600 €	600 €	1,200 €	1,800 €
	Sum Biomass	9,000 €	9,000 €	12,600 €	56,400 €
Wind Power Maintenance	0 €	0 €	0 €	0 €	
Photo Voltaics Maintenance	0 €	0 €	0 €	0 €	
Sum Non-Organics	0 €	0 €	0 €	0 €	
Sum Operative Cost		9,000 €	9,000 €	12,600 €	56,400 €
Interest Expenditure		11,340 €	10,841 €	12,738 €	7,446 €
Annual Average Cost Structure		13,590 €	13,091 €	25,338 €	63,846 €

Box 1: Biomass production area for a small installed power facility

Question: How many ha of *Miscanthus*, for example, is required to operate a combustion plant of 350kW installed power?

Measurements:

1 ha Miscanthus = 15 t biomass/ a

Calorific Value: 15 MJ/ kg

1 MJ = 0,278 kWh

degree of combustion working efficiency = 40 %

Calculation:

$$15 \text{ MJ/ kg} \times 0,278 \text{ kWh/ MJ} = 4,173 \text{ kWh/ kg}$$

$$15.000 \text{ kg/ ha} \times 4,173 \text{ kWh/ kg} = 62.550 \text{ kWh/ ha}$$

$$62.550 \text{ kWh/ ha} : (24 \times 365) = 7,14 \text{ kW / ha}$$

$$350 \text{ kW} : 7,14 \text{ kW} : 0,4 = 122,5 \text{ ha}$$

Conclusion: The site size greatly influences the range of on-site biomass conversion facilities. According to the worked example the amount of installed power should not exceed **160kW** in order to avoid excess capacity and its connected cost. For project management reasons (estimation of investment cost, e.g.) an on-site biomass utilisation facility is not included in the variations of project scenarios provided.

3.3.3 Energy Yields

Table 11 (based on Sächsische Landesanstalt für Landwirtschaft 2009) summarises typical energy yields for the energy crops considered in this worked example. These will be applied in the revenue model in Section 3.3.4. Poplar, willow, and Miscanthus have a similar calorific value in MJ/ kg. Maize has a lower calorific value; however this is counter-balanced by a greater harvestable output. Crop yields also depend on harvest frequency, e.g. annual for maize and once every three years or so for short rotation coppice. Harvesting frequency also means that different crops can have different types of cash flow. This is avoided in this worked example by applying a staggered planting time to allow annual harvesting of the coppice biomass (this means that the coppice biomass harvesting area each year is smaller).

Table 11: Biomass Crop Energy Yields³

Measurements		Wood Plantation		Halm based Cultures	
		Poplar	Willow	Miscanthus	Maize
Calorific Value	MJ/ kg	15.5	15.5	15.0	13.5
	kWh/ kg	4.31	4.31	4.17	3.75
	GJ/ ha	170.50	170.50	225.00	540.00
	kWh/ ha	47,399	47,399	62,550	150,120
Harvest	t/ ha/ a in general	11.0	11.0	15.0	40.0
	Number of ha	1.0	1.0	1.0	1.0
	Dryness	70%	70%	80%	70%
	Frequency _{Year}	4	4	1	1
Substitution Potential	Oil _{Eq.} (l) / ha	4,739.90	4,739.90	6,255.00	15,012.00
	CO _{2 Eq.} (t) / ha	12.51	12.51	16.51	39.63

3.3.4 Revenue Model

Table 12 provides an overall revenue model, considering direct income from biomass use. The price per tonne of biomass strongly depends on the regional supply and demand market conditions and the revenue model uses a cost per tonne dry weight typical for Germany, assuming supply of relatively unprocessed biomass (as would be required by the cement production facility).

Table 12: Revenue Model

Possible Turnover Structure					
Measurements		Wood Platantion		Halm based Cultures	
		Poplar	Willow	Miscanthus	Maize
Biomass Turnover	Selling Price per t	85 €	85 €	95 €	30 €
	Bonus per ha	0 €	0 €	0 €	0 €
	Bonus per t	0 €	0 €	0 €	0 €
Additional Cash Inflow	Price VER in CO _{2 Eq.}	1 €	1 €	1 €	1 €
	Selling of Fertilizer per t	0 €	0 €	0 €	0 €
	Receiving of organic matter in t	0 €	0 €	0 €	0 €
	Constructed Wetland for Waste Water Treatment	0 €	0 €	0 €	0 €
	Receiving of contaminated Soil (LagaZ-Value)	0 €	0 €	0 €	0 €
	Hunting Rental	0 €	0 €	0 €	0 €

³ Personal Communication 2009: Heitmann, C., energy crop farmer - 20.02.2009.

Table 12 also identifies possible additional indirect cash flows, although these are generally zero-rated in this example. They have been included to provide illustrations of additional cash flows that decision-makers might wish to consider. The worked example includes a carbon trading income from the voluntary trading of emission rights, although the likely income on offer appears to be low (TFS Green 2009). Furthermore, income from VER is probably unlikely in any of EU 15 under the current carbon regime (as described in Section 2.3 of the main report; Bardos *et al.* 2009), but may be a possibility in some new Member States in particular Romania and Bulgaria. It is included in the worked example purely for purposes of illustration.

Table 13 provides a cost model, on the basis of biomass use (using the yield and value information in Table 11, and a small amount of income via VERs for the four crop types considered, and no other additional income streams. Poplar and willow biomass and maize produce the greatest biomass yield. However, the value of maize biomass is substantially less.

Table 13: Turnover Structure harvest period

Turnover Structure per Harvest Period			Wood Plantation				Halm based Cultures			
			Poplar		Willow		Miscanthus		Maize	
Biomass Turnover	Selling Price per t produced t of Biomass		85 € 2,640	224,400 €	85 € 2,640	224,400 €	95 € 900	85,500 €	30 € 2,400	72,000 €
	Bonus per ha number of ha		0 € 60.0	0 €	0 € 60.0	0 €	0 € 60.0	0 €	0 € 60.0	0 €
	Bonus per t produced t of Biomass		0 € 2,640	0 €	0 € 2,640	0 €	0 € 900	0 €	0 € 2,400	0 €
	Sum Biomass		224,400 €		224,400 €		85,500 €		72,000 €	
Turnover non-Organics	Wind Power	Price per kWh number of kWh	0.097 € 0	0 €	0.097 € 0	0 €	0.097 € 0	0 €	0.097 € 0	0 €
	PV	Price per kWh number of kWh	0.4301 € 0	0 €	0.43 € 0	0 €	0.4301 € 0	0 €	0.4301 € 0	0 €
	Sum non-organics		0 €		0 €		0 €		0 €	
Turnover VER in CO ₂ Eq.	Price per VER		1 €		1 €		1 €		1 €	
	Biomass Cultivation		number of CO ₂ Eq.		3,003 3,003 €		991 991 €		2,378 2,378 €	
	Heat	BH&PP	number of CO ₂ Eq.		0 0 €		0 0 €		0 0 €	
		BH&PP	number of CO ₂ Eq.		0 0 €		0 0 €		0 0 €	
	Electricity	Wind Power	number of CO ₂ Eq.		0 0 €		0 0 €		0 0 €	
		PV	number of CO ₂ Eq.		0 0 €		0 0 €		0 0 €	
Sum VER		3,003 €		3,003 €		991 €		2,378 €		
Additional Cash Inflow	Price per sold t of Fertilizer number of t		0 € 0 €		0 € 0 €		0 € 0 €		0 € 0 €	
	Price per received t of organic matter number of t		0 € 0 €		0 € 0 €		0 € 0 €		0 € 0 €	
	Price per m ³ Constructed Wetland for Waste number of m ²		0 € 0 €		0 € 0 €		0 € 0 €		0 € 0 €	
	Price per receiving of contaminated Soil number of t		0 € 0 €		0 € 0 €		0 € 0 €		0 € 0 €	
	Price per Hunting Rental number of Hunting Rentals		0 € 0 €		0 € 0 €		0 € 0 €		0 € 0 €	
	Sum additional Cash Inflow		0 €		0 €		0 €		0 €	
Cumulative			227,403 €		227,403 €		86,491 €		74,378 €	

3.3.5 Investment Appraisal

This section applies standard investment appraisal tools (described in Annex 1) to the investment and return for the worked example site for the four different crop scenarios. Table 1 applies these standard assessments to the cost model in Table 10 and the revenue model in Table 12. This is based on annual assessments – reflecting a harvest each year - over a 20 year project life time. It also considers the establishment time for first harvest from the poplar or willow coppice (four years).

