Project No. SN-01/20

REJUVENATE

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

Final Research Report

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Project coordinator: Paul Bardos

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Abstract

This Rejuvenate project was a desk study carried out by four organisations from the United Kingdom, Sweden the Netherlands and Germany. Its goal has been to assess 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.

Kort sammanfattning

Projektet Rejuvenate är en skrivbordsstudie genomförd av fyra organisationer från Storbritannien, Sverige, Holland och Tyskland. Projektets mål är att belysa möjligheterna med att använda marginaliserad mark för att odla biomassa. Med begreppet marginaliserad mark avses landområden som tidigare varit exploaterade, underutnyttjade eller är förorenade av diffusa föroreningar. Projektet har huvudsakligen varit inriktat mot utnyttjandet av tidigare industrimark eller annan förorenad mark. Biomassan kan användas för energi, bränsleproduktion eller som råmaterial. Sådan användning av marginaliserad mark kan ge fördelar med avseende på hållbar utveckling i regioner där det finns betydelsefulla arealer av mark som inte, på ett för regionen tillfredställande sätt, kan användas för byggnadsutveckling. Dessutom kan kompost och annat återanvänt organiskt material spela en viktig roll som jordförbättringsmaterial vid odling av biobränsle och andra grödor som inte är avsedda som föda.

Abstrakt

Die Rejuvenate Studie wurde gemeinsam von Partnern aus England, Schweden, den Niederlanden und Deutschland auf der Basis von vorhandenen Datenmaterials durchgeführt. Das Ziel von Rejuvenate war die Bewertung von kontaminierten Brachflächen, mit Blick auf ihr Nutzungspotential zur Biomasseproduktion für eine energetische oder industrielle Nutzung. Eine derartige Nutzung von Brachflächen kann in Regionen mit hohem Anteil an minderwertigen Brachflächen nachhaltige Vorteile bieten. Zusätzlich können Kompost und andere organische Reststoffe eine wichtige Rolle bei der Bodenverbesserung und .dem Bodenmanagement im Rahmen von Anbaukonzepten bieten.

Executive Summary

The increasing importance of biomass for energy production and feedstocks for manufacturing processes (such as for plastics and biofuels) has become a worldwide phenomenon. Establishment of non-food crops for biomass 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. 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. 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. This land includes areas affected by mining, fallout from industrial processes such as smelting, activities related to forestry and the pulp and paper industry, areas elevated with contaminated dredged sediments, former landfill sites and many other areas where the decline of industrial activity has left a legacy of marginal land and economically disadvantaged communities. The extent of contamination may not be sufficient to trigger remediation under current regulatory conditions, and there may be little economic incentive to regenerate the areas affected. While the scale of this land bank can be seen as small compared to published estimates of likely areas needed for biomass crops, for example to meet the European Union (EU) Transport Fuel Directive, it can nonetheless be very significant in some regions and localities. Connecting the re-use of such land to biomass, biofuel and biofeedstock opportunities may be an important step in bringing this marginal land back into beneficial and sustainable use and removing its environmental, social and economic impacts on affected communities.

This project was a desk study carried out by four organisations from the United Kingdom (UK), Sweden the Netherlands and Germany. Its goal was to assess the potential opportunity for using marginal 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 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.

Hence the combination of biomass cultivation and soil rehabilitation could be an integral part of land rehabilitation and risk management in the long term. There may also be further benefits from this kind of land use, for example, providing: a self-funding land management regime, economic activity to deprived areas, a long term improvement in land values and environmental benefits such as carbon sequestration (substitution of fossil carbon resources, and “temporary” sequestration in managed soils).

The aims of this project were to:

1. Explore the feasibility of a range of possible approaches to combining risk based land management (RBLM) with non-food crop land-uses and organic matter re-use as appropriate,

2. Identify a range of potential opportunities worthy of further development in the UK, Germany and Sweden and in a wider European context, and

3. Assess how verification of their performance might be carried out and identifying what requirements remain for future research, development and demonstration.

Regulations governing restoration of marginal lands using organic waste materials vary from country to country, but two considerations will be important: the quality of the biomass produced, and the effective management of risks to human health and the wider environment. The transfer of potential contaminants from the marginal land (or secondary organic matter inputs) to biomass needs to be limited to levels tolerable by downstream biomass use (for energy, fuel or manufacturing feedstock). This consideration is important both from the standpoint of achieving a competitive product quality, and to avoid triggering a precautionary view that downstream processing of the feedstock generated needs special pollution control measures.

Potential Rrisks to human health and the wider environment from the marginal land and secondary organic matter inputs must be managed to local regulatory requirements or better. These potential risks might include for example toxic substance transfer to biomass, risks to human health of toxic substances by direct contact with contaminated surfaces or via dust blow; and risks to surface waters from run-off or groundwater from leaching. Risk management needs will be highly site and material specific. The key to managing risks

is that linkages between source, pathway and receptor, which pose significant risks, are broken and remain broken. It is also likely that pragmatic risk management strategies will be adopted that will protect the feedstock and the environmental risks from the site, but not necessarily lead to removal of toxic substances (except perhaps for those which are biodegradable). Pragmatism will be driven by finding the approach that is most likely to win regulatory acceptance, and is most economically feasible, both of which are vital to securing a beneficial re-use of the marginal land.

Four broad stages can be used to refine choices for bio-renewables on marginal land.

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, and its 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.

This report has been organised as a guidance document to support a wide range of potential users. The document is organised broadly in two halves. Its first five chapters outline the opportunity for growing renewables on marginal land across Europe, in particular the UK, Sweden and Germany. The second half provides guidance which is an underpinning framework for decision-making about:

- the use of marginal land for non-food crops for renewables, and
- the use of recycled organic matter in this process for soil improvement, and as supplementary biomass.

A worked example is provided in an accompanying report: *REJUVENATE Crop Based Systems for Sustainable Risk Based Land Management for Economically Marginal Degraded Areas – A Worked Example*.

There are significant amounts of marginal land which are not in beneficial use, including brownfields sites which are seen as “hard to develop”, often for economic reasons. There are significant amounts of waste-derived organic matter which could be used for restoration, soil improvement and as a fertiliser substitute. There is an increasing demand for land for biomass (for energy, fuel and feedstock) and an increasing interest in carbon management opportunities. The conjunction of these needs and interests create a new opportunity for sustainable development: use of marginal land for biomass production, which may also bring a wider range of benefits, and also provide leverage to support the re-use of “hard to develop” sites. The conjunction of several drivers (land restoration, organic matter re-use and biomass energy) as well as its wider sustainability benefits may make this land very attractive for “pioneering” biomass projects.

Biomass on marginal land projects may be important in localities and regions with a history of long term land dereliction. Quality will be a determining factor from regulatory and market perspectives. Consequently the uptake of contaminants into biomass should be limited.

The decision-making framework (or *decision support tool*) developed by Rejuvenate is serviceable in Germany, Sweden and the UK. These countries have substantive differences in their land and biomass re-use contexts. However, all can make 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 EU.

The potential opportunities for biomass on marginal land in tandem with organic waste recycling may be more easily identified using a Geographical Information System (GIS) system that pools crop suitability, biomass market, and bank and organic matter resource information.

Biomass on marginal land projects cut across a range of market and regulatory sectors. It may be useful to facilitate a cross-sectoral network to facilitate the dissemination of new projects.

It would be interesting to know, in a strategic sense, what the carbon impact and soil fertility benefits might be of improving soil organic matter content in marginal land areas, where soil quality is often low.

At a European level (and indeed within national jurisdictions) the findings of Rejuvenate indicate that there are data gaps which a range of demonstration projects of biomass re-use of marginal land could help to fill, to take into account different regional, economic and technological aspects, and to robustly test the decision making framework presented in this report.

Sammanfattning (Executive Summary – Swedish)

Den allt viktigare produktionen av energi från biomassa och råvaror för tillverkningsprocesser (såsom plast och biobränsle) har blivit ett fenomen världen över. Odling och etablering av grödor som inte är avsedda som föda utan som biomassa för energi och bränsleproduktion kan bidra till att politiska mål relaterade till förnyelsebar energi och hantering av kol kan uppnås. Användningen av större arealer för att producera biomassa för råvaror, bränsle och energi har dock blivit allt mer omtvistad och alltfler frågor kring miljö, ekonomiska och sociala aspekter har väckts. Marginaliserad mark kan vara ett möjligt bidrag för att minska belastningen på värdefull mark. Begreppet marginaliserad mark omfattar tidigare exploaterad mark, underutnyttjad mark samt mark som är förorenad av diffusa föroreningar. Över hela Europa finns det landområden som har försämrats genom tidigare användning och där det inte är möjligt att återställa marken på ett enkelt och hållbart sätt genom konventionella metoder. Dessa landområden inkluderar områden som påverkats av gruvdrift, nedfall från industriella processer (såsom t.ex. smältning), aktiviteter relaterade till skogsbruk samt massa- och pappersindustri, områden med förorenade sediment och före detta deponiområden och många andra områden där avveckling av industriell eller annan tidigare verksamhet har lämnat ett arv av marginaliserad mark och ekonomiskt missgynnade grupper. Föroreningens utbredning och mängd är kanske inte tillräcklig för att få igång en sanering och de ekonomiska incitamenten för att återskapa de påverkade områdena kan vara små. Även om omfattningen av denna mark kan ses som liten jämfört med offentliga beräkningar av sannolika markbehov för odling av biobränsle och annan biomassa, till exempel för att möta Europeiska unionens transport bränsledirektiv, kan dessa markområden ändå vara mycket betydelsefulla i vissa regioner och orter. Att använda marginaliserad mark för odling av biomassa, biobränsle och råvaror kan vara ett viktigt steg för att få marken brukbar (eller på annat sätt gynnsam) och hållbar igen. Det kan också vara ett steg för att minska nuvarande negativa miljö-, sociala och ekonomiska effekter på berörda grupper.

Projektet *Rejuvenate* är en skrivbordsstudie genomförd av fyra organisationer från Storbritannien, Sverige, Holland och Tyskland. Projektets mål är att undersöka och beskriva möjligheter att använda marginaliserad mark (i huvudsak tidigare industrimark eller annan tidigare exploaterad eller kontaminerad mark) för att producera biomassa. Denna biomassa kan användas för energi, bränsleproduktion eller som råmaterial. Användningen av marginaliserad mark kan ge hållbarhetsfördelar[1] i regioner där det finns betydelsefulla arealer av mark som inte, på ett för regionen tillfredställande sätt, kan användas för byggnadsutveckling.

Odling av biomassa kan utgöra en del av markförbättringen och riskhanteringen på lång sikt. Det kan även finnas fler fördelar genom en sådan markanvändning, t.ex. genom att bidra till ekonomisk aktivitet i annars försummade områden, långsiktig förbättring av markvärdet och miljömässiga fördelar såsom bidra till minskad utsläpp av växthusgaser (ersättning av fossila bränslen samt temporär kollagring i marken).

Projektets mål är att:

1. Utforska möjligheterna med en rad tänkbara och lämpliga strategier för att kombinera riskbaserad markhantering (Risk based land management, RBLM) med produktion av biobränsle och andra grödor som ej är avsedda som föda, samt återanvändning av organiskt material.
2. Identifiera möjliga strategier värda att vidareutvecklas i Storbritannien, Tyskland och Sverige samt i ett bredare europeiskt sammanhang, samt
3. Göra en bedömning av hur man skall kunna verifiera strategiernas lämplighet samt identifiera demonstrationsbehov och behov av forskning och utveckling.

Lagstiftning och regelverk som styr sanering och återställandet av marginaliserad mark, samt hur bioprodukter och organiskt avfallsmaterial kan används, varierar från land till land. Två faktorer har dock generellt sett identifierats som viktiga: 1) kvaliteten på den producerade biomassan samt 2) miljö- och hälsorisker. Transport och överföring av potentiellt främmande ämnen från den marginaliserade marken (eller via tillförseln av kompost eller annat sekundärt organiskt material) till biomassan måste vara begränsad till acceptabla nivåer för de som skall nyttja biomassan (till energi, bränsle eller tillverkning av råvaror). Detta är viktigt för att uppnå en konkurrenskraftig produktkvalitet men även för hantering av eventuella restprodukter.

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[1] Med hållbarhet avses ekonomiska, sociala och miljömässiga aspekter. Ekonomiska och sociala aspekter beaktas framförallt i ett lokalt och regionalt perspektiv, medan miljö även innefattar mer övergripande aspekter som till exempel kolbalans och växthuseffekt.

Kraven för tillsyn och kontroll av miljö- och hälsorisker som kan uppstå i samband med odling av biomassa på marginaliserad mark ska regleras enligt lokala regelverk eller enligt strängare krav. Exempel på risker som kan uppstå är överföring av giftiga substanser till biomassan, direktkontakt med kontaminerade ytor eller via damm, eller att yt- och grundvatten förorenas genom avrinning och urlakning. Riskerna, liksom hur de bör hanteras, är och måste vara plats-, material- och produktspecifikt. Nyckeln till att hantera risker är att länkarna mellan källa, spridningsväg och mottagare, som medför betydande risker, bryts och förblir brutna. En möjlig och pragmatisk strategi för riskhantering som skyddar råvarorna och reducerar miljö- och hälsoriskerna kan vara att inte nödvändigtvis extrahera bort giftiga substanser utan att till exempel göra dem mindre mobila. Denna typ av lösning kommer sannolikt att utvecklas genom att hitta den strategi som troligast kommer att vinna rättsligt godkännande och som är mest ekonomiskt fördelaktig. Båda dessa aspekter är nödvändiga för att säkra en gynnsam återanvändning av marginaliserade mark.

Rejuvenate har identifierat fyra steg som kan användas för att förfina valen inför odling av biomassa på marginaliserad mark.

1. Grödans lämplighet: Främst beaktas av en rad möjliga grödor lämpliga för området och dess marknad. Detta inkluderar en bedömning av marknad samt klimat och platstopografi. Detta steg ger en kort lista med lämpliga grödor. I respektive steg nedan vaskas en allt mer förfinad lösning fram och varje steg kommer sannolikt att medföra att listan kortas ned.

2. Platsens lämplighet: Beaktanden angående om platsens förhållanden är lämpliga för grödorna från listan ovan och vilka miljörisker det finns med grödans produktion; en plats kan passa vissa grödor eller den kan göras lämplig genom jord/riskhantering. Om det övervägs att ha en konverteringsanläggning (anläggning för biomassa till produkt) direkt på plats måste lämpligheten för anläggningen samt nödvändiga ingripanden beaktas (till exempel infrastruktur). Dessutom måste risker som kan uppstå genom annan påverkan på platsen bli ordentligt beaktade (som t.ex. byggnationer och annan markhantering).

3. Värde: Det finns en direkt kostnad-nytta ekvation som berör de fördelar som kommer av att utnyttja en mark för biomassa i relation till de investeringar som behövs. Det ingår i denna kostnad-nyttta ekvation också ett större hållbarhetsbeaktande, till exempel inverkan på biodiversitet, ökat kolupptag eller förbättringar för samhället. Det kan också vara lämpligt att inkludera andra åtgärder för att öka projektets övergripande värde, till exempel att samordna andra former av förnyelsebar energiproduktion med platsens återanvändning, eller kombinera användningen av biomassa med återanvändningen av jordbruks-, skogs- eller andra restprodukter.

4. Projektets risker: När ett företags projektplan har utarbetats och dess värde är attraktivt för dess utvecklare, måste projektets planering säkerställa dess lönsamhet så långt som möjligt innan några stora investeringar görs. I huvudsak är tre beaktanden viktiga: teknikstatus, detaljerad säkrad finansiering (t.ex. av finansiärer och projektpartners) samt att utveckla ett samförstånd mellan intressenterna.