Table 14 provides an economic overview and applies a dynamic investment calculation in the form of Net Present Value (NPV), amortisation time, Internal Rate of Return (IRR), and annuity (Reichmann 2006). A discounting factor (DCF) of 4% is used throughout the project. All investment terms are defined in Annex 1. Figure 13 shows crop specific NPV. Miscanthus and Maize are annually harvestable crops so generate income from year 1. Conversely willow and poplar and willow do not generate income until Year 4, which shows as a dip then rise in revenue in Figure 13. Maize is calculated to have the lowest economic potential, and Miscanthus the highest economic potential for this worked example.

Table 14: Investment Appraisal for Biomass Cultivation – Scenario 1

Investment Appraisal Comparison for Biomass Cultivation				
Method	Wood Plantation		Halm based Cultures	
	Poplar	Willow	Miscanthus	Maize
NPV	210,115 €	235,885 €	537,487 €	10,741 €
Amortisation	11	11	6	20
IRR	10.09%	10.98%	20.31%	4.80%
Annuity	15,461 €	17,357 €	39,549 €	790 €

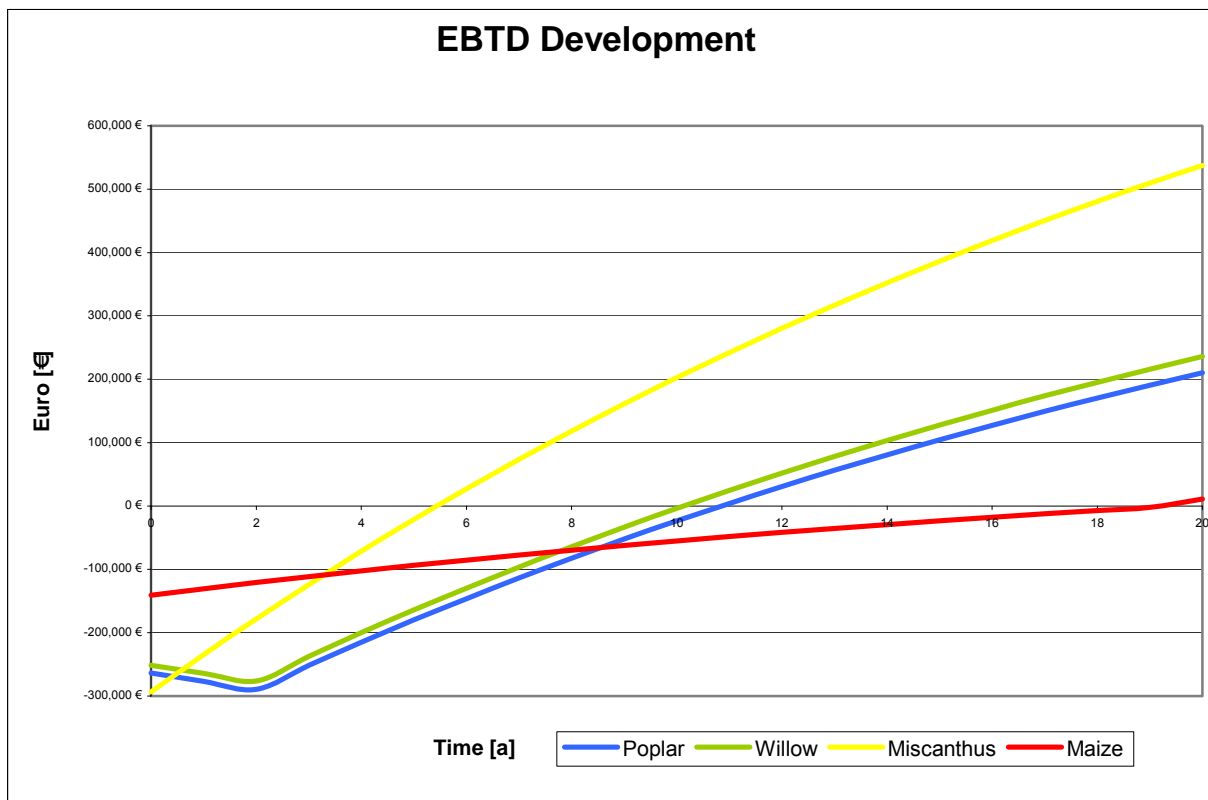


Figure 13: Illustration of projected Net Present Value Development along Project Horizon

What may be also interesting, particularly in countries like Germany which have guaranteed prices for the supply of electricity from renewable sources, is supplementing income from biomass by inclusion of photo-voltaics or wind energy. A scenario was modelled where photo-voltaics were sited on the roof of the building on the site. Table 15 illustrates how this would provide supplementary income based on the prevailing conditions of Germany where the worked example is located. The German Law for Renewable sources of Energy guarantees a secured compensation for electricity fed into the public grid, and the revenue data provided therefore apply to Germany only. Annex 2 reviews these additional renewable energy scenarios of wind and solar power for the site in more detail.

Table 15: Potential for Supplementary Revenue

Renewable - compensation for electricity & heat fed into the grid					
Measurement		< 150kW	< 500kW	< 5MW	> 20MW
Biogas	basic Commission	0.1167 €	0.0918 €	0.0825 €	0.0779 €
	Renewable Bonus	0.0600 €	0.0000 €	0.0000 €	0.0000 €
	Technology Bonus (BH&PP)	0.0300 €	0.0300 €	0.0300 €	0.0300 €
	Sum	0.2067 €	0.1218 €	0.1125 €	0.1079 €
Measurement		< 30kW	< 100kW	< 1000kW	> 1000kW
PV	undeveloped Area	0.32 €	0.32 €	0.32 €	0.32 €
	Roof Area	0.4301 €	0.4091 €	0.3958 €	0.3300 €
Measurement		< 150kW	< 500kW	< 5MW	> 5MW
Wind Power	basic Commission	0.097 €	0.097 €	0.097 €	0.097 €

Table 16 shows how these supplementary incomes would affect investment appraisals for different biomass types, considering four scenarios: biomass only; biomass and solar; biomass and wind; and biomass, wind and solar. Exploitation of wind or solar energy requires additional costs for technology installation and maintenance. Given the project time frame used of 20 years, wind power was not found to be economic: over 20 years the outcome is a “negative” return. Inclusion of solar power alone is feasible but over a 20 year time frame does not improve economic performance. However, a combination of biomass production and other renewable energy production concepts under the given site conditions may be interesting for timeframes greater than the 20 years modelled.

Table 16: Investment Appraisal Scenario Comparison

Investment Appraisal Scenario Comparison					
Method	Wood Plantation		Halm based Cultures		Scenarios
	Poplar	Willow	Miscanthus	Maize	
NPV	210,115 €	235,885 €	537,487 €	10,741 €	Scenario 1 Biomass
Amortisation	11	11	6	20	
IRR	10.09%	10.98%	20.31%	4.80%	
Annuity	15,461 €	17,357 €	39,549 €	790 €	
NPV	111,839 €	130,623 €	432,233 €	-94,513 €	Scenario 2 Biomass & Solar Power (SP)
Amortisation	15	14	8	Negative Investment	
IRR	6.91%	7.47%	15.47%	-1.90%	
Annuity	8,229 €	9,611 €	31,804 €	-6,954 €	
NPV	-592,436 €	-573,651 €	-269,210 €	-795,956 €	Scenario 3 Biomass & Wind Power (WP)
Amortisation	Negative Investment	Negative Investment	Negative Investment	Negative Investment	
IRR	1.42%	1.50%	2.85%	0.08%	
Annuity	-43,592 €	-42,210 €	-19,809 €	-58,568 €	
NPV	-764,380 €	-745,595 €	-374,465 €	-901,211 €	Scenario 4 Biomass & SP & WP
Amortisation	Negative Investment	Negative Investment	Negative Investment	Negative Investment	
IRR	0.67%	0.74%	2.42%	-0.42%	
Annuity	-56,244 €	-54,862 €	-27,554 €	-66,313 €	

3.3.6 Sustainability Appraisal

Within this section a detailed worked example is provided for considering energy substitution. An approach for wider sustainability appraisal is suggested but not elaborated in detail.

3.3.6.1 Quantification of Fossil Fuel Substitution by Renewable Sources of Energy

Table 17 presents the substitution potential of fossil fuels (Oil_{Eq.}) for the different crop scenarios considered in this worked example as equivalents of kWh and oil (kWh_{Eq.} and Oil_{Eq.}). These have also been costed in Euro. This uses an assumed price of 24,11 Cent Euro per kWh and 70 Cent Euro per Oil_{Eq.} with an annual rate of increase of 5% (CDM Update 2009). The possible enhancement of renewable energy production by using wind or solar sources is described in Annex 2.

Figure 14 plots the development of fossil carbon substitution over time for Miscanthus, poplar and willow, maize already having been ruled out on strictly economic grounds. The performance of willow and poplar are broadly similar and slightly less than Miscanthus *for the worked example*.

Table 17: Elaboration of Fossil Fuel Substitution Potential – Scenario 1 Approach

Elaboration of Fossil Fuel Substitution Potential per Anno - Scenario 1						
Categories	Wood Plantation				Halm based Cultures	
	Poplar		Willow		Miscanthus	
kWh/ ha	47,399		47,399		62,550	
number of ha	60	2,843,940	60	2,843,940	60	3,753,000
kWh/ Module	900		900		900	
number of Modules	0	0	0	0	0	0
kWh/ Module	5,700,000		5,700,000		5,700,000	
number of Modules	0	0	0	0	0	0
Sum of kWh	2,843,940		2,843,940		3,753,000	
Number of kWh	2,843,940		2,843,940		3,753,000	
Price per kWh	0.2411 €	685,674 €	0.2411 €	685,674 €	0.2411 €	904,848 €
Price Development (5 Years)	875,113 €		875,113 €		1,154,841 €	
Price Development (10 Years)	1,116,891 €		1,116,891 €		1,473,903 €	
Price Development (20 Years)	1,819,297 €		1,819,297 €		2,400,832 €	
Oil Equivalents	284,394		284,394		375,300	
Price per Oil Equivalent	0.7 €	199,076 €	0.7 €	199,076 €	0.7 €	262,710 €
Price Development (5 Years)	254,077 €		254,077 €		335,292 €	
Price Development (10 Years)	324,274 €		324,274 €		427,927 €	
Price Development (20 Years)	528,207 €		528,207 €		697,048 €	
CO₂ Eq. in t	751		751		991	

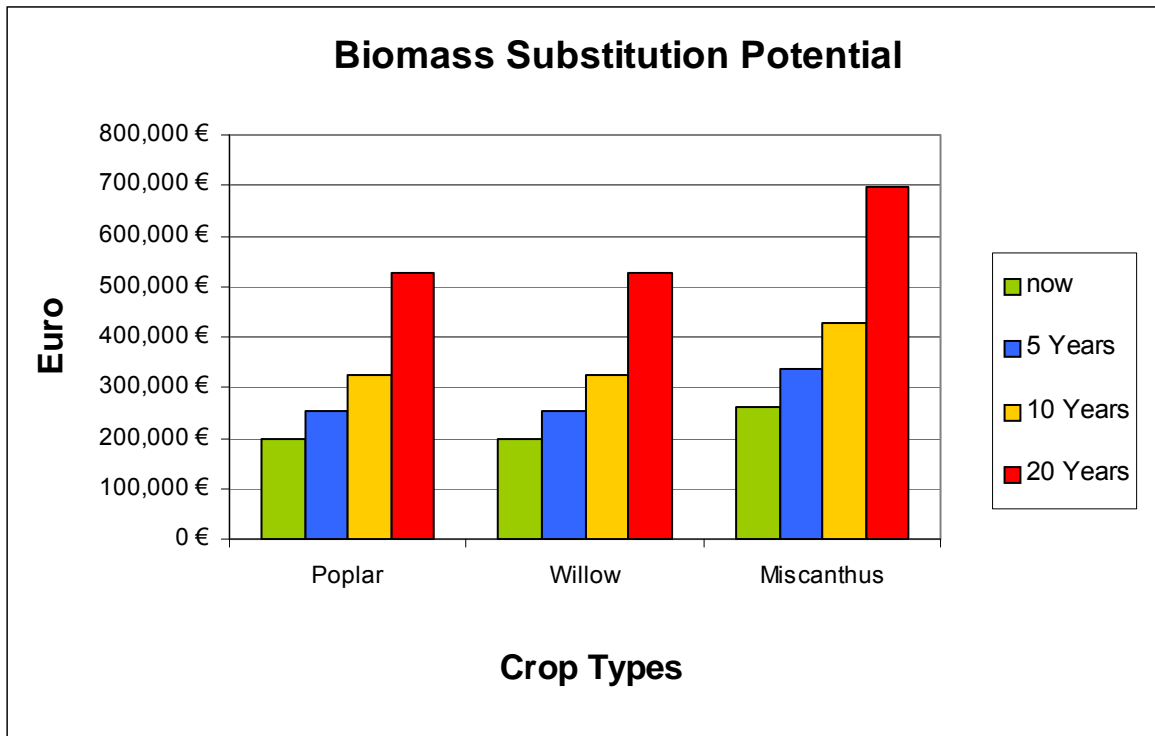


Figure 14: Biomass Substitution Potential

3.3.6.2 Broader Sustainability Appraisal

The Sustainable Remediation Forum in the UK (SuRF-UK) is developing guidance on sustainability appraisal for land restoration, which reflects an emerging international interest in maximising the sustainability benefit of remediation (CL:AIRE 2009a and 2009b).

Sustainability is a tapestry of individual threads, including particular environmental impacts such as climate change impacts and impacts on soil functionality, economic impacts such as direct costs and the resilience of a project; and social impacts such as protection of human health and equity. Indicators are used to assess each of these threads or “factors”.

An indicator is a single characteristic that can be compared between options to evaluate their relative performance towards specific sustainable development concerns. Indicators need to be measurable or comparable in some way that is sufficient to allow this evaluation.

An overarching assessment of sustainability will be a function of: the site and project context; the technological approaches to remediation being compared; and the views of the stakeholders involved in the decision making process. Achieving sustainable development will inevitably be highly specific to the site in question and the project(s) under consideration and the stakeholders involved and their interests. For example, a particular site might be influenced by a local authority sustainable development policy, regulatory compliance goals, a consideration of costs vs. benefits and organisational sustainable development reporting needs for the various stakeholders involved.

Table 18 lists a broad range of categories of factors that might be used in a sustainability comparison for different scenarios. In the context of this worked example the most likely sustainability comparison would include alternative land use scenarios, for example taking no action, and comparing these with the biomass based land uses that are applicable for the site and the management interventions need to produce them (which would have been identified by the end of Stage 2).

Table 18 Overarching categories of indicators for sustainability assessment of remediation options suggested by SURF-UK (CLAIRE 2009a)

Environmental	Social	Economic
1. impacts on air (including climate change);	1. impacts on human health and safety;	1. direct economic costs and benefits;
2. impacts on soil;	2. ethical and equity considerations;	2. indirect economic costs and benefits
3. impacts on water;	3. impacts on neighbourhoods or regions;	3. employment and capital gain;
4. impacts on ecology;	4. community involvement and satisfaction;	4. gearing;
5. use of natural resources and generation of wastes;	5. compliance with policy objectives and strategies;	5. life-span and 'project risks';
6. intrusiveness.	6. uncertainty and evidence.	6. project flexibility.