Denna rapport har skrivits som en slags vägledning för en rad olika användare. Dokumentet är i stort uppdelat i två delar. De första fem kapitlen behandlar möjligheterna att odla grödor avsedda för produktion av förnyelsebar energi eller andra produkter som inte avses användas som föda på marginaliserad mark över hela Europa, men med särskilt fokus på Storbritannien, Sverige och Tyskland. Den andra halvan ger vägledning i form av ett ramverk som ligger till grund för beslutsfattande om:

- användningen av marginaliserad mark för biobränsle och andra grödor (som inte är avsedda som föda), samt
- användningen av kompost och annat återanvänt organiskt material som jordförbättring

Ett exempel på hur ramverket kan användas ges i rapporten: *Rejuvenate Crop Based Systems for Sustainable Risk based Land Management for Economically Marginal Degraded Areas – A Worked Example*[2].

I Europa finns det idag många områden med marginaliserad mark (inklusive före detta industrimark) som inte används på ett gynnsamt sätt. Dessa områden ses ofta som "svåra att utveckla" på grund av ekonomiska aspekter. Därtill finns det stora mängder organiskt avfall vilket kan användas som jordförbättring och som gödningsersättning. Det finns ett ökande behov av landareal för produktion av biomassa (för energi, bränsle, och råvaror) och ett ökande intresse för möjligheterna att hantera kol i naturen (mark och luft). En sammanvägning av dessa behov och intressen skapar en ny möjlighet för hållbar utveckling: användning av marginaliserad mark för produktion av biomassa, temporärt kolupptag till marken från luften etc, som även kan föra med sig en rad fördelar och medverka till och stödja återanvändning av områden som idag är "svåra att utveckla".

Projekt med biomassa på marginaliserad mark kan bli betydelsefullt i orter och regioner med en historia av långvarigt förfall av landområden. Kvalitet kommer att bli en avgörande faktor ur lagstiftnings- och marknadsperspektiv. Följaktligen måste upptaget av föroreningar till biomassan vara begränsat.

Ramverket för beslutsfattande (eller beslutstödsverktyget) som utvecklats av Rejuvenate är användbart i Tyskland, Sverige och Storbritannien. Dessa länder uppvisar betydande skillnader vad gäller återanvändning av mark och biomassa. Likväl kan alla få användning av de gemensamma principer om gröda, område, värde och projektriskhantering som fastställts av Rejuvenate. Detta innebär att ramverket har förutsättningar för att tillämpas i ett bredare avseende så som inom EU och över hela Europa.

Möjligheterna för produktion av biomassa på marginaliserad mark, parallellt med återvinning av organiskt avfall, kan lättare bli identifierade om ett Geografiskt Informations System (GIS) används. I ett sådant system kan man illustrera och göra en sammanvägning av grödans lämplighet, marknad och tillgång liksom information om tillgänglighet av organiskt material.

Projekt med biomassa på marginaliserade landområden spänner över en rad marknads- och rättsligt reglerade områden och sektorer. Det kan således vara värdefullt att understödja ett sektorsövergripande nätverk för att underlätta kunskaps- och informationsspridningen av nya projekt.

Ur ett strategiskt perspektiv skulle det även vara intressant att öka kunskapen kring kollagringseffekten samt förstå vilka produktionsfördelar (t.ex. ökad bördighet) som kan uppnås genom att öka innehållet av organiska material i marken i marginaliserade områden där jordkvaliteten ofta är dålig.

På europeisk nivå (och även inom nationell jurisdiktion) indikerar resultaten från Rejuvenate att det finns kunskaps- och informationsluckor som en rad demonstrationsprojekt, bland annat med återanvändning av biomassa från marginaliserade områden, kan bidra till att fylla. Demonstrationsprojekt skulle också kunna användas för att beakta, tydliggöra och ytterligare förstå olika regionala, ekonomiska och tekniska aspekter, samt för att robusttesta, och vid behov utveckla, det ramverk för beslutsfattande som presenteras i föreliggande rapport.

[2] Rejuvenates system för grödobaserad hållbar och riskkontrollerad markhantering av ekonomiskt marginaliserade områden – Ett utarbetat exempel.

Zusammenfassung (Executive Summary – German)

Die Bedeutung von Biomasse zur Produktion von Energie und zur stofflichen Nutzung steigt weltweit. Die industrielle Nutzung von Biomasse kann politische Ziele mit Blick auf erneuerbare Energien und CO_2 Management unterstützen. Allerdings bestehen durch die stetig zunehmende Landnutzung auch ökologische, ökonomische und gesellschaftliche Bedenken. Die Nutzung kontaminierter oder vormals industriell genutzter Brachflächen ist ein neuer Aspekt in der Biomassediskussion. In ganz Europa existieren Brachfläche dieser Art, welche mit konventionellen Methoden nicht in den Nutzungskreislauf zurückgeführt werden können, dazu können Bergbaufolgelandschaften, Schwerindustriestandorte, Gebiete mit kontaminierten Sedimenten und andere Bereiche in Folge zurückgehender industrieller Aktivität zählen. Strukturschwache Regionen sind oftmals eine Begleiterscheinung dieser Flächen. Während der Anteil solcher Brachflächen, im Vergleich zum Biomassebedarf für die energetische Nutzung, insgesamt eher gering ist, kann er regional oder lokal durchaus von Bedeutung sein. Die Wiedernutzung solcher Standorte für die energetische und industrielle Biomasseproduktion kann somit ein wichtiger Schritt sein, um diese Brachflächen in den Nutzungskreislauf zurückzuführen und dadurch die ökologischen, sozialen und ökonomischen Rahmenbedingungen einer Region zu verbessern.

Die Rejuvenate Studie wurde von Partnern aus England, Schweden, den Niederlanden und Deutschland anhand vorhandenen Datenmaterials durchgeführt. Das Ziel von Rejuvenate war die Bewertung von kontaminierten Brachflächen bezüglich ihres Nutzungspotentials für die Biomasseproduktion zur energetischen oder industriellen Verwertung. Eine derartige Nutzung von Brachflächen kann in Regionen mit hohem Anteil an minderwertigen Brachflächen nachhaltige Vorteile bieten. In diesem Zusammenhang können Kompost und andere organische Reststoffe eine wichtige Rolle bei der Bodenverbesserung und dem Bodenmanagement im Rahmen von Anbaukonzepten spielen.

Langfristig kann die Kombination von Biomasseproduktion und Nachnutzung von Brachflächen ein integraler Bestandteil von Land- und Risikomanagement sein. Aus diesem Ansatz können sich weitere Vorteile ergeben, z.B.: ein selbsttragendes Landmanagementkonzept, ökonomische Aktivitäten in strukturschwachen Regionen, langfristige Steigerung des Landwertes oder ökologische Vorteile wie CO_2 Sequestrierung (Ersatz fossiler Brennstoffe, temporäre Sequestrierung in Böden).

Die Ziele des Projekts waren:

1. Untersuchung der Eignung verschiedener Ansätze zur Kombination von risikobasiertem Landmanagement, der Biomasseerzeugung und Möglichkeiten des Recyclings organsicher Reststoffe.

2. Identifizierung potentieller Entwicklungsmöglichkeiten in Großbritannien, Schweden und Deutschland sowie im weiteren europäischen Kontext.

3. Erarbeitung von Bewertungsansätzen für die Überprüfung von Nutzungskonzepten und Identifizierung von künftigem Forschungsbedarf.

Die gesetzliche Regelungen zum Aufbringen von organischen Reststoffen auf Brachflächen variieren in Europa, zwei Aspekte sind jedoch allgemein von Bedeutung, die Qualität der produzierten Biomasse und der Umgang mit ökologischen und Gesundheitsrisiken. Der Transfer von potentiellen Schadstoffen aus dem Boden (oder aus organischen Reststoffen) in die produzierte Biomasse muss entsprechend der geplanten Nutzung limitiert sein. Dieser Gesichtspunkt ist mit Blick auf eine konkurrenzfähige Produktqualität und Nutzungseinschränkungen durch Grenzwertüberschreitungen wichtig.

Um gesundheitliche und ökologische Risiken zu vermeiden müssen gesetzliche Anforderungen in allen Fällen eingehalten werden. Potentielle Risiken können sein: Der Transfer toxischer Stoffe in die Biomasse, gesundheitliche Risiken durch den direkten Kontakt (dermal) mit toxischen Stoffen im Boden oder durch Staub und Risiken Oberflächengewässer durch oberflächlichen Ablauf oder für Grundwasser durch Versickerung. Das daraus resultierende Risikomanagement muss standort- und materialspezifisch sein. Der Schlüssel zum Umgang mit solchen Risiken ist die langfristige Unterbrechung der Verbindungen zwischen Quelle, Pfad und Rezeptor. In der Anwendung werden sich pragmatische Risikomanagement Konzepte durchsetzen, die eine Biomasseproduktion erlauben, aber nicht notwendigerweise zu einer Entfernung von Schadstoffen aus dem Boden führen. In der Praxis gilt es Ansätze zu finden welche eine effiziente Nutzung der Brachflächen mit der Einhaltung regulatorischer Rahmenbedingungen vereinen.

Die Auswahl nachwachsender Rohstoffe für Brachflächen lässt sich in vier Schritten darstellen:

1. Eignung des Pflanzenmaterials: Welche Pflanzen gedeihen in einer Region und können potentielle lokale Märkte bedienen? Schritt eins schließt eine Bewertung der klimatischen und topographischen Begebenheiten ein. Im Ergebnis entsteht eine verkürzte Auswahlliste geeigneter Pflanzen, welche in den folgenden Schritten weiter konkretisiert wird.

2. Eignung des Standortes: Betrachtet für welche Pflanzen der Auswahlliste die Standortbedingungen geeignet sind und welche ökologischen Risiken beim Anbau entstehen könnten. Die Liste geeigneter Pflanzen kann durch Boden- und Risikomanagement Maßnahmen erweitert werden. Sollte eine on-site Verwertung der Biomasse geplant sein, muss dies in die Bewertung des Standortes (z.B. Flächen, Infrastruktur) eingehen. Des Weiteren müssen Auswirkungen aus der künftigen Standortnutzung auf das Risiko- und Bodenmanagement und die Standortentwicklung berücksichtigt werden.

3. Wertgebung: Es besteht eine direkte Aufwand – Nutzen Beziehung zwischen den Erträgen aus der Biomasseproduktion und den notwendigen Investitionen, aber auch ein Bezug zur Nachhaltigkeit, wie z.B. steigende Biodiversität, CO_2 Sequestrierung und Stärkung von Regionen. Unter Umständen kann es sinnvoll sein, ergänzende Maßnahmen zur Steigerung der Wertschöpfung des Projektes zu nutzen, z.B. erneuerbare Energien (Wind, Solar) oder die Verwertung organischer Reststoffe bei der Bodenverbesserung.

4. Projektrisiko: Sobald ein tragfähiges Projektkonzept erarbeitet ist muss dessen Machbarkeit überprüft werden bevor Investitionen getätigt werden. Drei Bereiche sind dabei von Bedeutung: Die technische Machbarkeit, die finanzielle Tragfähigkeit und die Kooperation aller Betroffenen und Beteiligten.

Dieser Bericht stellt eine Arbeitshilfe für eine breite Anzahl potentieller Nutzer dar. Das Dokument gliedert sich in zwei Teile. Die ersten fünf Kapitel befassen sich mit den Möglichkeiten des Anbaus nachwachsender Rohstoffe auf Brachflächen in Europa, besonders in Großbritannien, Schweden und Deutschland. Die zweite Hälfte bietet eine Entscheidungshilfe bei:

- der Nutzung von Brachflächen für den Anbau von non-food Biomasse und
- der Nutzung von organischen Reststoffen im Rahmen von Bodenverbesserungsmaßnahmen und als ergänzende Biomasse.

Ein Fallbeispiel ist dem Bericht beigefügt: *REJUVENATE Crop Based Systems for Sustainable Risk Based Land Management for Economically Marginal Degraded Areas – A Worked Example*.

Es existiert eine Vielzahl an Brachflächen, die oft nicht gewinnbringend genutzt werden. Hierzu zählen auch Industriebrachen, die, oft aus wirtschaftlichen Gründen, als “schwer erschließbar” eingestuft werden. Es gibt bedeutende Mengen von Biomasse aus Abfall, die für die Sanierung, zur Bodenverbesserung und als Düngerersatz eingesetzt werden können, weiterhin besteht ein zunehmender Bedarf an Land zum Anbau von Biomasse (zur energetischen und industriellen Nutzung) und ein wachsendes Interesse an Möglichkeiten zur CO_2 Limitierung. Die Verknüpfung beider Elemente schafft neue Möglichkeiten für eine nachhaltige Entwicklung: den Einsatz von Brachland für die Produktion von Biomasse, woraus sich umfassendere ökologische Vorteile ergeben können und ebenso finanzielle Möglichkeiten entstehen können, welche die Rückführung von “schwer erschließbaren” Flächen in den Nutzungskreislauf ermöglicht. Die Zusammenführung verschiedener Einflussfaktoren (wie z.B. die Flächensanierung, die Nutzung organsicher Reststoffe und die Energiegewinnung aus Biomasse) und die umfassenderen Vorteile bezüglich der Nachhaltigkeit machen diese Flächen sehr attraktiv für Pilotprojekte im Bereich “Biomasse”.

Besonders in Gegenden und Regionen, in denen schon seit langem erschlossene Flächen zunehmend ungenutzt bleiben und verfallen, können Projekte zum Biomasseanbau auf Brachflächen von großer Bedeutung sein. Die Qualität der erzeugten Biomasse wird der entscheidende Faktor aus regulativer und wirtschaftlicher Sicht sein. Daher ist es besonders wichtig, den Übergang der Bodenschadstoffe in die Biomasse zu begrenzen.

Das in Rejuvenate entwickelte Entscheidungsschema fokussiert primär auf Großbritannien, Schweden und Deutschland. Diese drei Länder weisen substantielle Unterschiede in Ihren Brachflächen und Biomasse Nutzungskonzepten auf. Trotz dieser Unterschiede ist das in Rejuvenate entwickelte Schema Pflanze –

Standort - Wert – Risikomanagement umsetzbar. Dies zeigt die Anwendbarkeit des Konzeptes in ganz Europa.

Die potentiellen Möglichkeiten und Chancen für Biomasseerzeugung auf Brachflächen, in Kombination mit der Wiederverwendung von organischem Reststoffen, lässt sich durch die Überlagerung der relevanten Nutzungs- und Bedarfsverteilungen mit GIS Systemen optimieren.

Projekte zum Biomasseanbau auf Brachflächen berühren unterschiedliche wirtschaftliche und regulatorische Bereiche. Ein bereichsübergreifendes Netzwerk ist daher für die Implementierung neuer Projekte von Vorteil.

Aus strategischer Sicht wäre es interessant zu wissen, welche Auswirkungen die Anreicherung von organsicher Substanz bei ertragsarmen Brachflächen auf die CO_2 Bilanz und die Bodenfruchtbarkeit hat.

Auf europäischem Niveau (und im nationalen Bereich) hat Rejuvenate Informationslücken aufgezeigt, welche über Demonstrationsprojekte zur Produktion von Biomasse auf (industriellen) Brachflächen geschlossen werden können. Dabei gilt es unterschiedliche regionale, ökonomische und technologische Aspekte zu berücksichtigen sowie die Flexibilität der vorgestellten Entscheidungshilfe zu testen.