3.3.7 Output of Stage 3

Based on the assumptions used in the cost and revenue models, Stage 3 finds that from an economic point of view, and from the point of view of fossil carbon substitution, Miscanthus is the preferred crop option. However, the performances of willow and poplar biomass are also good. Maize is not found to be a good biomass crop for this site. The economic analysis of wider renewable scenarios illustrates the attractiveness of at least considering additional renewable energy sources for the site to improve economic value and fossil carbon substitution potential (see Annex 2).

In practice willow was found, at Stage 2, to be the optimal biomass crop for the site from a technical point of view. However, for purposes of illustration, both Miscanthus and willow have been carried forward to Stage 4.

This worked example is necessarily simplified. In practice it would be advisable to carry out sensitivity analyses for the economic model and its assumptions. For example, it would be useful to explore how differences in yield might affect outcome. Because the economic model includes a number of activities, small changes may have more substantial effects because of their impact across several activities. The sensitivity analysis may therefore also need to consider several "best" and "worst" case scenarios.

3.4 Decision Tool Framework - Stage 4 Project Risk

Once a firm project concept has been elaborated whose value is attractive to its developers, the project planning needs to ensure as far as possible its viability before any major investment takes place. Three broad considerations are important: technology status, detailed diligence (e.g. of financial partners and project partners) and developing abroad stakeholder consensus, as illustrated in Figure 15. The output is a realistic appraisal of project risks and a mitigation strategy.

Stage 4.1: Stakeholder views, during this stage the project team offers their plans for detailed external comment and scrutiny now that a complete project concept exists. It is assumed that negotiation and discussion of the project with a range of stakeholders will have been ongoing through the project development, but at this stage detailed plans can be formally laid out.

Step 4.2: Technology status, during this stage the technical components are subjected to detailed scrutiny; for example feasibility study work based on desk studies may now need to be validated by pilot scale testing in the field. This may be triggered by particular stakeholder concerns, for example whether risk management assumptions based on biomass uptake of trace elements can be validated.

Step 4.3: Detailed diligence, during this stage the project team seeks firm finalises business planning and makes arrangements for execution, e.g. to raise capital. Environmental compliance details are finalised and the reliability of partners, across the whole site management and biomass production

(and conversion) system is scrutinised in detail. This is also the point at which investment, or public or regional funding or tax breaks are finally consolidated.

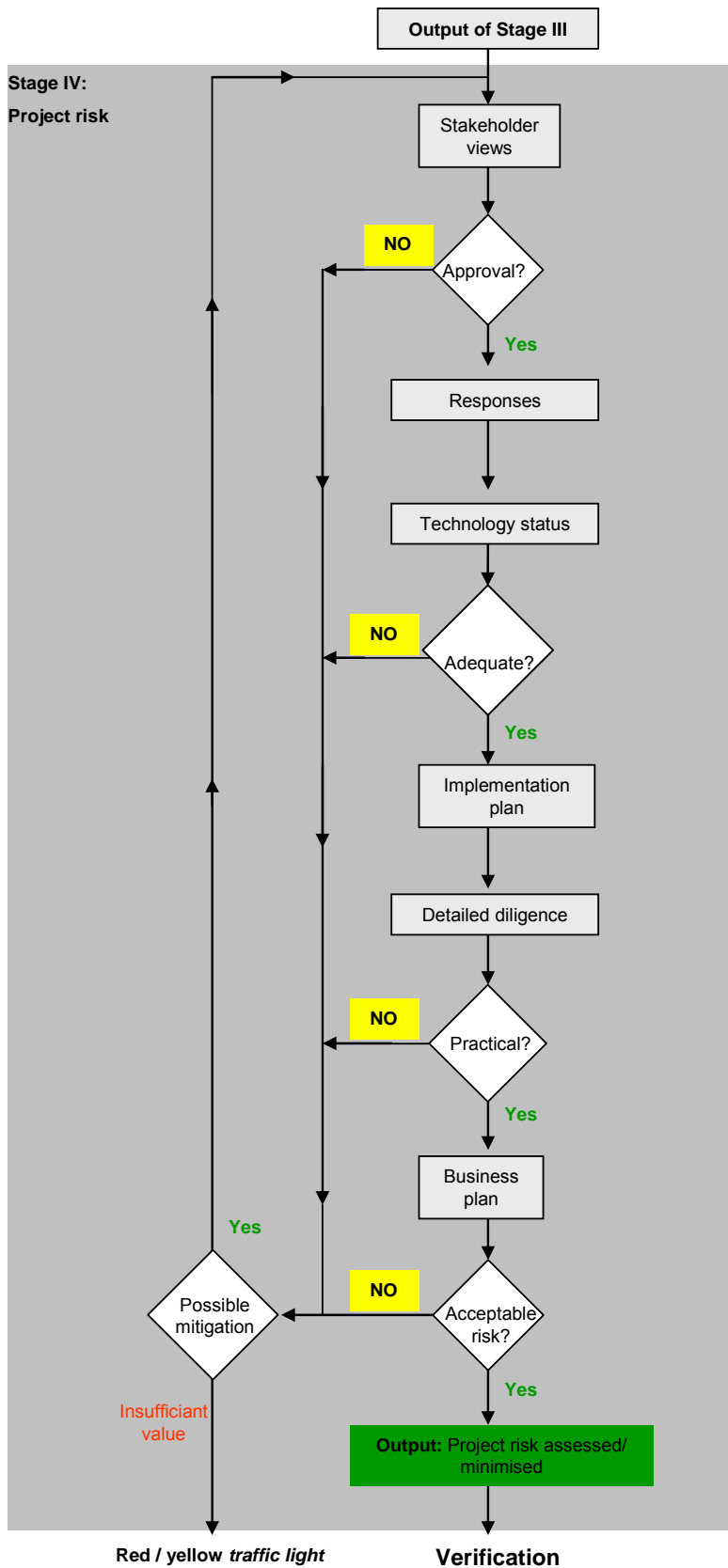


Figure 15: Decision Support Tool - Stage 4

The output of Stage 4 is therefore a firm project concept where project risks are known, and mitigated where necessary, that is ready for detailed planning and implementation. The order of consideration is important because stakeholder consultation may trigger questions about the technical approach and matters of due diligence that need to be addressed by subsequent stages of project risk management.

3.4.1 Stakeholder Views

The core stakeholders for the worked example (i.e. the decision makers) are the site owner, local regulators, the funder/ lender (i.e. federal bank) and a specialist consultant. All of these stakeholders had been kept informed by the site owner and specialist consultant through Stages 1 to 3 of decision making, and the case made to go forward with risk based land management and the production of bioenergy on the spoil heap was generally accepted. At this stage a prospectus for the scheme was developed and taken to public meetings in the communities adjacent to the soil heap, and the site owner (through the specialist consultant) approached the regional authorities for grant assistance (towards 20% of the project management cost). The regional authority sent the proposal for grant funding to an external expert for scrutiny.

These activities widened the range of stakeholders so far involved in the decision-making process, which resulted in additional feedback for the decision-making process which raised a range of points of detail for the project which could be resolved within the context of the plans already made. However, this wider feedback also raised two major concerns over the bioenergy approach being adopted, over its economic viability and its wider environmental impacts.

The public prospectus and meetings generally received the proposed site re-use for bioenergy in a positive way for several reasons: the improvement of the site; the provisions included for public amenity and access; the perceived value of producing bioenergy and the possibility of improving residential values by improving the landscape. However, a number of negative reactions emerged which were: concern over disease and odour risks from the use of sewage sludge and compost, worry about the road traffic impacts of the restoration work, and concern that a *Miscanthus* based bioenergy approach would lead to a diminution in landscape value and a loss in conservation value. Local conservation societies argued that the biodiversity value of willow was better.

The local regulators agreed with the site owner and specialist consultant that the concerns over organic matter recycling could be effectively addressed through the environmental permitting procedure for the site, as long as this procedure was open and transparent. The issue of road traffic impacts (including weight of traffic and concerns over spillage from vehicles) was to be taken forward at further public meetings, and ultimately regulated by local authority conditions on lorry movements and good practice for transportation. The concerns over biodiversity and conservation could not be quickly resolved.

The external scrutiny for the grant application was also generally positive, but identified what was felt to be a significant flaw in the economic model. In practice the economic performance of *Miscanthus* may be less than predicted by the model used here. The revenue model assumed that *Miscanthus* was harvested annually, and that the yield distribution was the same year on year. However, while *Miscanthus* can be harvested from the January after planting, it takes time to establish and "mature yields" may not be evident for three to five years depending on the quality of the land (Dept Agric Fisheries and Food 2009). Hence, the predictions in Figure 13 were seen as overly optimistic. A further consequence of this external scrutiny was to introduce an element of doubt from the perspective of the bioenergy user (the cement plant manager), who now wanted guarantees for energy supply and quality. The cement facility did not wish to take a risk on its energy supply contracts, and felt that this risk should be borne by the biomass supplier.

As a result of the stakeholder feedback received, the site owner and specialist consultant took the view that some more detailed investigation would be necessary for both conservation "value" and economic performance. They took this decision because the concerns of the grant provider threatened to destabilise the overall project investment (from the bank), and the concerns of the conservation society threatened to remove local support for the project. The site owner saw these concerns and their consequences as substantial project risks.

3.4.2 Technology Status

The stakeholder analysis identified two broad issues where better information was needed: understanding the biodiversity impacts / benefits of Miscanthus and willow use on the site and substantiating yield data used in the economic model. Initially the specialist consultant looked to published information to investigate these issues, but found that yield information for Miscanthus on marginal land was limited, and its biodiversity impacts were also not as well investigated as for willow. The specialist consultant identified two possible ways forward to mitigate these project risks: (1) to proceed directly with a full scale project using willow as more information was available for yields from this crop on marginal land and the use of willow carried greater local support; or (2) to carry out pilot scale plantings of willow and Miscanthus to compare yields and biodiversity value – and execute a full stage project on the basis of the findings of these pilot trials. The pilot trial duration was estimated to be four years.

3.4.3 Detailed Diligence

The aim of the diligence is to push the findings from the desk-based research and implement them into a full-scale practical project. Therefore, the acquisition of suppliers, products, services, and associated costs, employment requirements, and staffing structures, raising capital, legal restrictions and establishment of a company structure will become important factors (amongst others) to establish (Pinson, L. 2005). Key actions for finalising the project business plan would be as follows. Each of these actions will affect the overall project delivery and its economic performance.

- Determination of a grant application and any special conditions relating to this. The grant application for the full scale project is potentially stalled as described above.
- Finalisation of investment and credit arrangements, and meeting any special conditions relating to this. Investment decisions are not possible until the grant arrangements are resolved, unless alternative forms of capital for 20% of the project cost can be found.
- Finalisation of planning and permitting applications – these had gone forward on the basis of a bioenergy crop which could be willow or Miscanthus. However, the concerns raised over biodiversity have led to the site owner deciding to put this process on hold, pending a resolution of these concerns, as a consensus based way forward would reduce risks of failure to achieve permissions with the local authority
- Contracts for green waste and sewage sludge suppliers with the local green waste composting plant and the municipal waste water treatment plant need to be arranged – these would be based on earlier agreements in principle used for the economic model in Stage 3. Contracts cannot be initiated until the project is permitted / licensed and finance agreements are in place.
- Negotiations are underway for a 20 year bioenergy supply contract to the cement plant. This was originally seen as beneficial for both sides by removing market uncertainties. However, contracts cannot be finalised until permits / licenses and finances are in place. In addition, the cement facility is now looking for a guaranteed level of energy supply.
- Arrangements for site maintenance and harvesting have been developed in outline (during Stage 2). This will involve annual harvesting of Miscanthus over the entire planting area, or of willow over one third of the planting area. During the detailed diligence stage the specialist consultant will determine the most cost effective means of delivering site maintenance and harvesting. Options under consideration are for a dedicated section within the site owner's own organisation, or the use of subcontract services managed by the specialist subcontractor. Negotiations are continuing, but cannot be finalised until the crop decision is finally made.

The way forward under consideration by the site-owner is to proceed with willow biomass as its uncertainties are fewer for this particular site, and its degree of acceptability to stakeholders is higher. The site owner does not consider that he can wait for a four year pilot plot test programme to deliver a definitive answer in a choice between Miscanthus and willow for this site, particularly as grant funding and investment support are immediately available. However, the specialist consultant has argued that Miscanthus may deliver higher revenue over time, and so a Miscanthus test plot will be established on the spoil heap to collect information that can be used to inform future biomass projects on other areas

of marginal land in the site owner's possession, given the high predicted NPV calculated for Miscanthus in the economic model (double that for willow).

Consequently, the detailed diligence tasks can be completed. The economic performance of the project will form a key part of the overall project verification. The concerns of the cement plant manager will be dealt with by offering a fixed amount of willow biomass by dry tonnage on a yearly in advance basis, allowing the possibility of change as yields are expected to increase over time. The site owner has committed to arranging additional biomass supply to cover any shortfall from the willow plantation. This carries a financial risk for the site owner, who might then be faced with the situation of having to buy wood chip on the open market and supply it to the cement facility within the existing price structure (calculated for locally produced biomass). The site owner has, in their view, found a way to manage this risk by taking an option to buy all of the compost "oversize" woody waste from the nearby composting plant that is supplying compost for site restoration and maintenance, pending some biomass quality testing for the material. This is seen as an opportunity by both the site owner and compost facility manager as the yearly revision of biomass supply could allow for an increasing amount of compost oversize use as confidence in the willow plantation yields grows. The compost facility manager and site owner are discussing an agreement which would allow the compost facility to collect woody wastes from a local catchment, which if of appropriate quality, could enter the biomass fuel deliveries to the cement plant.

3.4.4 Output of Stage 4

The completion of Stage 4 aims to provide a firm and "bankable" project concept where project risks are known and mitigated where necessary. At this stage, the project is ready for more detailed planning and implementation. This process begins with the agreement of a verification strategy which meets the needs of the site owner, the local regulators, the grant funder and the investor.

The conclusion of this stage has not been a purely technical process, and a number of operational "business" decisions have been taken by the site owner to ensure a timely project that has the greatest chance of commercial success. The stakeholder analysis and resulting detailed technical scrutiny were vital to this decision making. While negotiations are still underway, the outcome looks as if it will be a willow based biomass project, with a pilot test for Miscanthus to inform future site decisions.

The detailed diligence for the site has found that the site owner will need to take on an unexpected liability, which is to guarantee energy supply to the cement facility. The local compost facility provides an opportunity to reduce this potential liability, and indeed generate an additional revenue opportunity.

3.5 Verification

The verification of project performance will need to consider the following:

- Specific environmental goals agreed with regulators
- Economic goals of the project required to achieve suitable economic performance
- Wider sustainable development performance (in particular if sustainability goals have been agreed as part of any public grant or funding)

Table 19 sets out the likely verification requirements for this worked example.