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Contents

List of Abbreviations

AFOR	Association for Organics Recycling
BMW	Biodegradable Municipal Waste
Ca	Calcium
CaO	Calcium Oxide
CHP	Combined Heat and Power
CLARINET	Contaminated Land Rehabilitation Network for Environmental Technologies in Europe
CLO	Compost Like Output
CO_2	Carbon Dioxide
DCLG	Department for Communities and Local Government
Defra	Department for Environment Food and Rural Affairs
DF	Discounting Factor
DST	Decision Support Tool
DUN	Derelict, Underused and Neglected
EC	European Commission
EDTA	Ethylene-Diamine-Tetra-acetic Acid
EEA	European Environment Agency
ERA-Net	European Research Area Network
EU	European Union
FAO	Food and Agriculture Organisation (of United Nations)
GHG	Greenhouse gas(es)
GIS	Geographical Information System
ha	Hectare
IRR	Internal Rate of Return
K	Potassium
K_2O	Potassium Oxide
LCA	Life Cycle Assessment
MBT	Mechanical Biological Treatment
Mg	Magnesium
MIFO	Metodik för Inventering av Förorenade Områden
	(Methodology for the inventory work concerning contaminated areas in Sweden)
MNA	Monitored Natural Attenuation
MSW	Municipal Solid Waste

N	Nitrogen
N_2O	Nitrous Oxide
NGO	Non-governmental Organisation
NICOLE	Network for Industrially Contaminated Land in Europe
NIEA	Northern Ireland Environment Agency
NLUD	National Land-Use Database (England)
NPV	Net Present Value
NVZ	Nitrate Vulnerable Zone
OECD	Organisation for Economic Cooperation and Development
OM	Organic Matter
P	Phosphorus
P_2O_5	Phosphorus Pentoxide
PA	Per Annum (per year)
PAH	Polynuclear Aromatic Hydrocarbon
PDL	Previously Developed Land
POP	Persistent Organic Pollutant
PTE	Potentially Toxic Element
R&D	Research and Development
RBLM	Risk Based Land Management
S	Sulphur
SA	Sustainability Appraisal
SCM	Site Conceptual Model
SDS	Sustainable Development Strategy
SDVLS	Scottish Derelict and Vacant Land Survey
SEPA	Scottish Environmental Protection Agency
SEPA	Swedish Environmental Protection Agency
SGI	Swedish Geotechnical Institute
SGV	Soil Guideline Values
SME	Small or Medium Sized Enterprise
SNOWMAN	Sustainable Management of Soil and Groundwater Under the Pressure of Soil Pollution and Soil Contamination
SPZ	Source Protection Zone
SRC	Short Rotation Coppice
SURF-UK	Sustainable Remediation Forum - UK

t / te	Tonne (Metric)
UK	United Kingdom
UN	United Nations
VER	Voluntary Emission Rights
WFD	Water Framework Directive
WRAP	The Waste and Resources Action Programme (UK)

Glossary

This glossary is not intended to be a set of formal definitions, nor to supplant terms defined by any standards organisation. Rather it is intended to convey the meaning of terms as they have been used in this report.

Term	Contemporary Usage
Bio-compost	Synonym for compost like output, more acceptable to some stakeholders.
Biodegradable municipal waste	The fraction of municipal waste which will degrade within a landfill, giving rise to methane emissions.
Bioenergy	Energy derived from biomass.
Biofuel	Fuel produced directly or indirectly from biomass, such as fuelwood, charcoal, bioethanol, biodiesel, biogas (methane) or biohydrogen [colloquially biofuel tends to be restricted as a term to liquid fuels].
Biomass	Non-fossil material of biological origin such as energy crops, agriculture and forestry waste, and by-products, manure or microbial biomass.
Brownfield land	Brownfield land has been defined at a European level as referring to sites which have been affected by former uses of the site or surrounding land, are derelict or underused, are mainly in fully or partly developed urban areas, require intervention to bring them back to beneficial use, and may have real or perceived contamination problems.
Carbon balance / footprint	A carbon footprint is a measure of the impact human activities have on the environment in terms of the amount of GHG produced, measured in units of carbon dioxide. A carbon balance is calculations of tonnes of carbon in the various inputs and outputs of a system. Related concepts are water or waste footprints.
Compost like output	Compost or digestate produced from materials extracted from mixed wastes as opposed to separately collected wastes (may also be referred to as "bio-composts" or "grey composts").
Contaminant	A substance which is in, on or under the land and has the potential to cause harm (or to cause pollution of controlled waters).
Contaminated land (UK)	Land that has been designated as "contaminated" by regulatory authorities because of unacceptable risks to human health, water or other receptors
Cost benefit analysis	A form of economic analysis in which costs and benefits are converted into monetary values for comparison
Cradle to grave	'Cradle-to-grave' assessment considers stage of a product's life-cycle, from the time natural resources are taken from the environment, through each subsequent stage of manufacturing, transportation, product use, and ultimately, disposal. [In cradle to cradle production all material inputs and outputs are seen as technical or biological nutrients. Technical nutrients can be recycled or reused with no loss of quality and biological nutrients composted or consumed. Cradle to grave refers to a company taking responsibility for the disposal of goods it has produced, but not necessarily putting products' constituent components back into service.
Decision making role	The decision making role describes the type of decision making being supported, e.g. for managing a single site, or for prioritising a number of sites. This deals with the overarching decision being made at the site.
Decision support	Assistance for, substantiation and corroboration of, an act or result of deciding; typically this deciding will be a determination of an optimal or best approach.
Decision support system	A Decision Support System is the complete decision making approach, including all of its components.
Decision support tool	A Decision Support Tool supports one or more components of decision making.

Term	Contemporary Usage
	(Note some writers use “tool" and "system" interchangeably.)
Duty of care	A duty to ensure that any waste you produce is handled safely and within the law.
Evaluating wider impacts	Assessment systems for the key elements of sustainability appraisal (economic, environmental, resource and social evaluations).
Fit for purpose	That the material, process or land management action is appropriate, and of a necessary standard, for its intended use.
Flow charts	A diagrammatic representation of a procedure or protocol or series of procedures / protocols.
Functional unit	The function or service that a system provides – for use as a reference point to make comparisons of environmental impacts. An appropriate functional unit for composting processes is the treatment of a specified amount of compostable organics (e.g. 1 tonne of collected wastes per year).
Grey compost	Synonym for compost like output, more acceptable to some stakeholders.
Headline indicator	Some indicators may be selected as headline indicators – usually because they describe key issues. They are often supported by a subset of indicators. Usually they form a quick guide or overview and can be used to engage public awareness and focus attention. For instance, the UK sustainable development project has 15 headline indicators which are used to make up a quality-of-life barometer. In this case the “headline” indicator can perhaps be seen as “an indicator of indicators”. Aggregated or composite indicators may also be used as headline indicators to provide an overarching view of several individual indicators.
Indicator	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 is some way that is sufficient to allow this evaluation.
Life cycle	The life cycle of a product encompasses its manufacture, its use and its disposal / fate.
Life cycle assessment	Life cycle assessment is a tool to evaluate the environmental consequences of products or services from cradle-to-grave, and their use.
Life cycle inventory	Modified data used to determine the total environmental impact associated with processes in a system. Derived from a number of sources, including research data, consultation and experimentation. Mathematical transformations are usually required to adapt data for use in the context of an life cycle assessment and to adhere to the goals and scope of a study.
Map	A figurative illustration of decision processes, the route taken for a decision.
Marginal land	Land that has been previously used in an industrial or urban context, or agricultural and other land that has been damaged by pollution, which is perceived to be unsuitable for the production of food or for urban or industrial re-use.
Master-planning	Refer to Box 6.1 for definition and explanation.
Mechanical biological treatment	A form of waste processing facility that combines a mechanical sorting facility with biological treatment such as composting or anaerobic digestion.
Monitoring	Observation of conditions.
Multi criteria analysis	A structured system for ranking alternatives and making selections and decisions.
Municipal solid waste	Waste collected by or on behalf of a local authority. It comprises mostly household waste and it may include some commercial and industrial wastes.
Municipal waste	Waste from households, as well as waste which, because of its nature or composition, is similar to waste from households.
Pathway	A means by which a receptor can be exposed to, or affected by, a contaminant.

Term	**Contemporary Usage**
Phytoremediation	Direct use of living green plants for *in situ* risk reduction for contaminated soil, sludges, sediments and groundwater.
Pollutant linkage	Relationships between a contaminant source, a pathway and a receptor.
Previously developed land	Land which is or was occupied by a permanent structure (excluding agriculture or forestry buildings) and associated fixed surface infrastructure.
Procedure	Mode of conducting business, system laid down for actions / calculations etc.
Protocol	A written means of setting out a framework for action of some kind / calculation of some quality, agreed or to be negotiated by stakeholders.
Receptor	Something that could be adversely affected by a contaminant, such as people, an ecological system or a water body.
Risk assessment	The process of assessing the hazards and risks associated with a particular site or group of sites.
Site / project specific	Pertaining to an individual site or project / dependent on individual site or project characteristics.
Stakeholders	Stakeholders typically include any individuals or groups that may be affected by the environmental contamination. Stakeholders include federal, state, and local regulators, local businesses, citizens, citizen groups, problem holders, environmental industry, and public health officials.
Sustainability appraisal	A system intended to determine the contribution of a particular project or action to achieving sustainable development.
Sustainable development:	Development that meets the needs of the present without compromising the ability of future generations to meet their own needs (Brundtland 1987).
System	Collection of materially and energetically connected unit processes which performs one or more defined functions (e.g. windrow composting system).
System boundary	Interface between a product system and the environment or other product systems.

1 Introduction

1.1 Scope

Waste Not Want Not – old English Proverb

Rejuvenate was a desk study being carried out by four organisations from the UK, Sweden the Netherlands and Germany. Its goal was to assess the potential opportunity for using marginal 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 an industrial feedstock. The use of marginal 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 an overarching review of the opportunities for re-using marginal land for renewables. These renewables may be biofuels, biomass for energy or biofeedstocks (e.g. for plastics) or even natural fibres. Rejuvenate has developed an inclusive decision support approach, which is sensitive to the different national and regional contexts, caused by varying policy, regulatory and market drivers. A good example of these different contexts found in the current project is the interest in the UK of some small or medium sized enterprises (SMEs) in the integration of biomass use with on-site or local small scale waste management and energy solutions, compared with how the interest in Sweden has a greater focus on the sale of biomass off-site for energy conversion by big companies. However, Rejuvenate believes that the fundamental decision making process for bringing marginal land back into use for non-food crops is the same across Europe. The Rejuvenate team has identified the following key steps:

1. The identification of crop and use opportunities;

2. The management and improvement of soil and control of risks;

3. Understanding and maximising value and sustainability; and

4. The management of project risks such as technology status, due diligence and stakeholder perceptions.

These are the key steps in the Rejuvenate decision framework developed by this project and being taken forward, we hope, in a Rejuvenate 2 proposal. This proposal is in negotiation, and if funded, will include case studies that develop this framework further, with practical implementation; demonstration and pilot scale projects; and research and development (R&D) for specific decision making needs.

This project addressed SNOWMAN Call 1 Topic 4: *Application of Science and Technologies*. It began by considering phytoremediation to yield a product as well as risk management. While most work to date has focused on applications producing biomass, Rejuvenate sought to extend consideration to other emerging bioenergy interests such as bio-diesel and bio-ethanol, as well as other non-food crop applications. Rejuvenate focused on sites which are economically marginal for conventional regeneration. Over the course of the project it became clear that restricting its scope to phytoremediation excluded a wide range of possibilities where the crop was not also the remediation method, and so a more generic decision making framework was developed to widen the range of renewables opportunities and so increase the likelihood of this type of land re-use being adopted across different regions of Europe.

1.2 Aims

The aims of Rejuvenate have been to:

1. Explore the feasibility of a range of possible approaches to combining RBLM with non-food crop land-uses and organic matter re-use as appropriate,

2. Identify a range of potential opportunities worthy of further development in the UK, Germany and Sweden and in a wider European context, and

3. Assess how verification of their performance might be carried out and identifying what requirements remain for future research, development and demonstration.

The project was organised in two Work Packages. Work Package 1 included the project management and dissemination tasks. Work Package 2 included the technical work to realise Rejuvenate's aims, which was organised as eight tasks:

1 Identify opportunities for RBLM + non-food crop land use

2 Appraisal of technological status and verification and R&D needs

3 Identify key decision making factors, taking into account regional perspectives

4 Land bank assessment

5 Stakeholder analysis

6 Organic matter re-use assessment

7 Review of carbon balance opportunities

8 Consultation and review

1.3 Partners

Rejuvenate includes four partners from Germany, the UK, the Netherlands and Sweden: r^3 environmental technology ltd www.r3environmental.com (co-ordinator), Swedish Geotechnical Institute www.swedgeo.se, DECHEMA e.V. www.dechema.de and Bioclear www.bioclear.nl. These partners included two SMEs and two research institutions. The Swedish team also included input from a Swedish SME, Fb Engineering AB www.fbe.se.

While the Rejuvenate project's official SNOWMAN start date was October 1st 2008, it had been in negotiation for some 18 months. The project team began work over this period on a self-funded basis, and during summer 2008 funded work in Sweden was officially initiated.

1.4 Report Structure

This report is the *Final Report* of the Rejuvenate Project and is formally project deliverable D3. It has been organised as a guidance document to support a wide range of potential users. The document is organised broadly in two halves. Its first five chapters outline the opportunity for growing renewables on marginal land across Europe, in particular the UK, Sweden and Germany. The second half provides guidance which is an underpinning framework for decision-making about:

- the use of marginal land for non-food crops for renewables, and
- the use of recycled organic matter in this process for soil improvement, and as supplementary biomass.

A worked example is provided in an accompanying report: *REJUVENATE Crop Based Systems for Sustainable Risk Based Land Management for Economically Marginal Degraded Areas – A Worked Example*.

The report concludes with a series of conclusions and suggestions for the further use of this decision making framework. The main body of the report has been kept deliberately simple and short to facilitate its use by a broad range of users.

This report is the main output of the Rejuvenate project, but draws on two reports published by SGI (Andersson-Sköld *et al.* 2009 and Suer *et al.* 2009) as part of the Rejuvenate Project, which provide more detailed information about phytoremediation and its wider carbon and life-cycle benefits.

2 The sustainable development opportunity for biomass production integrated with risk based land management and soil improvement for marginal land

Sustainable development as a concept was defined in the 1987 “Brundtland Report” by the World Commission on Environment and Development (Brundtland 1987) as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs”. It had long been assumed that land remediation was by its nature intrinsically sustainable because, for example, it controlled risks from pollutants and facilitated the re-use of previously developed or brownfield land so reducing greenfield redevelopment processes. However, it has increasingly been realised that this simple assumption may not always be true. Large areas of brownfield land exist for which there is no economic case for restoration to conventional functional re-use and/or no realistic prospect for "hard” re-use[3]. Not only is there no economic driver, but even if there was, the levels of resource and energy use that would be needed to conventionally restore this land may not be environmentally sustainable either. Consequently local communities and landscapes remain affected by marginal land under varying levels of management. The use of this marginal land for growing biomass for energy and feedstock production could be an important means of unlocking development that is both environmentally and economically sustainable, and that also provides wider societal benefits for the affected communities.

All across Europe there are areas of land which have been degraded by past use that are not easy candidates for conventional regeneration, or for which conventional regeneration may not be the most sustainable approach (European Environment Agency – EEA, 2007b). Such previously developed land included areas affected by mining, fallout from industrial processes such as smelting, activities related to forestry and the pulp and paper industry, areas elevated with contaminated dredged sediments, former landfill sites and many other areas where the decline of industrial activity has left a legacy of marginal land and economically disadvantaged communities. The extent of contamination may not be sufficient to trigger remediation under current regulatory conditions, and there may be little economic incentive to regenerate the areas affected. The available land bank is discussed further in Chapter 3 (below).

2.1 Perspective – missed opportunities

The increasing importance of biomass for energy production and feedstocks for manufacturing processes (such as for plastics and biofuels) has become a worldwide phenomenon. The Food and Agriculture Organisation of the United Nations - UN (FAO 2008) defines:

- *Biomass* as non-fossil material of biological origin such as energy crops, agriculture and forestry wastes, and by-products, manure or microbial biomass
- *Biofuel* as fuel produced directly or indirectly from biomass, such as fuelwood, charcoal, bioethanol, biodiesel, biogas (methane) or biohydrogen [colloquially biofuel tends to be restricted as a term to liquid fuels], and
- *Bioenergy* as energy derived from biomass.

Establishment of non-food crops for biomass, biofuel and energy can contribute to sustainable development policy goals related to renewable energy and carbon management (Defra 2003, EC 2007). It has been suggested that on a worldwide basis, energy production on abandoned agricultural land could supply up to 8% of world energy (Engelhaupt 2008). However, the use of land to produce any type of biomass for feedstocks, fuels and energy has become increasingly contentious in Europe and North America (BBC 2008, Moore 2008, Scharlemann and Laurence 2008), with a range of concerns about the sacrifice of food growing land, food security, food poverty and habitat land conservation issues (FAO 2008, Organisation for Economic Cooperation and Development - OECD and FAO 2007, OECD Round Table on Sustainable Development 2007, Oxfam 2007). It has been questioned whether some biofuels even have a positive carbon balance at all if the impact of the biomass cultivation on nitrous oxide (N_2O) emissions from soil are considered[4] (Crutzen *et al.* 2008, RFA 2008) and also factors such as transportation of biomass and change in land use (Environment Agency 2009a and b). The wider environmental impacts of biomass production could also well

3 www.cabernet.org.uk

4 A *Nitrous Oxide Focus Group* was formed in 2008 to explore the action of the GHG, Nitrous Oxide; its role in climate change, the role of bacteria in the GHG emissions and to develop techniques to mitigate its effect. www.nitrousoxide.org

be significant, including the impacts on soil and water and the carbon and resource costs of artificial fertilisers and pesticides (Zah *et al.* 2007). There is also some concern that production of biomass for energy may threaten supplies of biomass used as feedstocks, for example for soaps, cosmetics and pharmaceuticals (Anon 2007b),

A European Environment Agency Scientific Committee (EEA 2008a) has questioned the sustainability of existing European Union (EU) commitments to biofuels, and suggested that the EU target to increase the share of biofuels used in transport to 10 percent by 2020 (EC 2008a) should therefore be suspended. This suggestion was echoed by the European Parliament in September 2008. Compromise was reached in December with the proviso that the wider impacts of biofuel production on land use were taken into account (European Parliament 2008b). The EEA opinion was in part based on a sustainable land use report it commissioned, which found that in 2005, an estimated 36,000 km^2 of agricultural land in the EU-25 was directly devoted to biomass production for energy use, which was projected to rise to reach 190,000 km^2 by 2030 (EEA 2007b). Conversely an EEA report (2006) has concluded that "significant amounts of biomass can technically be available to support ambitious renewable energy targets, even if strict environmental constraints are applied."[5] However, several studies indicate that large scale substitution of fossil fuel by biofuel is not possible without impacting food supplies (e.g. Hill *et al.* 2006, Russi 2008)

A similar debate about the extent to which biofuels can be produced and used sustainably has been taking place in the UK (e.g. House of Commons 2008a and 2008b, RAB 2008b – *The Gallagher Report*).

Remediate Land, Produce Biomass - "Buy land, they aren't making it any more." Mark Twain

The use of marginal land is an emerging opportunity in this biomass debate that can address some of the concerns about biomass production on agricultural or virgin / wilderness land. The extent of contamination may not be sufficient to trigger remediation under current regulatory and economic conditions, but use for biomass may be an incentive to regenerate the areas affected.

An international "Roundtable on Sustainable Biofuels" has proposed a series of principles, as part of a standard for sustainable biofuels, which should underpin biofuel production (Round Table on Sustainable Biofuels 2008) which includes requirements for biofuels to significantly reduce greenhouse gas (GHG) emissions compared with fossil fuels, that their production should not violate human rights, nor land rights and should not impair food security nor impact negatively on biodiversity, habitat or conservation. Biofuel production should also seek to improve soil conditions and optimise use of surface and groundwater. The re-use of marginal land has a good fit with these principles. The European standards body CEN has set up a technical committee to develop sustainability criteria for biomass - with the aim of publishing draft standards during 2009 (Anon 2008c). In the UK the Government has suggested that suppliers of biofuels should be encouraged to report on the sustainability of the biofuels that they supply (Dept Transport 2008), although not all stakeholders see the need for this (Ecofys and E4tech 2008). The current EU position is summarised on the Biofuels Technology Platform web site[6]. Development of sustainability criteria for biomass for energy in general is also underway on an EU wide basis (Biomass Technology Group 2008, EC 2008d) and under the remit of the UN (UN 2007).

2.2 A broad vision

Food cultivation may not be appropriate on marginal land, for example because of public concerns over the possible presence of soil contaminants. However, not only is marginal land a useful opportunity in many places for biomass production, but the substitution of non-renewable inputs (such as fertilisers) with renewable inputs (such as compost) further improves sustainability. Other organic materials in the area such as agricultural and forestry residues can be a supplementary source of biomass. Hence the combination of biomass cultivation and soil improvement could be an integral part of land rehabilitation and risk management in the long term. There may also be further benefits from this kind of land use, for example, providing: a self-funding land management regime, economic activity in deprived areas, a long term improvement in land values and environmental benefits such as carbon sequestration (substitution of fossil carbon resources, and "temporary" sequestration in managed soils). Similar ideas have been advanced in

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[5] The use of biomass (and legislative demands) for transport, heating and electricity is covered by the EC Biomass Action Plan - http://ec.europa.eu/energy/res/biomass_action_plan/doc/2006_02_08_comm_eu_strategy_en.pdf, which is also supported by the EU Strategy for Biofuels (2006)

[6] http://www.biofuelstp.eu/legislation.html

the UK by the "SUBR:IM" project[7]. They point out the broad synergies and sustainability advantages of providing green space in urban areas on urban brownfield, again using compost as a soil improver where needed (CL:AIRE 2009). It would be interesting indeed to see if linking urban brownfield regeneration with green space *and* biomass might allow energy linkages that could provide renewable energy and heat to adjacent built developments.

The ideal technical interventions for managing marginal land are those that are: fit for purpose, e.g. manage the risks posed by the contamination; sustainable, i.e. they have small environmental impacts and low use of resources and energy, provide economic benefit rather than stringent costs and have wider social benefits; and attractive to implement, i.e. they do not cost much, need little active management, are readily acceptable to land owners, authorities and the public, stimulate interest. It is possible that long term use of marginal land for biomass production may at least offset the costs of its management, and potentially generate profit.

Of course, set against the scale of agricultural land use overall, the marginal land bank may not seem large, but it can *offset* the use of some prime agricultural land. However, using it as a biomass resource is important for several reasons: the land bank may be very significant in particular localities and regions, and these are often areas with economic under-performance; it is an effective means of returning productivity to marginal land; and it brings wider sustainability benefits. Some examples of these wider benefits, taken from a 2004 UK Feasibility Study are set out in Figure 2.1 (AEA and r3 2004). It is perhaps also important to take the land opportunity for biomass that marginal land affords, to reduce, at least in part, agricultural or wilderness land use for biomass and biofuels that is likely to occur inside and outside the EU in response to European renewable energy policy. The GHG emission, and wider sustainable development, consequences of changing land use, for example from pasture to biofuel crops land take may greatly outweigh any perceived benefit from biofuel or biomass production (Gibbs *et al.* 2008).

Even within a European context, there may be benefits in re-using marginal land for biomass, compared with reusing agricultural land or agricultural land returned to habitat as "set aside". However, the benefits of re-using marginal land for biomass would appear to be greater than for changing, for example, use of agricultural land, especially set aside. This is because the impacts of land use change can negate possible GHG emission savings from biomass to energy, and this negation is significant for formerly fallow land, and substantial for permanent grassland (Environment Agency 2009b). This negation applies even to second generation biofuels produced from lignocellulosic biomass such as from Switchgrass (see Section 4.2.4), although to a lesser extent than for current first generation biofuels produced from grain (Searchinger *et al.* 2008).

	Environmental	**Economic**	**Social**
Project related	• soil functionality • resources • land stewardship • carbon / energy	• self-funding • revenue generating	• removal of blight
Wider	• biodiversity •reducing pollutant fluxes	• employment • capital appreciation • local business	• amenity • education & training

Figure 2.1 Possible wider sustainability benefits for biomass production on marginal land with secondary materials use (r3 and AEA 2004)

Case studies carried out by SGI using standard quantitative tools for life cycle assessment (LCA) and carbon foot-printing support the view that the re-use of marginal land for non-food crops has strong sustainability benefits. The SGI work found that GHG emissions; other emissions to air, soil and water; energy; off-site use of land; and the use of pristine soil and other resources were substantially less for bioenergy re-use of land compared with conventional restoration strategies (Suer *et al.*, 2009).

[7] http://www.subrim.org.uk

A clear message in the English Partnerships 2003 *Brownfields strategy* is that this long term derelict land is hard to develop (bring back into re-use) using conventional means, largely for economic reasons. Biomass may provide leverage that can "unlock" the dereliction on such land and bring it back into productive use, at a lower cost to society than alternative means. Furthermore the conjunction of several drivers (land restoration, organic matter re-use and biomass energy) as well as its wider sustainability benefits may make land that has been marginal over long periods very attractive for "pioneering" biomass projects, compared with the use of land previously designated as agricultural set aside. This may make a quick start more likely than for projects where the change in land use may be more controversial.

The use of recycled organic matter for biomass production on marginal land is likely to fall into two stages. The first is the conditioning and restoration of marginal land to create conditions suitable for biomass production. The second might be ongoing additions for maintaining soil productivity and fertiliser substitution. Depending on the biomass being grown, this reuse of organic matter (e.g. compost) is likely to be far greater in terms of volume required per unit area than the single applications of compost conventionally used for the restoration of marginal land, such as for public amenity use as "country parks" or nature areas. Biomass on marginal land is therefore potentially a significant outlet for recycled organic matter, depending on the quality of the organic matter used (see Chapter 5). Recycled organic matter may also be important as a supplementary source of biomass. For example, the viability of direct thermal conversion of biomass to energy via a central plant is already well established technology. The volume of biomass from a particular marginal land portfolio may not be a sufficiently large economic opportunity for a conversion facility, and transportation costs to an existing facility may be prohibitive. In this circumstance integration of biomass production on marginal land with locally available organic matter such as woody wastes and green waste composting residues may provide sufficient volume to justify a new conversion facility.

The draft Soil Framework Directive sets out a vision that remediation should be evaluated on the basis of economic, environmental and social indicators (i.e. that it should be sustainable). The UK Sustainable Remediation Forum[8] has been developing an assessment framework. An initial set of overarching sustainability categories is set out in Table 2.1. The Network for Industrially Contaminated Land in Europe (NICOLE) also has a working group considering how sustainability in land remediation should be considered and implemented[9].

Table 2.1 Suggested Overarching Sustainability Considerations

Environmental	Economic	Social
1. Impacts on air 2. Impacts on water 3. Impacts on soil 4. Impacts on ecology 5. Intrusiveness 6. Resource use and waste	1. Direct costs and direct economic benefits 2. Indirect costs and indirect economic benefits 3. Gearing 4. Employment / human capital 5. Life-span and "project risks" 6. Flexibility	1. Community involvement and community satisfaction 2. Human Health 3. Ethical and equity considerations 4. Impacts on neighbourhoods or regions 5. Fit with planning and policy strategies and initiatives 6. Uncertainty and evidence

2.3 Carbon balance

There are two basic forms of carbon management benefit that may result from the use of marginal land for bio-renewables:

- Emissions reduction: a permanent effect resulting from the substitution of bioenergy for fossil carbon resources, and

[8] www.claire.co.uk/surfuk

[9] http://www.nicole.org/WorkingGroups/WGSustainableRemediation/default.aspx

- Sequestration: a temporary effect resulting from changes in organic carbon levels in managed soils and the standing crop of biomass on-site.

Sequestration in soils and biomass is seen as temporary as it depends on the continuation of a particular land management regime, and may then gradually diminish over time as the biomass standing crop changes and soil organic carbon is gradually oxidised by natural processes. The extent to which a bio-renewable on marginal land will achieve sequestration depends on a series of carbon inputs and outputs, which in turn depend on the crop types selected; how they are cultivated, processed and converted; and what inputs are needed for the management of the site and the system (Bolinder *et al.* 2007, Kim *et al.* 2009). The potential for soil carbon increase for short rotation coppice (SRC) willow was found to be greatest where organic carbon in the soil had been depleted (Grogan and Mathews 2002). Managing soil carbon is seen as an important part of managing climate change (ClimSoil Consortium 2008). Improvement of soil carbon levels in marginal land, for example by soil improvement and judicious selection of biomass cultivation may be a useful adjunct to this.

Carbon impacts from biomass use of land may result from soil disturbance by cultivation and soil nitrogen metabolism. Disturbance of undisturbed soils, for example beneath pasture may lead to GHG release as soil organic matter is oxidised (Gibbs *et al.* 2008). However, marginal land may already be highly disturbed and have only low levels of pre-existing soil organic matter. Hence over time a net increase in soil organic matter is likely (as discussed above). Emissions of nitrous oxide (N_2O) from the nitrogen content of added organic matter may reduce the overall GHG benefit (ADAS 2002), and there may be wider environmental impacts from large scale deployment of dedicated energy crops, for example on landscape (Rowe *et al.* 2009).

There are two broad approaches to carbon balance appraisal that can be used to estimate a projects carbon management performance:

Carbon footprint: a measure of the impact human activities have on the environment in terms of the amount of GHG produced, measured in units of carbon dioxide (CO_2). A carbon footprint is made up of the sum of two parts, the direct / primary footprint and the indirect / secondary footprint. The primary footprint is a measure of our direct emissions of CO_2 from the burning of fossil fuels including domestic energy consumption and transportation. The secondary footprint is a measure of the indirect CO_2 emissions from the whole lifecycle of products - those associated with their manufacture and eventual breakdown. Note the carbon footprint is not measured in terms of area. The world's first standard approach was recently published in the UK, PAS 2050 (Carbon Trust *et al.* 2008a & 2008b).

Carbon balance: In the UK the Department for Environment Food and Rural Affairs (Defra) have recently published a major report on Carbon Balances and Energy Impacts of the Management of UK Wastes (Defra 2006a). This uses carbon balance diagrams that show calculations of tonnes of carbon in various inputs and outputs, and how this balance changes for different waste management scenarios. The major flows of both carbon/GHG and energy through waste management systems result from: the use of fuel and energy in processing; the transportation of waste to and from sites (including collection); direct releases from waste materials on processing (e.g. biological processing or thermal treatment) or disposal in landfill; avoidance of GHG emissions or energy use elsewhere in the economy; and sequestration of carbon in landfill and soil. The carbon balance diagrams for each waste material and scenario detail: the carbon that remains within the material fraction following treatment or disposal (both carbon in inert fractions that have been deposited in land; as well as organic carbon that has not degraded but is sequestered in landfill or other soil carbon sink); carbon that is contained in products, such as recyclate or composts; and carbon that is released to atmosphere, as CO_2 (fossil / biogenically derived) or methane. Carbon balance diagrams can also show GHG balance calculations shown in tonnes of equivalent CO_2.

SGI has carried out two carbon footprint appraisal case studies (using the PAS 2050 method) considering the phytoremediation of (a) Vänerhamn a former oil depot with soil contaminated by organic compounds, and (b) Fagervik a former industrial site with mixed inorganic and organic contamination. Short rotation willow cultivation was compared with excavation and off-site treatment for Vänerhamn, and with conversion to park land for amenity use for Fagervik; and for both sites with willow cultivation on agricultural land. These carbon footprint appraisals did not explicitly consider how the harvested biomass would be converted, but even so showed major carbon benefits for the willow based re-use of the contaminated sites compared with the other site management alternatives being considered, and the production of willow biomass on agricultural land. A major source of these benefits was the avoidance of the carbon impact of the alternative future land uses.

Carbon neutrality may be an important opportunity for biomass on marginal land projects to generate value. Carbon neutrality means that – through a transparent process of measuring emissions, reducing those emissions and offsetting residual emissions – net calculated carbon emissions equal zero (DECC 2009a). This concept can generate value in two ways: firstly it may be a means of allowing a larger redevelopment project to achieve carbon neutrality for example by calculating the cumulative carbon balance for a project that includes built redevelopment and biomass on a particular site; and secondly, for European projects, by generating income from *voluntary* offsetting of carbon emissions (ENDS 2009).