Table 19 Project Verification Requirements

<p>Specific environmental goals agreed with regulators</p>	<p>Requirements related to the risk management of land contamination, for example specifications for minimum restoration activities, control of access and a monitoring plan for water quality in the adjacent brook, contamination levels in surface soil and vegetation. These would be the responsibility ultimately of the site owner⁴.</p> <p>Requirements related to the supply of organic material for restoration of and maintenance of the site to ensure that the material met appropriate quality standards, that its use and rates of use were in compliance with the permit received; and that public and animal health precautions relating to the use of the sewage sludge and compost were met (for example relating to bioaerosols, and organic matter pathogen levels). Quality assessment would likely be seen as the responsibility of the organic matter “producer”. However, the site owner would be expected to demonstrate that they had used products of sufficient quality and had applied them in compliance with the agreements reached with the regulator.</p> <p>Additional requirements might relate to ensuring site operations were restricted in time to avoid nuisance and that there was a site management plan to minimise nuisance from traffic, litter and odour. These would be the responsibility ultimately of the site owner.</p>
<p>Project economic Goals</p>	<p>Project economic goals would be set out in the detailed business plan after conclusion of Stage 4.3. These might include operational measures on an annual basis and overall project aims, for example, amortisation within 12 years. Project economic goals would be the responsibility of the site owner, and would likely have to be reported, at least in part, to the public and private investors in the project.</p>
<p>Wider sustainable development performance</p>	<p>A range of wider sustainable development goals might be set for the project. These might relate to issues such as fossil carbon replacement (for example a certain figure for CO₂ eq. per year. For this project it is possible that some form of biodiversity monitoring would be required. The local authority might wish to monitor job creation levels from the scheme and wider measures of economic well being such as neighbouring property values, and agree targets with the site owner related to amenity and public access. It may be that some form of working party considers sustainability monitoring, with shared responsibilities as the site owner may be unwilling to commit to undertaking this work on their own.</p>

⁴ Although possibly delegated to a contractor / service provider

4 Conclusions

The decision support approach of Rejuvenate was developed by partners from Germany, Sweden and the UK. These countries have substantial differences in the context of land and biomass re-use, as set out in the main report (Bardos *et al.* 2009). Nonetheless the Rejuvenate project has proposed a set of common principles that can be adopted by any project in each of these countries to suit its specific requirements. This implies that the decision making framework will also have a wider applicability across the EU Member States. The purpose of the worked example in this report has been to illustrate the application of the decision making framework.

The worked example is set in the context of western Germany. Marginal land is a substantial problem in Germany where there has been estimated to be around 530,000ha of marginal degraded land (Federal Environmental Agency 2007b). However, the decision-making process in the worked example is intended to be illustrative for other countries as well.

The worked example shows how the complexity of decision making can be managed by taking a staged approach to decision-making in which viable opportunities are identified from a wider range of prospective opportunities. The rationale for decision-making in stages is to permit robust and transparent decision-making on the basis of the minimum information at each stage. This means that decision-making cost is focused on effort on the possible approaches can be shown to be most viable.

The example elaborates the four stages of the decision-making framework to identify the lowest risk alternative of crop cultivation on marginal land from environmental and economic viewpoints, taking into account regional and site conditions. Stage 1 (crop selection) provides a rationale for a shortlist of three crop types (poplar, willow, and *Miscanthus*).

Stage 2 considered site characteristics to identify, soil management and risk assessment needs and their impact on crop selection, along with the wider environmental impacts of biomass production. Stage 2 would in practice select only willow for further evaluation. Soil depth was insufficient for *Miscanthus* and costs of increasing soil depth would be prohibitive. Poplar was discounted as it is seen as too susceptible to disease. The soil management selected was based on the use of green compost and sewage sludge to improve the soil quality without degrading the risks. The estimated cost of management was found to be €1,510 per ha.

The key focus of Stage 3 is concerned with the selection of crop types providing the most attractive prospects in terms of revenue and sustainability. In this example Stage 3 compared maize, *Miscanthus*, poplar and willow for the purposes of illustration for Stages 3 and 4. On the basis of the economic modelling in Stage 3 *Miscanthus* and willow were taken forward to Stage 4. However in practice maize, *Miscanthus*, poplar would have been discounted at Stage 2.

Stage 3 found that, had it been possible to grow it, *Miscanthus* would have been the most the financially attractive crop, and maize had the poorest financial performance. In addition, supplementing on site energy generation using wind and/or solar energy could have been attractive as project enhancements (reviewed in more detail in Annex 2). Both willow and *Miscanthus* were considered in Stage 4, for purposes of illustration.

Within Stage 4, broader feedback from stakeholders hitherto not involved with the project identified a difficulty with the economic model forecasting for *Miscanthus* and also a concern over biodiversity impacts for *Miscanthus*. This led to a requirement for pilot testing of *Miscanthus* production in comparison with willow, or proceeding with a full scale willow project. The uncertainties caused by this situation led to a demand for energy supply guarantees from the main bioenergy client, which placed a new liability on the site owner should they decide to proceed with the biomass project. Ultimately the site-owner took a pragmatic approach in decision-making to proceed with a willow based project immediately, and carry out *Miscanthus* pilot tests in parallel given the possible benefits of *Miscanthus* for future restoration projects. The site owner found a potential collaboration with the green waste compost supplier was an attractive route to providing energy supply guarantees, that both limited liability and potentially created a new business opportunity for harvesting local wood waste as biomass (providing it was of suitable quality for use for bioenergy).

This worked example is an illustration only. It is intended to show the benefits of a staged approach in determining viable re-use options for biomass based restoration. The illustration shows how options

should be refined as early as possible in decision-making, to minimise decision-making effort. In fact, in practice only one viable option remained after Stage 2. However a range of options were retained purely to show the functioning of the later decision-making stages of the framework. The value of this has been to show how economic analysis can support decision making, and how practical and commercial decisions are likely to have a major impact in managing project risks.

The conclusion of the worked example of the decision support tool at this (fictional) German mine site location was that use of willow short rotation coppice over most of the 60 ha of the site, supported by soil improvement using compost and sewage sludge. This would be accompanied by a test plot for ingoing Miscanthus trials.

The worked example is fictitious and strictly related to the spoil heap described. It is not intended to convey any general conclusions about the suitability of biomass crops for coalfield restoration outside this context. It is intended to illustrate a decision making process.

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Annex 2 – Supplemented Scenario Calculations

a) Scenario 2 Approach: Addition of Solar Energy

The difference between Scenario 1 (biomass alone modelled in Chapter 3) and Scenario 2 is the additional installation of 150m² on the building roof (see Figure 1, Table 17, and subchapter 2.1.3).

Table 18: Photo Voltaic & Wind Power Measurements

Photo Voltaic		per Module	Wind Power		Type Enercon E-82
Module _{Year}	8 m ²	1 kWp	Module _{Year}	Price _{net}	3,340,000 €
	Price _{net} per kWp	3,400 €		Degree of Efficiency	ca. 40 %
	Degree of Efficiency	ca. 20%		Installed Power	2 MW
	Power _{average} kWh	900		r. Wind Level _{average}	7,51 m/s
	Utilisation Duration	20		kWh _{year}	5,700,000
Installation Area (m ²)	8.00	1	Number of Modules	Utilisation Duration	20
	kWp			kWh	1
	kWh			900	5,700,000
Substitution per Module _{Year}	Oil Eq. per Module	90	Substitution per Module _{Year}	Oil Eq. per Module	570,000
	t CO ₂ Eq. per Module	0.2376		t CO ₂ Eq. per Module	1,505

(Birmelin, A./ Westphal, M. 2008)