The Kyoto protocol created an opportunity to trade “carbon credits” whereby developed countries could offset carbon emissions against projects that removed atmospheric carbon in developing countries, which have ratified the Kyoto Protocol (UN 1998). Additionally voluntary carbon trading has emerged as a means of companies demonstrating carbon offset, outside the Kyoto Protocol compliance system (Bayon *et al.* 2009, Yamin 2005). These tradable voluntary emission rights (VER) may offer additional revenue to project activity. For example, in the USA, the Chicago Climate Exchange is developing a protocol for issuing offsets to projects that avoid GHG emissions through composting or other similar approaches (McComb 2009).This is not a regulated market, however, voluntary standards do exist (VCS Association 2007a and b). Overall, four broad principles underpin VER

1. Additionality: VERs must represent real emissions reductions in addition to the business-as-usual scenario.
2. Sustainability: projects should reduce emissions, and contribute to local sustainability. The voluntary market, sensitive to sustainability concerns due to the impact on pricing and relative value, and VERs associated with projects that are seen as having a broader sustainability benefit tend to be worth more.
3. Verifiability: independent scrutiny is required to verify emissions reductions .
4. Reliability: It needs to be proven that the VERs have not already been sold or used elsewhere.

However, at present the use of VERs for land management schemes in developed countries signed up to Kyoto may not be attractive to investors, because carbon reductions may be perceived as being double counted with national emission reduction statistics. There may be more scope to use VERs in the new EU Member States, particularly Romania and Bulgaria[10].

3 The nature of long term marginal land in Germany the UK and Sweden

3.1 Context

En plats för var sak och var sak på sin plats (One place for every thing and every thing in the right place) Swedish saying

The focus of Rejuvenate is on land which is degraded in some way and also economically marginal for conventional regeneration. A working definition for “marginal land” is land that has been previously used in an industrial or urban context, or agricultural and other land that has been damaged by pollution, which is perceived to be unsuitable for the production of food or for urban or industrial re-use.

The Rejuvenate team has collected the land bank information that is available on marginal land, based on publicly available inventories in Germany, Sweden and the UK, and information collated by the EEA. This information is reviewed below. The working definition of marginal land suggested above covers a range of “national” definitions including: brownfields, contaminated sites, derelict land, previously developed land and under utilised land, and these definitions vary from country to country. The quality of available data is also highly variable and cannot always be “broken out” into data related regions and localities.

3.2 Germany

In Germany the marginal land includes areas affected by mining, fallout from industrial processes such as smelting, areas elevated with contaminated dredged sediments, former landfill sites and many other

[10] Eco-Securities Ltd (2009) Personal Communicatiob

categories. Brownfields are defined as locations, which are currently unused, whose previous use has been for industrial, military, infrastructure, and/ or mining activities. These activities have caused a wide variation of point source and diffuse pollution. The majority of point source pollutions have been treated successfully in the past decades, whereas areas with widespread, low level diffuse pollution often remain untreated.

The information structure in Germany concerning brownfields is affected by its Federal nature, with data typically compiled (if it is compiled) by individual lände for environmental and land use issues. Thus nationally compiled information related to brownfields and marginal land shows a high degree of variability, and no national register exists. Several extrapolations of available brownfield data across the Federal Republic of Germany have been carried out, and at a national level the Federal Ministry for Building and Regional Planning the Federal Environmental Agency of Germany designed a methodical approach for the estimation of national brownfield potentials (Dransfeld *et al.* 2002). This suggests that in Germany there are: 19,000 ha of industrial and 20,000 ha of infrastructure related brownfields, 38,800 ha of Federal properties, and 50,000 ha of properties in conversion from military to civil use. Burmeier (1999) estimated that there were 127,800 ha of brownfield in Germany, summarised in Figure 3.1, while the Federal Environmental Protection Agency (UBA) has estimated that the area is 530,000 ha if military areas are also taken into account (UBA 2008).

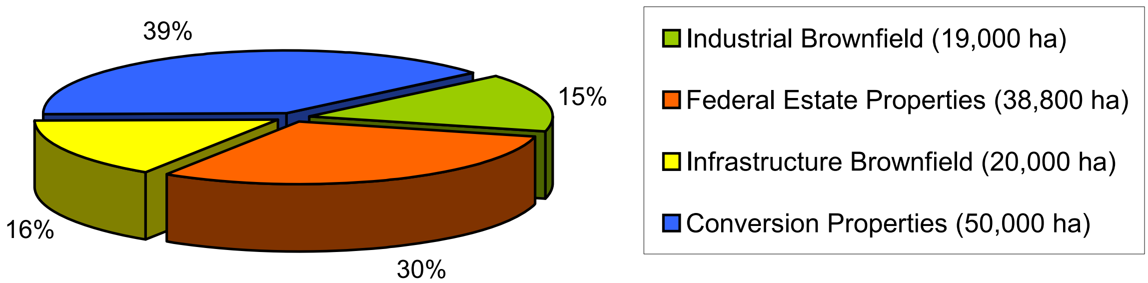

Figure 3.1 Burmeier (1999) estimate of brownfield in Germany

3.3 Sweden

Marginal land, as a term, is consistent in Sweden with the definition used in this report. *Contaminated sites* refers to any landfill, land, groundwater or sediment showing concentrations of pollutants that are significantly elevated above background levels, due to local emissions. The sites are classed according to the (industrial or other) activity that has taken place on the site using 82 categories, such as: petrol station, dry cleaning, sawmills, landfill etc. The County Administrative Board's regional databases use 71 of 82 categories, the other 11 categories have lower priority or are data collected by other agencies (e.g. the Swedish military authorities or the Swedish Rail Administration).

Inventories of contaminated sites are conducted by local and regional authorities into regional databases. Each year the Swedish Environmental Protection Agency (SEPA) integrates these data into a national progress report (Swedish Environmental Protection Agency 2008). A national database is under development but not available at present. Regional MIFO[11] databases have been used to assess the extent of contaminated land in Sweden that could be used for arable purposes such as energy crops. In total 40,226 sites have been registered across the 71 categories (MIFO 2008). SEPA has estimated the total number of contaminated sites in Sweden to be about 70,000 (Swedish Environmental Protection Agency 2008).

The MIFO databases do not include the areas of the contaminated sites. The *area* of contaminated land that could be used for arable purposes has therefore been estimated on the basis of estimates of the usable area for sites in particular categories. On this basis the total potential arable area of contaminated sites in Sweden was estimated to be up to 778 km^2, about 0.2% of the land area of Sweden, out of a total area of contaminated sites that was estimated to be 2,936 km^2, which is about 0.7% of the land area of Sweden.

[11] Methodology for the inventory work concerning contaminated areas in Sweden

Hence this arable area constitutes around 26% of the total contaminated area of Sweden (Andersson-Sköld *et al.*, 2009)

Mean areas were calculated across up to five randomly selected sites for each of the 71 categories in the database for the County of Skånes (MIFO, 2008), using the areas reported by owners to the Land Registry. Also estimated were a “mean arable site factor” and a “mean arable conjunction factor”. The “mean arable site” and “mean arable conjunction” factors reflect how current land use may affect the potential of cultivation. For example, a site containing buildings and housings would probably be less fit for cultivation than an open industrial site. There are two other uncertainties in this estimation process. Firstly the areas reported are based on overall site areas in the land registry and not the actual contaminated area of each site. Secondly not each of the categories had a listing, so an “expert assessment” was used to provide mean area data for these categories.

This is very much a first estimate, and the uncertainties are likely to lead to an overestimation rather than an underestimation of arable area. However, this estimate *excludes* sites in the 11 categories not collated by Counties, which constitute about 7% of all reported sites in Sweden (MIFO, 2008). Despite these large uncertainties, the estimate indicates that there is a significant potential area available for cultivation of biomass or other non food crops in Sweden.

The total annual use of fossil fuel in Sweden is 130 TW and the European target is to replace 10% of the fossil fuel with biofuel by 2020 (EC 2008, Rydberg, 2008). This replacement would require around 30,000 km^2 land in Sweden for biofuel production (Rydberg, 2008, Semelsberger *et al.*, 2006, Andersson-Sköld *et al.*, 2009). The area estimate for arable land in the Swedish contaminated sites inventory therefore looks a little small. However, together with other biomass sources, such as agricultural and municipal waste, a significant contribution to renewables could be made by biomass on marginal land, to join other renewable sources such as wind, hydro and solar energy and measures related to sustainable energy consumption.

3.4 United Kingdom

There is a range of land descriptions used in the UK which could potentially encompass marginal land.

Brownfield land has been defined at a European level as referring to sites which have been affected by former uses of the site or surrounding land, are derelict or underused, are mainly in fully or partly developed urban areas, require intervention to bring them back to beneficial use, and may have real or perceived contamination problems[12]. The term is widely used in the UK in this context (English Partnerships 2003), but for data collection purposes has now been replaced by the term Previously Developed Land – PDL (Department for Communities and Local Government -DCLG 2002). PDL is land which is or was occupied by a permanent structure (excluding agriculture or forestry buildings) and associated fixed surface infrastructure. It is also defined as “land that was developed but is now vacant or derelict, or land currently in use with known potential for re-development” (DCLG, 2007). PDL may occur in both built up and rural settings (DCLG 2002). Active and former landfill sites are considered as PDL from a regulatory point of view. Information about the occurrence of PDL is collated across England from local authorities by the National Land Use Database (NLUD)[13], across a range of categories (NLUD 2003) including landfill[14]. In 2006 the NLUD indicated that there were 62,700 ha of previously developed land in England, of which 34,900 ha (55%) were vacant or derelict (as opposed to in use but with scope for rehabilitation). This decreased in 2007, to 62,100 ha (DCLG 2008). Figures for 2008 are still in calculation. This decrease in PDL is attributed to a strong policy of house-building on previously developed as opposed to greenfield land, for example, it is estimated that 78% of dwellings built in 2008 (including conversions) were built on PDL (DCLG, 2009).

Derelict land (and buildings) is land which has been so damaged by development, that it is incapable of development for beneficial use without rehabilitation. In addition the land must currently not be used for the purpose for which it is held or a use acceptable in the local plan. Land also qualifies as derelict if it has an un-remedied previous use which could constrain future development. (Scottish Government 2009). In England derelict land is a category of PDL.

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[12] www.cabernet.org.uk

[13] http://www.nlud.org.uk/

[14] it is possible that some landfill sites are not listed because they are located outside of urban areas, and other older landfills that remain undetectable amongst other categories due to their informal nature.

A regional survey of ***derelict, underused and neglected*** (DUN) land in the Northwest of England was carried out in 2002 (Forestry Commission 2004). This survey considered sites greater than or equal to 1 ha in size. 26,385 ha of land across 3,893 sites were designated as DUN land. Of this area 14,915 ha (over 1,627 sites) was previously developed land (Forestry Commission 2004). The study went on to consider the suitability of these sites to be reclaimed for soft end uses including community woodland. A total area of 22,116 ha (over 3,113 sites) was thought to have potential to be reclaimed for soft end uses. One of the implications of this survey is that the area of land that is underutilised adds substantially to the derelict land area. So far the Northwest is the only region where such a detailed study has been undertaken.

Vacant land is land which is unused for the purposes for which it is held and is viewed as an appropriate site for development. This land must either have had prior development on it or preparatory work has taken place in anticipation of future development and is reported separately in Scotland (Scottish Government 2009). In England vacant land is reported as a category of Previously Developed Land. An inventory of derelict and vacant land is compiled annually in Scotland from local authority returns, most recently for 2008 (Scottish Government 2009) via the Scottish Derelict and Vacant Land Survey (SDVLS). There were found to be 10,832 ha of derelict and urban vacant land recorded in the 2008 survey[15], of which 2,630 ha (24%) were urban vacant and 8,203 ha were derelict (76%)[16]. An estimate of the amount of potentially contaminated land was attempted in 2005. It was recorded that 171 sites covering 1,186 ha were known to be contaminated, however contamination of 89% of the urban vacant and derelict land was not determined (Scottish Executive 2006b).

At present, there is no equivalent land use data collection process for Northern Ireland or Wales[17]. A survey in Wales (Welsh Office 1988) identified over 6,800 ha of derelict land that had been reclaimed, with a further 10,900 ha in need of reclamation. Most of the derelict land in Wales is a by-product of the coal industry, mining and quarrying. Informal data sources indicate that between 1990 and 2003, almost 600 ha of derelict in Wales was reclaimed and developed[18,19]. In 1996, the Environment and Heritage Service in Northern Ireland developed a *Land Use Database* which estimated that there might be around 12,000 sites that may potentially be contaminated[20].

Contaminated land has a specific legal meaning in the UK: it is land that has been designated as such by regulatory authorities because of unacceptable risks to human health, water or other receptors (Defra 2006b). A wider term used is land affected by contamination, which describes land with elevated levels of substances of concern. Brownfield land, derelict land, PDL or vacant land are *not necessarily* affected by contamination. In 2005, the Environment Agency estimated, on the basis of land use modelling, that in England and Wales there were 33,500 sites covering as much as 67,000 ha that were ***affected by contamination*** to some degree. These formed a subgroup of 325,000 sites (300,000 ha) where previous land use was *potentially* contaminative. In addition, it was estimated that 27,000 ha of land might be radiologically contaminated (Environment Agency 2005). However, the proportion of these land areas which would fall under the legal definition of contaminated land is small. In May 2009 SEPA published a report on *Dealing with land contamination in Scotland"* which estimated that there might be 82,000 ha of land affected by contamination (across 67,000 sites) in Scotland.

Land affected by ***diffuse contamination*** for example from smelter fall-out or other aerial deposition sources, or former use for "sewage farming" are not explicitly mapped. The British Geological Survey holds maps that might be informative for diffuse contamination land, based on soil and stream sediment sampling data. The Geochemical Baselines project is in the process of carrying out a systematic geochemical baseline survey (G-Base[21]) across the UK. So far this includes soil analyses for up to 50 inorganic parameters, at present mostly for central and eastern England, including 25 urban centres. An extensive soil and herbage survey was published by the Environment Agency in 2007, which determined the concentrations of 12 metals and arsenic, 22 polycyclic aromatic hydrocarbons (PAHs), 26 polychlorinated biphenyls (PCBs) and 17 polychlorinated dioxins and furans (dioxins) in soil and herbage at 122 rural, 28 urban and 50 industrial locations. However, a recent review (Defra 2007b) has highlighted the potential for the loading of soil with potentially toxic elements (PTEs) to be increased by the application of wastes, such as organic material, to soils (see Section 5.1).

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15 http://www.scotland.gov.uk/Topics/Statistics/Browse/Environment/seso/sesoSubSearch/Q/SID/201

16 Land use data from the SDVLS do not follow the same format as the English NLUD therefore categories are not directly comparable.

17 Personal Communication from the Homes and Communities Agency May 2009

18 http://www.environment-agency.gov.uk/research/library/data/34405.aspx

19 http://grc.engineering.cf.ac.uk/lrn/resources/land/contamination/extent.php

20 http://www.eugris.info/FurtherDescription.asp?Ca=1&Cy=1&DocID=C&DocTitle=Statistics_and_related&T=United%20Kingdom&e=456

21 www.bgs.ac.uk/gbase

Redevelopment of land is usually categorised as “hard” or “soft”. Hard end-use refers to built redevelopment. Soft end-use describes non-built end-use. Soft end uses can be either non-commercial (e.g. in the amenity, landscaping and habitat sectors) or commercial (e.g. non-food crops). While there has undoubtedly been success in stimulating house building on PDL, not all PDL is suitable for hard end-uses such as housing. Some sites may have remained unused for long periods because of their location and nature, particularly if there is little economic incentive to regenerate the areas affected. The amount of land that remains degraded over the long term is a matter of concern, and there are strong quality-of-life, social and political arguments for some form of action. This type of land, along with land damaged by diffuse pollution or otherwise marginalised might find a future beneficial use in biomass production.

English Partnerships (2003) estimated the scale of long-term (i.e. longer than ten years) derelict sites greater than 2 ha in size at 16,523 ha. There is no dataset to estimate the total area of long-term derelict sites that are less than two hectares. However, anecdotal information (Cameron *et al.* 2008) from Local Authorities suggests that the unrecorded land area occupied by such smaller sites could be up to an additional ten percent. This would indicate approximately 1,700 ha in this category, making an estimated total of 18-20,000 ha of long-term derelict land in England. In the UK a proportion of this marginal land has been managed with “soft” restoration, for example for amenity use such as “country parks” (recreational areas in rural or semi-rural locations). On the other hand, the Waste Resources Action Programme (WRAP) estimates that the area available for compost use in the restoration of brownfield sites in England totals approximately 3,000 ha, which would produce a market for (source segregated) compost of 52,650 tonnes by 2010 (WRAP, 2006) largely based on restoration for forestry and amenity use.

So while in theory this kind of nationally collated land bank information could be used to make a conjecture about the scale of marginal land bank in the UK, and its potential value in biomass production, the information available is very variable. Consequently, this *Rejuvenate Project* report is reluctant to make a conjecture about the available “marginal land” bank available for biomass production across the UK.

1 million ha of land across the UK, *equivalent to 17% of total UK arable land*, has been identified as suitable for biomass production in the UK by the “Biomass Task Force” (Defra 2005a and 2005b) in its interim and final reports[22], and used by the UK Biomass Strategy (Defra, DoT and DTI 2007).

At one end of the spectrum the estimate that brownfield restoration area available for compost use in England is 3,000 ha is very much less than this. The estimate for the area available for community woodland in a single region of the England, the Northwest is nearly nine times greater (at 26,385 ha) than this WRAP estimate, and also greater that the estimate of long term derelict land in England of 18,000 – 20,000 ha.

The area of land subject to potentially contaminative use in the past in England and Wales is 300,000 ha, which is a more significant proportion of the Biomass Task Force area estimate. These data also exclude areas affected by diffuse contamination or other possible sources of marginalisation, but on the other hand the proportion of urban land reusable in this figure is unknown.

The DUN land survey in the North West indicates that marginal land banks may be significant in particular regions. Interestingly, while this is a region where organic matter to land options are limited because of its concentration of livestock farming (Anon 2009b), anecdotal information from a “compost like output (CLO)[23]” producer in the area is that they have found it difficult to find marginal land areas to produce biomass or woodland with CLO use.

The usable land bank for biomass is dependent on site and market opportunities at a local / regional scale. Furthermore there is a relationship between the size of a site and proximity to biomass users that affects the viability of a site for biomass production. Consequently “national” land bank estimates may have limited value in any case. Perhaps future efforts may be better directed towards understanding opportunities at the local scale in a functional way that can link land availability to biomass markets and available organic matter resources (a national picture could be assembled from those more local assessments). This approach appears to fit very well with how the relevant information is already collected in the UK.

- Local authorities already collect datasets for the NLUD and this information could potentially be an important asset in identifying marginal land opportunities for biomass.

[22] Note: the derivation of this area was not described in the Task Force’s reports.

[23] Materials produced by mechanically and biologically treating mixed municipal solid waste (see Chapter 5)

- Under Part 2A of the Environmental Protection Act 1990 local authorities are expected to identify contaminated land within their regulatory areas. Although a recent Environment Agency report on the state of contaminated land for England and first report for Wales (Environment Agency 2009e) found that by the end of March 2007, most local authorities in England and Wales had inspected less than 10 per cent of their areas for contaminated land.
- Information on municipal waste management is also collected from local authorities via Waste Dataflow and sewage sludge arisings may also be obtainable at least on a regional basis (see Chapter 5).
- A recent survey for Defra investigating markets for solid recovered fuel from waste (Defra 2009c) has also identified regional opportunities for biomass combustion in some detail.

The potential therefore exists, if agreement from information providers is forthcoming, to use a mapping approach to identify realistic opportunities for biomass on marginal land, taking into account available land, organic matter resources and off-site biomass use (at least for direct combustion) at a local level in the UK using a Geographical Information System (GIS). Such an undertaking would need to put significant effort in data quality assurance to overcome some of the limitations of the existing datasets, but a pragmatic first stage project could identify sufficient potential for a viable longer term effort to be undertaken. GIS mapping has already been widely used for this type of mapping, for example, in the USA to map brownfield resources for renewable energy[24], and also in the US State of Wisconsin to map biomass resources (Kures 2009).

3.5 European Environment Agency Land Bank Information

Relatively little consistent data exists to assess the scale of soil contamination across Europe (EEA 2000). In August 2007 the EEA (EEA 2007b) concluded that soil contamination requiring clean up is present at approximately 250,000 sites in the EEA member countries. This number is expected to grow. Although the data is very variable from country to country, the Agency continues “Potentially polluting activities are estimated to have occurred at nearly 3 million sites (including the 250,000 sites already mentioned) and investigation is needed to establish whether remediation is required. If current investigation trends continue, the number of sites needing remediation will increase by 50% by 2025.” National reports indicate that PTEs and mineral oil are the most frequent soil contaminants at investigated sites, while mineral oil and chlorinated hydrocarbons are the most frequent contaminants found in groundwater. The EEA (2007b) also found that a “considerable share of remediation expenditure, about 35% on average, comes from public budgets. Although considerable efforts have been made already, it will take decades to clean up a legacy of contamination”.

Unfortunately, these data represent only a proportion of the contaminated land bank because they tend to be compiled on the basis of point sources. Diffuse contamination may be a more widespread problem, resulting for example from atmospheric fallout from industrial facilities such as smelters, the re-use of materials on land, and contaminants in soil amendments such as cadmium in phosphate fertilisers. Data about areas of land affected by diffuse contamination is harder to find (EEA 2000), largely because it has not had a very high policy profile until recently and because it is technically difficult to assess. However in areas like Avonmouth, UK; Kempen, Belgium and the Netherlands; and the Nord Pas de Calais, France many km^2 of land are affected by smelter fallout alone and 1000’s of km^2 are suspected in Eastern Europe, e.g. Lithuania and Ukraine (EC 2004). The use of contaminated land in Belarus in the vicinity of Chernobyl for biofuel production has been proposed by the Belarus government (Anon 2008b). Diffuse inputs over large areas can also arise from natural inputs, for example arsenic in the south west of England (Defra 2007b).

Based on these data, two overarching conclusions can be drawn about soil resources degraded by contamination in Europe: (1) it is a large problem the full scale of which is only just emerging; and (2) a large proportion of the cost of dealing with this problem under current conditions is or will be borne by the Public Sector. In a European context it is forecast that the number of brownfield and potentially contaminated sites across Europe is expected to grow, making brownfield land a significant and ongoing land management issue for the foreseeable future.

NB: In the EU27 in 2007, 42% of treated municipal waste was landfilled, 20% incinerated, 22% recycled and 17% composted (EUROSTAT 2009).

[24] www.epa.gov/renewableenergyland

4 Possible integrated biomass production, soil improvement and risk management scenarios

Making a silk purse from a sow's ear?

In most countries Government policy recognises that when dealing with past contamination, the opportunity to maintain a clean environment has already gone. In this situation, as well as considering the degree of contamination, it is also necessary to consider to what extent the substances present may harm human health or the wider environment, or damage property such as buildings or pollute controlled waters. In short, what risk, if any, is caused by contaminants, and is that risk unacceptable? The overall approach in dealing with past land contamination is therefore one of risk management which encompasses "all the processes involved in identifying, assessing and judging risks, taking actions to mitigate or anticipate them, and monitoring and reviewing progress" (Environment Agency 2004, Federal Ministry of Environment, 2004, , Grossmann *et al.* 2005). Risk is a combination of the probability, or frequency, of occurrence of a defined hazard and the magnitude of the consequences of the occurrence. In the context of land contamination, there are three elements in risk assessment:

- A contaminant - a substance which is in, on or under the land and has the potential to cause harm (or to cause pollution of controlled waters)
- A receptor – in general terms, something that could be adversely affected by a contaminant, such as people, an ecological system or a water body, and
- A pathway – a means by which a receptor can be exposed to, or affected by, a contaminant.

Each of these elements can exist independently, but they create a risk only where they are linked together – so that a particular contaminant affects a particular receptor through a particular pathway (Environment Agency 2004). Hence an underlying principle in risk management is identifying and then breaking the relationships between a contaminant source, a pathway and a receptor. The UK term for this relationship is a "pollutant linkage". Without a pollutant linkage, there is not a risk – even if a contaminant is present. Hence the process of mitigating risks (risk management) operates in one or more of the following ways: reducing or changing the source; managing contamination in the pathway or by protecting the receptor (for example by restricting land use). Figure 4.1 illustrates this pollutant linkage concept and the possible risk management interventions.

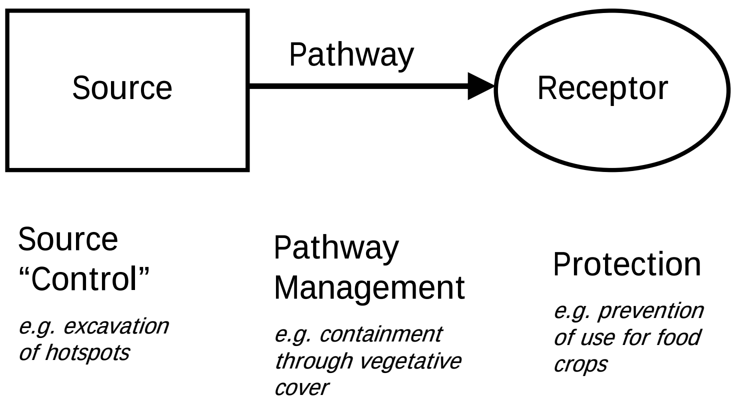


Figure 4.1 Components of a Pollutant Linkage where Actions Can Be Taken to Minimise Risk

The European network CLARINET: the Contaminated Land Rehabilitation Network For Environmental Technologies in Europe was funded and supported by the EC and by national agencies and regulators (Vegter *et al.* 2002) to develop technical recommendations for sound decision making on the rehabilitation of contaminated sites in Europe and to identify research and development needs. In a seminal report (Vegter *et al.* 2002) CLARINET concluded that contaminated land management decision making needs to consider three main broad issues: (1) fitness for use, (2) protection of the environment and (3) long-term care, illustrated in Figure 4.2. The first two describe goals for safe use of land, including prevention of harm and resource protection. The third allows for a more rigorous assessment of the way in which these goals are achieved, to ensure that it is a sustainable way. The three components need to be in balance with each other to achieve an appropriate solution. CLARINET called this concept *Risk Based Land Management* (RBLM). RBLM is primarily a framework for the integration of two key decisions for remediation of contaminated land:

1. The time frame: this requires an assessment of risks and priorities, but also the consideration of the longer term effects of particular choices.
2. The choice of solution: this requires an assessment of overall benefits, costs and environmental effects, value and circumstances of the land, community views and other issues.

These two decisions have to take place at both an individual site level and at a strategic level, especially as the impact of contaminated land on the environment can have not only a large scale regional dimension but also potentially wide ranging long term impacts.

Figure 4.2 The main components of Risk Based Land Management (Taken from Vegter *et al.* 2002)

RBLM emphasised the importance of sustainable development for contaminated land management. Risk based decision making in contaminated land management was seen as consistent with sustainable development because it provides a scientific rationale for the costs of remediation that society has to bear. But furthermore CLARINET suggested that where possible the "natural capacities" of soil and water should be used to effect risk management (e.g. through the exploitation of natural attenuation). However, CLARINET pointed out that not all remediation projects are necessarily sustainable development. Remediation processes themselves will have economic, environmental and social burdens. For example, removal of contaminated soils to landfill may only represent a transfer of contamination from one place to another, even if it does facilitate a redevelopment, and that transfer has economic, environmental and social costs associated with lorry movements, which may outweigh the benefits arising from any risk reduction on the contaminated site. CLARINET suggested that considering the true contribution of remediation work to sustainable development is an emerging challenge at least as great in its difficulty as the development of risk based decision making, and with the same capacity to profoundly change how we manage contaminated land in the future.

From the point of view of RBLM then the use of marginal land for biomass crops needs to consider:

1. The time frame: this requires an assessment of risks and priorities, but also the consideration of the longer term effects of particular choices. For biomass crops this will mean that the possibility of creation of new pollutant linkages by the biomass crops themselves will need to be considered as part of the overall site risk management planning.
2. The choice of solution: this requires not only an assessment of the direct value of a project (that creates a *viable* project) but also its wider sustainability context in terms of the environmental, social and economic elements of sustainability.

Site conceptual models (SCM) are widely used in risk assessment and risk management decision making (Nathanail and Bardos 2004). A SCM is a representation which sets out the critical pollutant linkages of concern for a particular land contamination problem. The selection of appropriate remediation techniques for those risk management goals is one of the primary planning tools that can be used to support the decision making process managing contaminated land and groundwater on a large scale. The SCM is used to collate and organise available information about a site in a clear and transparent structure and so facilitate the identification of data and information gaps. It is an iterative tool, as new information and data are collected they can be integrated in the model. This may lead to revision of the model and a refinement of decision goals, if required[25]. For biomass use of marginal land SCMs will need to be developed to include the biomass component of the project, and also other site management activities, for example soil "forming" and maintenance and crop cultivation including water use and ongoing soil improvement. Soil "forming" refers to the processes that lead to the creation of soil. Marginal land may have poor quality soil, or indeed may not have natural soil, in which case soil development is necessary. This soil development is usually based on the incorporation of "soil forming materials" which could include aggregates, organic matter sources or other materials depending on the circumstances[26].

4.1 Biomass from phytoremediation systems

A starting concept is that the risk management approach for the site is entirely based on phytoremediation, i.e. the use of plants to facilitate contaminant degradation, removal, containment or stabilisation of contaminants (Nathanail *et al.* 2007, SUMATECS Consortium 2008, US EPA 1999a), and that *therefore the biomass crop used would be the biomass produced by the phytoremediation plants*. This starting concept is illustrated in Figure 4.3. It encompasses single solutions that could be applied to particular kinds of areas in particular regions, for example, phytoextraction into willow short rotation coppice (SRC) for an area affected by smelting fallout, or phytostabilisation using a grass crop or oil seed rape with harvestable biomass for an area affected by polynuclear aromatic hydrocarbons (PAHs) etc (Paulson *et al.* 2003). Figures 4.4 and 4.5 illustrate this concept, and show how this biomass based re-use of land can be integrated with a range of other sustainable development activities, such as the re-use of organic matter, carbon management and amenity and leisure use of restored land.

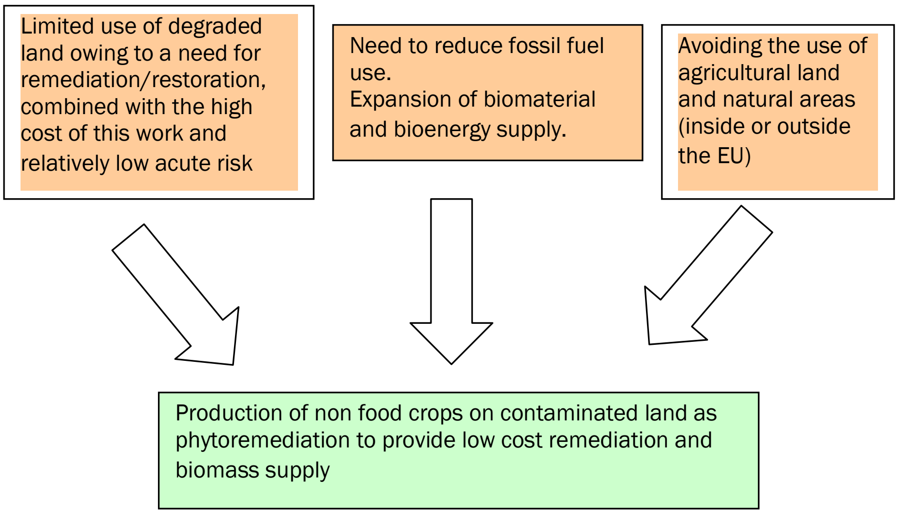


Figure 4.3: Starting Concept: *using biomass produced by phytoremediation from Andersson-Sköld et al., 2009*

However, from a risk management perspective these marginal land areas are large and may be complex. Opportunities for over-arching phytoremediation solutions might exist, but their practical feasibility is strongly dependent on site specific circumstances, so that a single phytoremediation based risk management approach may only be suitable for a limited number of situations. For example, a former mining area will include zones with potentially acute problems demanding an immediate risk management response, with other areas with limited land uses by reason of topography, soil condition and/or levels of contamination. As a result, the biomass based re-use of marginal land should also encompass how biomass might be produced on marginal land where the risk based land management might be undertaken by a variety of means, and not depend solely on phytoremediation, as described in Section 4.2.