Scenario 2

Cultivation Cost Structure for 60 ha		Wood Plantation		Halm based Cultures	
		Poplar	Willow	Miscanthus	Maize
Capital Cost	Plant Material	132,000 €	120,000 €	162,000 €	0 €
	Plant Protection	9,000 €	9,000 €	9,000 €	0 €
	Fertilizer	6,000 €	6,000 €	6,000 €	0 €
	additional Invervention Cost Stage II	90,600 €	90,600 €	90,600 €	96,600 €
	Sum Biomass	237,600 €	225,600 €	267,600 €	96,600 €
	Wind Power	0 €	0 €	0 €	0 €
	Photo Voltaic	63,750 €	63,750 €	63,750 €	63,750 €
	Sum Non-Organics	63,750 €	63,750 €	63,750 €	63,750 €
Operative Cost	Business Planning Cost	25,000 €	25,000 €	25,000 €	25,000 €
	Test Cultivation	1,000 €	1,000 €	1,000 €	1,000 €
	Sum Initial Cost	26,000 €	26,000 €	26,000 €	26,000 €
	Sum Capital Cost	327,350 €	315,350 €	357,350 €	186,350 €
	Plant Material	0 €	0 €	0 €	10,800 €
	Plant Protection	0 €	0 €	0 €	9,000 €
	Fertilizer	1,200 €	1,200 €	1,800 €	18,000 €
	total Labour cost	3,600 €	3,600 €	4,800 €	8,400 €
total Machinery cost	3,600 €	3,600 €	4,800 €	8,400 €	
Logistics	600 €	600 €	1,200 €	1,800 €	
Sum Biomass	9,000 €	9,000 €	12,600 €	56,400 €	
Wind Power Maintenance	0 €	0 €	0 €	0 €	
Photo VoltaiCs Maintenance	5,100 €	5,100 €	5,100 €	5,100 €	
Sum Non-Organics	5,100 €	5,100 €	5,100 €	5,100 €	
Sum Operative Cost	14,100 €	14,100 €	17,700 €	61,500 €	
Interest Expenditure	14,204 €	13,705 €	15,602 €	10,311 €	
Annual Average Cost Structure	21,554 €	21,055 €	33,302 €	71,811 €	

Scenario 2

Turnover Structure per Harvest Period			Wood Plantation				Halm based Cultures			
			Poplar		Willow		Miscanthus		Maize	
Biomass Turnover	Selling Price per t produced t of Biomass		85 € 2,640	224,400 €	85 € 2,640	224,400 €	95 € 900	85,500 €	30 € 2,400	72,000 €
	Bonus per ha number of ha		0 € 60.0	0 €	0 € 60.0	0 €	0 € 60.0	0 €	0 € 60.0	0 €
	Bonus per t produced t of Biomass		0 € 2,640	0 €	0 € 2,640	0 €	0 € 900	0 €	0 € 2,400	0 €
	Sum Biomass		224,400 €		224,400 €		85,500 €		72,000 €	
Turnover non-Organics	Wind Power	Price per kWh number of kWh	0.097 € 0	0 €	0.097 € 0	0 €	0.097 € 0	0 €	0.097 € 0	0 €
	PV	Price per kWh number of kWh	0.4301 € 16,875	7,258 €	0.43 € 16,875	7,258 €	0.4301 € 16,875	7,258 €	0.4301 € 16,875	7,258 €
	Sum non-organics		7,258 €		7,258 €		7,258 €		7,258 €	
Turnover VER in CO ₂ Eq.	Price per VER		1 €		1 €		1 €		1 €	
	Biomass Cultivation		3,003	3,003 €	3,003	3,003 €	991	991 €	2,378	2,378 €
	Heat	BH&PP	0	0 €	0	0 €	0	0 €	0	0 €
		BH&PP	0	0 €	0	0 €	0	0 €	0	0 €
	Electricity	Wind Power	0	0 €	0	0 €	0	0 €	0	0 €
		PV	4	4 €	4	4 €	4	4 €	4	4 €
Sum VER		3,007 €		3,007 €		994 €		2,381 €		
Additional Cash Inflow	Price per sold t of Fertilizer number of t		0 €	0 €	0 €	0 €	0 €	0 €	0 €	0 €
	Price per received t of organic matter number of t		0 €	0 €	0 €	0 €	0 €	0 €	0 €	0 €
	Price per m ³ Constructed Wetland for Waste number of m ²		0 €	0 €	0 €	0 €	0 €	0 €	0 €	0 €
	Price per receiving of contaminated Soil number of t		0 €	0 €	0 €	0 €	0 €	0 €	0 €	0 €
	Price per Hunting Rental number of Hunting Rentals		0 €	0 €	0 €	0 €	0 €	0 €	0 €	0 €
	Sum additional Cash Inflow		0 €		0 €		0 €		0 €	
Cummulative			234,665 €		234,665 €		93,752 €		81,639 €	

Scenario 2

Investment Appraisal Comparison for Biomass Cultivation				
Method	Wood Plantation		Halm based Cultures	
	Poplar	Willow	Miscanthus	Maize
NPV	136,809 €	162,578 €	432,233 €	-94,513 €
Amortisation	14 Years	13 Years	8 Years	Negative Investment
IRR	7.48%	8.20%	15.47%	-1.90%
Annuity	10,067 €	11,963 €	31,804 €	-6,954 €

b) Scenario 3 Approach: Addition of Wind Energy

Scenario 3 includes the installation of one wind power module (see Table 16) in Scenario 1. The general structure and approach are otherwise the same as the Scenario 1 approach.

Scenario 3

Cultivation Cost Structure for 60 ha		Wood Plantation		Halm based Cultures	
		Poplar	Willow	Miscanthus	Maize
Capital Cost	Plant Material	132,000 €	120,000 €	162,000 €	0 €
	Plant Protection	9,000 €	9,000 €	9,000 €	0 €
	Fertilizer	6,000 €	6,000 €	6,000 €	0 €
	additional Invervention Cost Stage II	90,600 €	90,600 €	90,600 €	96,600 €
	Sum Biomass	237,600 €	225,600 €	267,600 €	96,600 €
	Wind Power	3,340,000 €	3,340,000 €	3,340,000 €	3,340,000 €
	Photo Voltaic	0 €	0 €	0 €	0 €
	Sum Non-Organics	3,340,000 €	3,340,000 €	3,340,000 €	3,340,000 €
Business Planning Cost	25,000 €	25,000 €	25,000 €	25,000 €	
Test Cultivation	1,000 €	1,000 €	1,000 €	1,000 €	
Sum Initial Cost	26,000 €	26,000 €	26,000 €	26,000 €	
Sum Capital Cost		3,603,600 €	3,591,600 €	3,633,600 €	3,462,600 €
Operative Cost	Plant Material	0 €	0 €	0 €	10,800 €
	Plant Protection	0 €	0 €	0 €	9,000 €
	Fertilizer	1,200 €	1,200 €	1,800 €	18,000 €
	total Labour cost	3,600 €	3,600 €	4,800 €	8,400 €
	total Machinery cost	3,600 €	3,600 €	4,800 €	8,400 €
	Logistics	600 €	600 €	1,200 €	1,800 €
	Sum Biomass	9,000 €	9,000 €	12,600 €	56,400 €
	Wind Power Maintenance	33,400 €	33,400 €	33,400 €	33,400 €
Photo Voltaics Maintenance	0 €	0 €	0 €	0 €	
Sum Non-Organics	33,400 €	33,400 €	33,400 €	33,400 €	
Sum Operative Cost		42,400 €	42,400 €	46,000 €	89,800 €
Interest Expenditure		151,674 €	151,174 €	153,071 €	147,780 €
Annual Average Cost Structure		187,324 €	186,824 €	199,071 €	237,580 €