25 See EUGRIS: http://www.eugris.info/EUGRISmain.asp?EUGRISID=48&Category=Content_Digests

26 See http://www.forestry.gov.uk/fr/INFD-5WQDCD

Phytoremediation is the direct use of living green plants for *in situ* risk reduction for contaminated soil, sludges, sediments and groundwater (ITRC 2009, McCuthceon and Schnoor 2003, US EPA 2000 and 2005). Phytoremediation also re-establishes a vegetative cover at sites where natural vegetation is lacking due to high metal concentrations in surface soils or physical disturbances in superficial materials, which may be supported by amendments to reduce metal toxicity to plants (Leggo *et al.* 2006, Nwachukwu and Pulford 2008). Restoring vegetation to sites decreases the potential migration of contamination through wind erosion transport of exposed surface soils and leaching of soil contamination to groundwater (US EPA 1999b). Phytoremediation is seen as offering a cheap and low input method for remediation of areas that are not candidates for conventional regeneration. The optimal conditions indicating an opportunity for phytoremediation are large land areas with low or intermediate contamination (McCuthceon and Schnoor 2003, Raskin 1994, SUMATECS consortium 2008). Phytoremediation can be used as an adjunct to other remediation methods to deal with contamination "hot-spots". The principal types of phytoremediation processes are summarised in Table 4.1.

Table 4.1 Phytoremediation Process Variants (From Nathanail *et al. 2007*)

Phytoextraction	Use of plants that accumulate contaminants in harvestable biomass. Hyper-accumulators are plants that can accumulate metals to % levels of dry matter, mainly Cruciferae. Few commercially practical types exist. More common is the use of woody biomass such as willow and poplar. A few trials have been carried out using chelating agents such as Ethylene-Diamine-Tetra-Acetic (EDTA) to flood soils and so increase metal availability, and hence uptake, by plants such as Indian Mustard (Bardos *et al.* 2001)
Phytovolatilisation	Use of plants for extraction of volatile contaminants from shallow aquifers which are dispersed to atmosphere by the aerial parts of the plants.
Phytostabilisation	Immobilisation of contaminants in soil and groundwater in the root zone and/or soil materials. Immobilisation may be a result of adsorption to roots and/or soil organic matter (e.g. of PAHs), or precipitation of metals. These effects may be a direct effect of plant growth, or result from soil microbial and soil chemical processes caused by root growth. The net effect is to reduce contaminant mobility.
Phytocontainment (alternative covers)	Use of plants and cultivation techniques (such as the regular addition of organic matter) can increase depth of topsoil, which can establish a cover layer over sites, such as spoil heaps and on landfill caps and reduce the migration of contaminants. Plant growth and organic matter addition may also produce a stabilisation effect, e.g. by controlling pH and redox conditions in the subsurface and phytostabilisation effects described above. Phytocontainment may also interrupt contamination of aquifers by percolating water, through interception of water by plant roots (although this effect is seasonally dependent).
Phytodegradation	Degradation of organic contaminants through plant metabolism, which may be within the plant (by metabolic processes) or outside the plant (through the effect of enzymes or other compounds that the plant produces).
Phytostimulation/ biostimulation	Stimulation of microbial biodegradation of organic contaminants in the root zone, e.g. the roots provide conditions favouring microbial establishment and activity; this microbial activity results in the degradation or stabilisation of organic contaminants.

Phytoremediation is seen by some researchers as having important advantages as a risk management tool, because it is low maintenance and relatively cheap, and has the potential to produce a fertile and usable soil (Suthersan, 2002). In addition, as an *in situ* treatment it avoids excavation of soil and disposal to landfill of soils or *ex situ* treatment residues (Marmiroli, 2003). The limitations of phytoremediation are that it is relatively slow, and can only be applied in conditions that can sustain plant growth, and the remediation effect is largely limited to the rooting depth of the plants (Huang *et al.*, 1995, Suthersan, 2002, Marmiroli, 2003). Where plants have accumulated contaminants they may provide a source for contaminants to move through the food chain in the local ecology.

Combining biomass recovery with phytoremediation has so far been largely limited to phytoextraction, and a number of small to large scales trials have been and are being carried out (Biorew Consortium 2002, Environment Agency 2002, French *et al.* 2007, Lord *et al.* 2007 and 2008, Vangronsveld *et al.* 2009, Greger and Landberg 2003, Keller 2006, EPA 1999, White et al, 2005, Federal Environment Agency 2000), generally with willow SRC on metal contaminated sites, including radionuclide contaminated sites (Dutton and Humphrys 2005). Maize has also been tested (Vangronsveld *et al.* 2009). These projects typify both the promise and the problems of biomass on marginal land. The phytoextraction is not a particularly effective form of “source removal” as the amounts accumulated by the willow biomass are small and vary depending on biomass cultivar, leading to projected treatment times in the order of decades (Environment Agency 2002, Vangronsveld *et al.* 2009). In addition, the treatment effect is unlikely to be complete, for example materials not penetrated by the rooting system, such as inside solid fragments or material outside the rooting zone, will not be treated. Hence the risk management performance is limited. Additionally the harvested biomass contains elevated levels of metals, which may mean in many countries it would be designated as a “waste” and could only be used in specialised facilities with appropriate licensing and permitting. This could greatly reduce the revenue generating capacity of the biomass (Bardos *et al.* 2001, Andersson-Sköld *et al.*, 2009, Haensler 2003). Grain types commonly used to produce biofuel, such as wheat and rape seed, also appear to have elevated metals when grown in soils amended with metal containing composts (Zhang *et al.* 1998, Lubben 1995).

Biomass types vary in the extent to which they accumulate contaminants such as potentially toxic elements. Combining biomass with stabilisation, biostimulation and containment, and seeking biomass types that tend to exclude rather than accumulate contaminants seems more likely to yield usable biomass. To date this approach, although it has been considered (AEA and r3 2004), has yet to be tested at field scale. Figures 4.4 and 4.5 illustrate this concept. An important unknown is the extent to which the harvested biomass will contain undesirable substances. Discussions with stakeholders in Germany, Sweden and the UK undertaken by the Rejuvenate team indicate that concerns about contaminants in biomass, and how such biomass would be regulated, are hurdles to investment in biomass on marginal land, along with a lack of well documented case studies.

It seems likely that the site management approach needed is one which relies on a wider risk management approach, for example generation of a “clean” soil horizon and the immobilisation of contaminants in the original surface materials. It may also be useful to consider a wider range of biomass types, which either tend not to accumulate metals in their usable parts or where contaminants will be removed by downstream processing (although this will likely liberate a waste product). This point of view does not necessarily reflect the position of all phytoremediation researchers. A parallel SNOWMAN project concluded that phytoextraction was suitable for removal of metals from sites with low levels of metal contamination (SUMATECS Consortium 2008). However, it would at least seem prudent to consider the likely market and regulatory position for biomass harvested from phytoextraction projects at an early stage of project planning before substantial resources are committed.

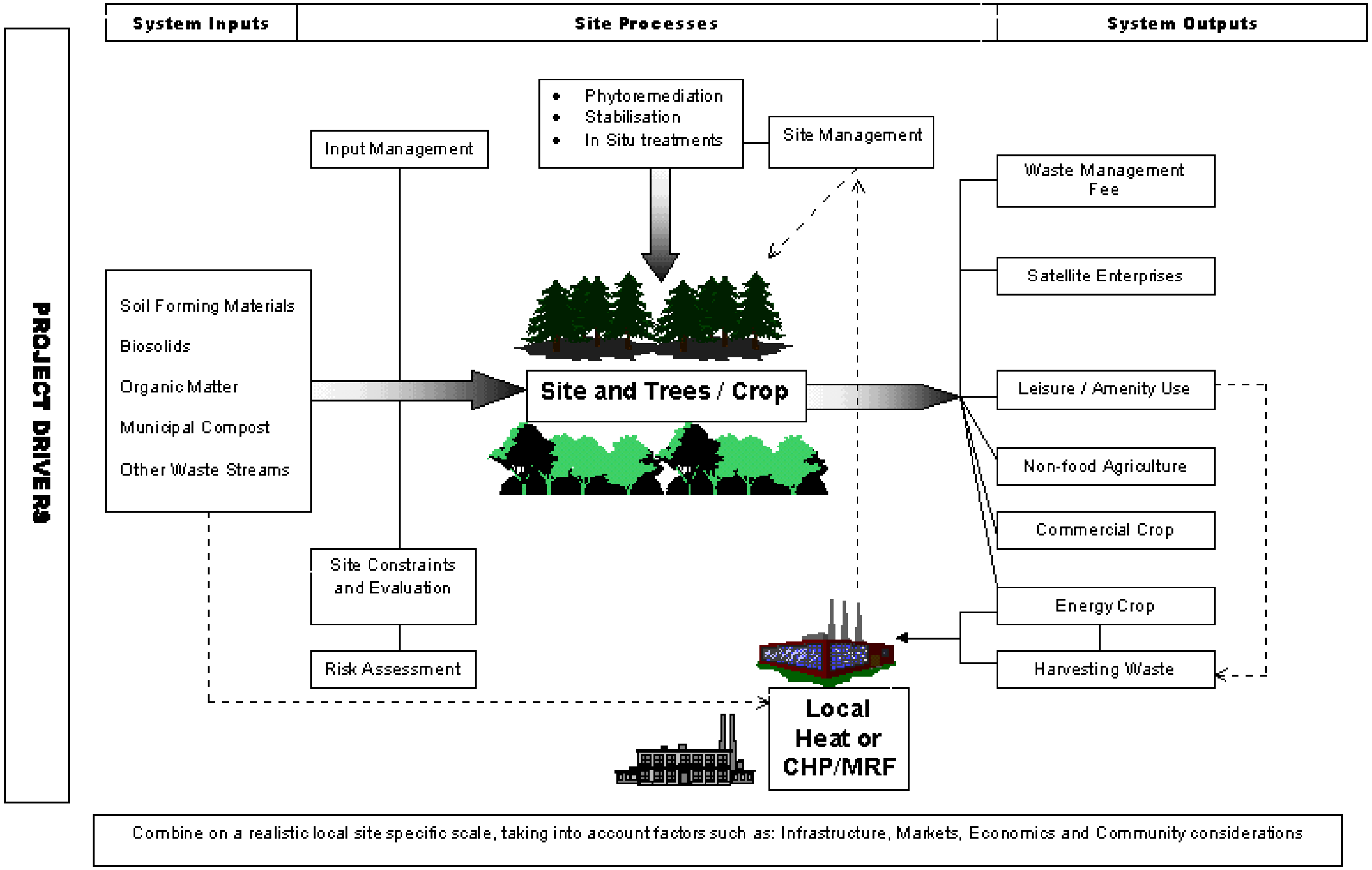


Figure 4.4 Phytoremediation and biomass concept based on SRC Part 1: inputs and outputs (Bardos *et al.* 2001)

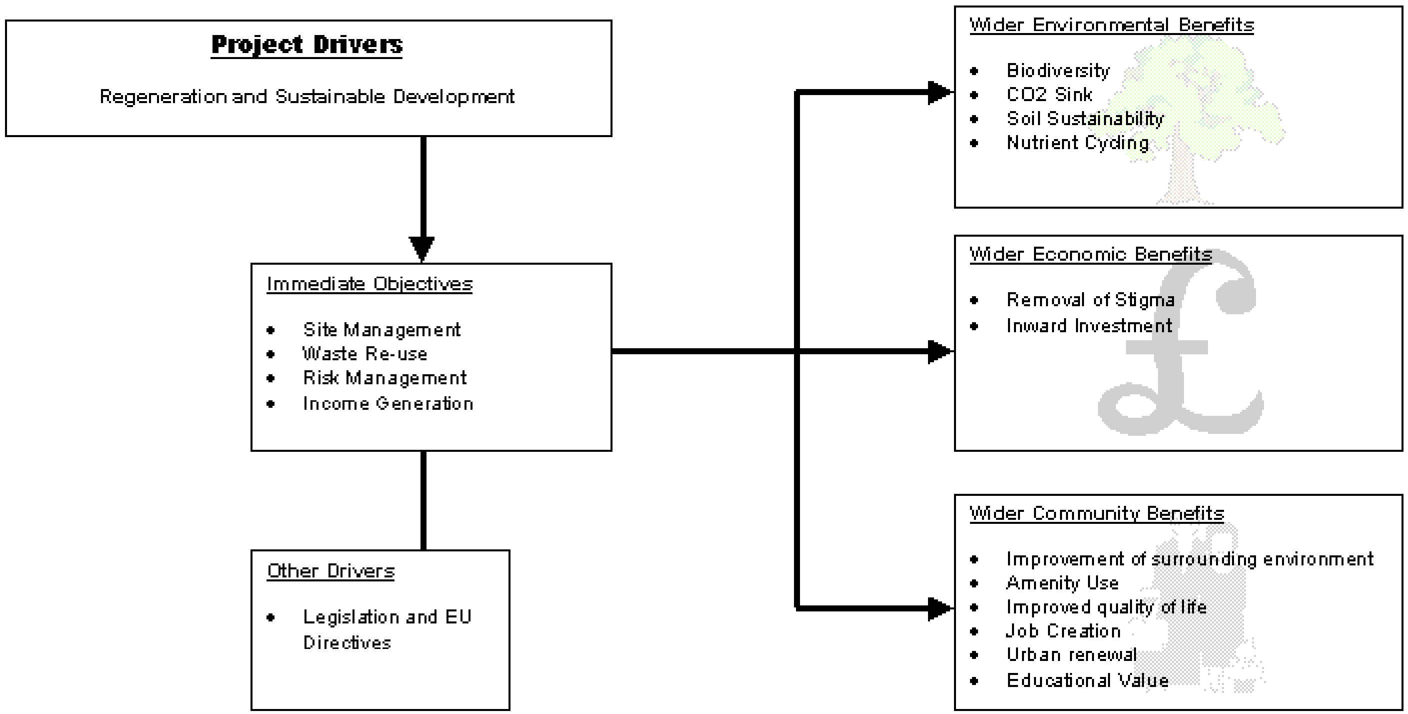


Figure 4.5 Phytoremediation and biomass concept based on SRC Part 2: sustainability (Bardos *et al.* 2001)

4.2 Biomass production where biomass is not necessarily from phytoremediation

In phyto-extraction, biomass removal is an explicit part of the risk management process (as described in Section 4.1). However, it is also possible that biomass production is simply a part of the envisaged future land use, with risk management being achieved by other means, or it may be one part of several risk management actions for example managing pathways by assisting with containment and stabilisation of contamination[27]. It is possible that several risk management strategies may be employed across a site producing biomass, some of which are mediated by plants, some of which are not. This *decoupling* of biomass production from risk management would increase the range of possible biomass production uses of marginal land.

The technical components of a biomass on marginal land project (see Figure 4.6) include the biomass crop and its cultivation; the development and management of the soil on the land to be used for the biomass production; the management of any risks associated with the marginal land use for biomass; the utilisation of the biomass and sustainable development. These components will tend to be inter-linked and will have to be considered in an integrated way.

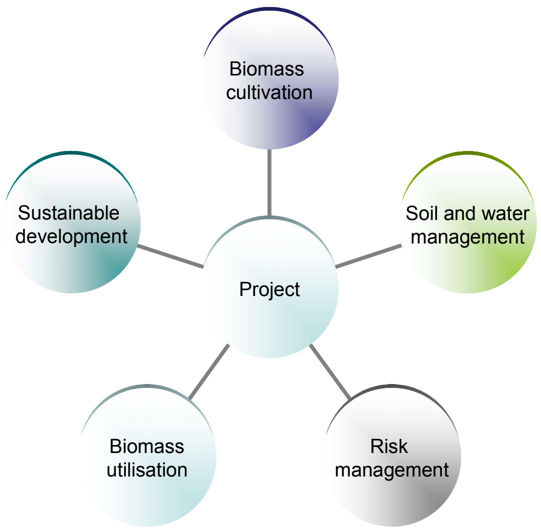


Figure 4.6 The technical components of a biomass on marginal land project

4.2.1 Biomass cultivation

Table 4.2 lists temperate biomass (and fibre crops) that might be considered in the UK, Germany and Sweden along with sources of further information and their key properties. From a cultivation point of view, the selection of a suitable crop will depend on local climatic conditions (which will vary from site to site even within a region) and the topography and size of the marginal land area. Climatic conditions may be seen as limiting, for example owing to temperature[28] or levels of rainfall.