Scenario 3

Turnover Structure per Harvest Period			Wood Plantation				Halm based Cultures			
			Poplar		Willow		Miscanthus		Maize	
Biomass Turnover	Selling Price per t produced t of Biomass		85 € 2,640	224,400 €	85 € 2,640	224,400 €	95 € 900	85,500 €	30 € 2,400	72,000 €
	Bonus per ha number of ha		0 € 60.0	0 €	0 € 60.0	0 €	0 € 60.0	0 €	0 € 60.0	0 € 0 €
	Bonus per t produced t of Biomass		0 € 2,640	0 €	0 € 2,640	0 €	0 € 900	0 €	0 € 2,400	0 € 0 €
	Sum Biomass		224,400 €		224,400 €		85,500 €		72,000 €	
Turnover non-Organics	Wind Power	Price per kWh number of kWh	0.097 € 5,700,000	552,900 €	0.097 € 5,700,000	552,900 €	0.097 € 5,700,000	552,900 €	0.097 € 5,700,000	552,900 €
	PV	Price per kWh number of kWh	0.4301 € 0	0 €	0.43 € 0	0 €	0.4301 € 0	0 €	0.4301 € 0	0 €
	Sum non-organics		552,900 €		552,900 €		552,900 €		552,900 €	
Turnover VER in CO ₂ Eq.	Price per VER		1 €		1 €		1 €		1 €	
	Biomass Cultivation		number of CO ₂ Eq.		3,003 3,003 €		3,003 3,003 €		991 991 €	
	Heat	BH&PP	number of CO ₂ Eq.		0 0 €		0 0 €		0 0 €	
		BH&PP	number of CO ₂ Eq.		0 0 €		0 0 €		0 0 €	
	Electricity	Wind Power	number of CO ₂ Eq.		1,505 1,505 €		1,505 1,505 €		1,505 1,505 €	
		PV	number of CO ₂ Eq.		0 0 €		0 0 €		0 0 €	
Sum VER		4,508 €		4,508 €		2,496 €		3,883 €		
Additional Cash Inflow	Price per sold t of Fertilizer number of t		0 € 0 €		0 € 0 €		0 € 0 €		0 € 0 €	
	Price per received t of organic matter number of t		0 € 0 €		0 € 0 €		0 € 0 €		0 € 0 €	
	Price per m ³ Constructed Wetland for Waste number of m ²		0 € 0 €		0 € 0 €		0 € 0 €		0 € 0 €	
	Price per receiving of contaminated Soil number of t		0 € 0 €		0 € 0 €		0 € 0 €		0 € 0 €	
	Price per Hunting Rental number of Hunting Rentals		0 € 0 €		0 € 0 €		0 € 0 €		0 € 0 €	
	Sum additional Cash Inflow		0 €		0 €		0 €		0 €	
Cumulative			781,808 €		781,808 €		640,896 €		628,783 €	

Scenario 3

Investment Appraisal Comparison for Biomass Cultivation				
Method	Wood Plantation		Halm based Cultures	
	Poplar	Willow	Miscanthus	Maize
NPV	2,040,725 €	2,066,494 €	-269,210 €	-795,956 €
Amortisation	12 Years	11 Years	Negative Investment	Negative Investment
IRR	9.60%	9.68%	2.85%	0.08%
Annuity	150,160 €	152,056 €	-19,809 €	-58,568 €

c) Scenario 4 Approach: Addition of Solar and Wind Energy

Scenario 4 includes the installation of 150m² photovoltaics on the building roof (see Figure 1, Table 16, and subchapter 2.1.3) and one unit of wind power

Scenario 4

Cultivation Cost Structure for 60 ha		Wood Plantation		Halm based Cultures	
		Poplar	Willow	Miscanthus	Maize
Capital Cost	Plant Material	132,000 €	120,000 €	162,000 €	0 €
	Plant Protection	9,000 €	9,000 €	9,000 €	0 €
	Fertilizer	6,000 €	6,000 €	6,000 €	0 €
	additional Invervention Cost Stage II	90,600 €	90,600 €	90,600 €	96,600 €
	Sum Biomass	237,600 €	225,600 €	267,600 €	96,600 €
	Wind Power	3,340,000 €	3,340,000 €	3,340,000 €	3,340,000 €
	Photo Voltaic	63,750 €	63,750 €	63,750 €	63,750 €
Sum Non-Organics	3,403,750 €	3,403,750 €	3,403,750 €	3,403,750 €	
	Business Planning Cost	25,000 €	25,000 €	25,000 €	25,000 €
	Test Cultivation	1,000 €	1,000 €	1,000 €	1,000 €
Sum Initial Cost	26,000 €	26,000 €	26,000 €	26,000 €	
Sum Capital Cost		3,667,350 €	3,655,350 €	3,697,350 €	3,526,350 €
Operative Cost	Plant Material	0 €	0 €	0 €	10,800 €
	Plant Protection	0 €	0 €	0 €	9,000 €
	Fertilizer	1,200 €	1,200 €	1,800 €	18,000 €
	total Labour cost	3,600 €	3,600 €	4,800 €	8,400 €
	total Machinery cost	3,600 €	3,600 €	4,800 €	8,400 €
	Logistics	600 €	600 €	1,200 €	1,800 €
	Sum Biomass	9,000 €	9,000 €	12,600 €	56,400 €
Wind Power Maintenance	33,400 €	33,400 €	33,400 €	33,400 €	
Photo Voltaics Maintenance	5,100 €	5,100 €	5,100 €	5,100 €	
Sum Non-Organics	38,500 €	38,500 €	38,500 €	38,500 €	
Sum Operative Cost		47,500 €	47,500 €	51,100 €	94,900 €
Interest Expenditure		154,538 €	154,039 €	155,936 €	150,644 €
Annual Average Cost Structure		195,288 €	194,789 €	207,036 €	245,544 €

Scenario 4

Turnover Structure per Harvest Period			Wood Plantation				Halm based Cultures			
			Poplar		Willow		Miscanthus		Maize	
Biomass Turnover	Selling Price per t produced t of Biomass		85 € 2,640	224,400 €	85 € 2,640	224,400 €	95 € 900	85,500 €	30 € 2,400	72,000 €
	Bonus per ha number of ha		0 € 60.0	0 €	0 € 60.0	0 €	0 € 60.0	0 €	0 € 60.0	0 € 0 €
	Bonus per t produced t of Biomass		0 € 2,640	0 €	0 € 2,640	0 €	0 € 900	0 €	0 € 2,400	0 € 0 €
	Sum Biomass		224,400 €		224,400 €		85,500 €		72,000 €	
Turnover non-Organics	Wind Power	Price per kWh number of kWh	0.097 € 5,700,000	552,900 €	0.097 € 5,700,000	552,900 €	0.097 € 5,700,000	552,900 €	0.097 € 5,700,000	552,900 €
	PV	Price per kWh number of kWh	0.4301 € 16,875	7,258 €	0.43 € 16,875	7,258 €	0.4301 € 16,875	7,258 €	0.4301 € 16,875	7,258 €
	Sum non-organics		560,158 €		560,158 €		560,158 €		560,158 €	
Turnover VER in CO ₂ Eq.	Price per VER		1 €		1 €		1 €		1 €	
	Biomass Cultivation		3,003	3,003 €	3,003	3,003 €	991	991 €	2,378	2,378 €
	Heat	BH&PP	0	0 €	0	0 €	0	0 €	0	0 €
		BH&PP	0	0 €	0	0 €	0	0 €	0	0 €
	Electricity	Wind Power	1,505	1,505 €	1,505	1,505 €	1,505	1,505 €	1,505	1,505 €
		PV	4	4 €	4	4 €	4	4 €	4	4 €
Sum VER		4,512 €		4,512 €		2,499 €		3,886 €		
Additional Cash Inflow	Price per sold t of Fertilizer number of t		0 €	0 €	0 €	0 €	0 €	0 €	0 €	0 €
	Price per received t of organic matter number of t		0 €	0 €	0 €	0 €	0 €	0 €	0 €	0 €
	Price per m ³ Constructed Wetland for Waste number of m ²		0 €	0 €	0 €	0 €	0 €	0 €	0 €	0 €
	Price per receiving of contaminated Soil number of t		0 €	0 €	0 €	0 €	0 €	0 €	0 €	0 €
	Price per Hunting Rental number of Hunting Rentals		0 €	0 €	0 €	0 €	0 €	0 €	0 €	0 €
	Sum additional Cash Inflow		0 €		0 €		0 €		0 €	
Cumulative			789,070 €		789,070 €		648,157 €		636,044 €	

Scenario 4

Investment Appraisal Comparison for Biomass Cultivation				
Method	Wood Plantation		Halm based Cultures	
	Poplar	Willow	Miscanthus	Maize
NPV	1,967,419 €	1,993,188 €	-374,465 €	-901,211 €
Amortisation	12 Years	12 Years	Negative Investment	Negative Investment
IRR	9.33%	9.41%	2.42%	-0.42%
Annuity	144,766 €	146,662 €	-27,554 €	-66,313 €