Initial screening of biomass opportunities for economic viability is strongly dependent on local conditions. Some key recent biomass market references include:

- Important sources of market information for potential biomass use in Germany include: •Fachagentur (Nachwachsende Rohstoffe 2006), Fachagentur Nachwachsende Rohstoffe (2007a and 2007b)
- In Sweden forestry is one of the largest economical sectors and the Swedish Forest Agency is the Government's expert authority on forests and forest policy with the mission to work for a sustainable

[27] Note, in the US the idea of powering remediation processes by biomass in some circumstances is under consideration (US EPA 2008).

[28] Interestingly, a comparison of short rotation coppice (SRC) in the south of Sweden (Skåne) versus further north (700 km) did not find a poorer productivity at the northern site (Lundström and Hasselgren, 2003).

utilisation of the Swedish forests. The Swedish forests already play an important role as a domestic renewable energy resource, creating employment - especially in rural areas. Almost 50 percent of the total harvest from the Swedish forests is used in energy generation. Of this large quantities come from the by-products of the forest industry (Swedish Forest Agency, 2007). Currently biomass provides more than 18% of the total energy production in Sweden. The main biomass sources are (Energiläget 2007, Formas, 2007): wood (wood, bark, sawdust and energy forest); pulping liquor and pine tree oil from the pulp industry (tall oil pitch); peat; waste and ethanol (pure to the industry and for mixing in 95 octane petrol and other fuels E85 and E92). There are several national initiatives and activities promoting bioenergy and other alternatives to fossil fuel. Below some examples of the present ongoing activities are listed (Energiläget 2007) and further details and examples are presented in Andersson-Sköld *et al.*, 2009: heat and electricity (renewable electricity certificates, aid for conversion from electric and oil-fired heating system, aid for energy efficiency and renewable energy in public places) climate investment programmes (phase out fossil fuel)

- Important sources of market information for potential biomass use in the UK include: Defra 2005a, 2005b, 2008c, 2009c, and Defra *et al.* 2007. Yields of biomass depend on soil quality, water availability, site situation and climate. French *et al.* (2006) found yields of *Populus* cv. Ghoy and Trichobel on degraded, derelict sites in the North West (e.g. derelict allotments with neglected grassland and scrub, a former landfill site and intensively managed amenity grassland) to be 3.8 and 6.0 oven-dry tonnes (ODT) ha^{-1} yr^{-1} respectively. Yields of several *Salix* cultivars were higher, ranging between 4.2 ODT ha^{-1} yr^{-1} (Calodendron cultivar) up to 7 ODT ha^{-1} yr^{-1} (Orm and Coles cultivars). These yields are approximately 2/3 yields of these cultivars in UK commercial SRC plantations e.g. 6.45 and 9.08 ODT ha^{-1} yr^{-1} for *Populus* Ghoy and Trichobel respectively and 8.33, 7.14 and 9.31 ODT ha^{-1} yr^{-1} for *Salix* Orm, Germany and Tora respectively (Aylott *et al*, 2008), with similar patterns of mean yields across species and cultivars. Biomass yields on contaminated land tend to be lower than yields achieved on more favourable soil conditions of agricultural land. Therefore it would be beneficial to amend the existing degraded soils to improve conditions for plant growth. For example, yields of willow and Miscanthus grown on un-amended cement quarry soils were low (38.3 and 39.6 kg $dmha^{-1}$ respectively) however increasing applications of co-composted green waste and bio-waste fines increased yields up to 67.0 and 39.1 kg $dmha^{-1}$ respectively (ADAS, 2008). Miscanthus can however yield an average of 12.8 t ha^{-1} when grown on UK arable land (Richter *et al*, 2008).

4.2.2 Soil and water management

Soil in a marginal land area may need to be made suitable for the crop cultivation, for example they need to be of adequate structure, depth and fertility. Soil and cultivation requirements will vary from crop to crop, key parameters are summarised in Table 4.3 (above). Crop requirements for nutrients will include: nitrogen (N), phosphorous (P), potassium (K), magnesium (Mg), calcium (Ca) and sulphur (S) and a variety of trace elements. Conventionally these are supplied as mineral fertilisers; however compost or other recycled organic matter may substitute for mineral fertilisers to reduce the use of primary resources and fossil fuel based inputs (WRAP 2008). Dickinson *et al.* (2005) describe a range of indicators of soil health for use in the reclamation of brownfield land, which is somewhat wider than indicators under review by the Environment Agency (Environment Agency 2006).

Soil management also needs to take account of the impacts of site management, including the preparation for and maintenance of crop production. These impacts can include compaction, oxidation of soil organic matter and soil losses. Some arable biomass crops, such as sugar beet, may be associated with large losses of soil through harvesting (Ruysschaert *et al.* 2007). Addition of compost and other forms of recycled organic matter to soil may also help improve its physical and biological properties enabling, for instance, better water supply and nutrient buffering for crops, as well as improving the ease with which soil can be cultivated (Foley and Cooperland 2002, Golabi *et al.* 2007, Melero *et al.* 2007, Pagliai *et al.* 2004, Stukenholtz *et al.* 2002, Tejada *et al.* 2008). A recent European demonstration project in Sweden and Finland has trialled the recycling of wood ash to improve the “sustainability” of bioenergy production (RecAsh Consortium 2007). For some crops (for example willow) it may be possible to entirely substitute composts for mineral fertilisers because of their relatively low carbon requirements (Adegidi *et al.* 2003). Chapter 5 discusses organic matter soil improvers in more detail.

Table 4.2 Example Major Biomass Crop Types (including biofuel, biofeedstock and fibre crops)

Crop Type	Application and crop portion used	Species	Climatic and topographical suitability	References
SRC biomass	Harvested woody biomass, may be combusted directly from domestic to industrial scales, thermally converted to gas. C*urrent research and demonstration efforts focus on* its use a feedstock for second generation biofuel or biofeedstock.	Willow (SRC) and Poplar (SRC)	Both SRC Willow and Poplar share similar climatic and topographical suitability. Will produce good yields where moisture levels remain available within 1m of soil surface. Therefore will tolerate a range of climatic conditions but not areas with low soil moisture availability. Ideally should be grown on a medium textured soil with good moisture retention that remains well aerated. Ideal annual rainfall between 600-1000mm. Can be cultivated on slopes ≤15% however most suitable slope for harvesting machinery is ≤7%. Can withstand seasonal flooding but not permanent water-logging (which is also highly unsuitable for heavy machinery and harvesting becomes unfeasible). SRC cultivation requirements are detailed in Table 4.3.	Defra (2004b) Tubby and Armstrong (2002)
Grasses and straw	Straw may be combusted as briquettes from domestic to industrial scale. Otherwise harvested biomass may be combusted directly, thermally converted to gas. C*urrent research and demonstration efforts focus on* its use a feedstock for second generation biofuel or biofeedstock	Miscanthus (China Reed, Elephant Grass)	Originates from East Asia. Grows well in cool temperate climates although late Spring frosts can damage yields. Does not grow below 6^{o}C. Growth of *giganteus* from dormant winter rhizome occurs when soil temperature reaches or exceeds ~9^{o}C. Tolerates a range of climatic conditions although productivity is limited in temperate regions if emergence is late but earlier emergence may be susceptible to frost damage. Requires a consistent ample supply of water however it has a high water-use efficiency (C_4 metabolism).	Defra (2007c) Farrell *et al.* (2006) Karp and Shield (2008) RHS (1992)
		Switchgrass	A warm-season grass native to the USA. Grow across a wide geographical distribution, from central Mexico to 55^{o} northern latitude. Also C_4 like Miscanthus, therefore has a high water-use efficiency. There are both upland and lowland ecotypes, however lowland ecotypes require longer growing seasons.	Karp and Shield (2008) RHS (1992)
		Reed Canary Grass	Native to temperate regions of Europe, Asia and North America. Favours moist, cool climates with average mean winter temperatures ≤ 7^{o}C and mean summer temperatures ≤ 27^{o}C. Can be cultivated in climates and soils outside of range if managed.	Klages (1942)

Fibre	Harvested biomass may be combusted directly, fibre may be used in manufacturing	Hemp	Tolerates temperatures > 1°C with a land sloping < 10%. Grows under 700m elevation above sea level. Requires a mild, humid climate and a highly fertile soil, in particular calcareous soils.	Hanf-Faser-Fabrik, Hompage (2009)[29] Klages (1942)
		Linen (Linseed)	(Fibre flax) Demands moist, cool weather during early part of growing season (March-June), followed by warm and relatively dry climate early summer. Extreme rainfall (e.g. storms) can be detrimental to crop due to lodging (produces poor quality fibre). Optimal climatic conditions allow production of long stems, producing the most desirable fibre. Grown extensively in temperate and tropical regions. Cultivation of linseed is confined to lower elevations but can be grown up to 770m above sea level. Rainfall requirement ranges between 450-750mm. Fibre crop does well in cool, moist climates whereas seed crop thrives in moderately cold climates.	Klages (1942) Krishiworld website[30]
		Nettle	Tends to grow >25m elevation. For cultivation requirements please refer to Table 4.3	Nettle World, Homepage (2009) – follow link in Table 4.3 RHS (1992)
Grain	Bioethanol and biodiesel. Straw *may* be used as biomass	Barley used for bioethanol	Native to Northern temperate climates, mainly in open and dry habitats. Natural populations exist in the Middle East 'fertile crescent', extending from Jordon Valley Northward to Antolia-Syria border and along the Iraq-Iran borders. Able to mature in shorter seasons than other crop commodities. Demands moderate temperatures and an abundant supply of moisture. Can grow at relatively high elevations (up to 2100, even 3000m). The Northern limit of production is 65° latitude in Russia. Climatic factors influence malting quality and disease prevalence. Managed (irrigated, fertilised, pest/weed-controlled) according to local climatic conditions.	Klages (1942) Sauer (1994) Wilsie (1962)
		Maize - bioethanol	Originated in the Middle Eastern 'fertile crescent' along with Wheat and Barley. Subject to a millennia of improvement by man however most significant advances during 'green revolution' 1960-80's. Best adapted to long and warm growing seasons (18-24°C, remaining above 14°C during the night) with relatively ample annual precipitation (≥ 890mm) and grown from 40° South to 58° North. In the tropics, Maize is grown from near sea	Karp and Sheild (2008) Klages (1942) Wilsie (1962)

[29] http://www.hanffaser.de

[30] http://www.krishiworld.com/html/comm_crops7.html

			level to elevations up to ~4000m. Cultivated worldwide and managed (irrigated, fertilised, pest/weed-controlled) according to local climatic conditions. For cultivation requirements refer to Table 4.3.	
		Oil seed rape (canola) - biodiesel	Native to the winter rain Mediterranean regions, growing in rocky, open habitats. Have now expanded Northward into Europe and Eastward into Asia. Managed (irrigated, fertilised, pest/weed-controlled) according to local climatic conditions. For cultivation requirements refer to Table 4.3.	Sauer (1994)
		Sugar Beet - bioethanol	Demands a temperate climate with mean summer temperatures ~21^{o}C with a dry autumn. Also requires a uniform availability of moisture provided either by natural precipitation or by irrigation. Originally a European crop, developed for manufacture in the 18th Century and by 1900, European sugar beet production almost matched world-wide sugar cane production. Now produced across the globe.	Klages (1942) Sauer (1994)
		Wheat - bioethanol	Originated in relatively dry Caucasus-Turkey-Iraq and Afghanistan-West-Central-Asiatic areas, the fertile crescent of the Middle East. Cultivated and adapted worldwide (40^{o} South to 60^{o} North latitude), most extensively in continental grassland climates. Prefers moderate temperatures but can grow successfully in a range of humidity and temperature if managed. Grows in multiple climates where there is a cool, moist growing season followed by dry, warm ripening season. Poorly adapted to consistently hot areas due to disease and storage difficulty. Managed (irrigated, fertilised, pest/weed-controlled) according to local climatic conditions.	Wilsie (1962) Klages (1942) Karp and Shield (2008)

Table 4.3 Indicative Soil Requirements for Example Major Biomass Crop Types

Crop	Soil Requirements	NPK Fertiliser requirements[31]	Lifespan	Cultivation requirements
Willow (coppiced)	Can establish on a wide range of soil types from heavy clay, sand through to reclaimed land. Ideal soils are clay or sandy loams that retain moisture but remain well aerated. pH 5.5-7 (Defra 2004b; Tubby and Armstrong 2002)	200 kg Nitrogen (N), 80 kg Phosphorus pentoxide (P_2O_5), 120 kg Potassium oxide (K_2O), 40 kg Magnesium oxide (MgO) and 240 kg Calcium oxide (CaO)	>20 years (Abrahamson *et al*, 1998)	Soil preparation, planting for example as "rods", coppicing at the end of year one to encourage multiple stems, coppicing every 3 or 4 years subsequently. May require weed control measures and annual soil improver dressings (Paulson *et al.* 2003)
Poplar (coppiced)	As for willow however prefers soil pH between 5.5-7.5 and more fertile, deep soils (Defra 2004b; Tubby and Armstrong 2002)	See willow	Circa 25 years	As for willow
Miscanthus (China Reed, Elephant Grass)	Low to medium grade agricultural quality soil. Prefers well drained fertile soils[32], however free-draining soils or elevated northerly sites are limiting (MAFF, 1988). Soil pH optimum range 5.5-7.5 but toleration exceeds this range (Defra 2007c)	150 to 180 kg K_2O/ha, 30 bis 50 kg P_2O_5/ha and ca. 30 kg MgO/ha	Circa 20 years	Established from rhizome cuttings planted in May at densities of 10-20,000 ha^{-1} (MAFF, 1988). Requires planting to a depth of 10cm into a fine seedbed and will require careful weed management during establishment (first 2-3 years) due to the 1m wide planting gaps[33].
Switchgrass	Hardy plant, adapted to a range of soils and climates, however it is easier to establish on loamy or sandy soils than clay soils (as clay takes longer to warm in the	Fertilisation not recommended during establishment year as this encourages weed competition (George *et al*, 2008). Response of established switchgrass stands to N additions	Circa 10 years (depending on appropriate management) (George *et al*, 2008).	Can yield well at southerly locations although reliable establishment techniques not fully developed (DTI, 2006). Successfully established using conventional tillage and drill planting, no-till planting into crop stubble or pasture or frost seeding (Rinehart, 2006). Plant 4.5-12 kg seed

31 In general crops require a wider range of nutrients including Mg, Ca, S and trace elements. Specific fertiliser requirements can be found in agricultural handbooks such as MAFF 2000

32 www.findmeplants.co.uk

33 http://www.ukagriculture.com/crops/Miscanthus.cfm

	spring and clay lumps reduce seed-soil contact) (George *et al*, 2008).	is only likely in sandy soils or soils with little previous fertiliser input (George *et al*, 2008).	Does not reach full productivity for 3 years (DTI, 2006).	per ha at depth of 0.25-0.5 inch (Rinehart, 2006).
Reed canary grass	Tolerate soil pH range 4.9-8.2, well adapted to wet soils and also productive on upland sites (Sheaffer *et al*, 1990).	Requires N fertiliser for full yield potential to be reached (DTI, 2006). Will respond to N fertiliser (annual applications between 110-165 kg ha N) and to a lesser extent potassium (K) and phosphate fertilisers (Sheaffer *et al*, 1990).	Commercially productive within 2 years and has a productive life of between 5 and 7 years, after which productivity declines and the crop requires re-sowing[34].	Seed mid April to early June, apply 9-12 kg seed per ha, between 0.25-0.5 inches below soil surface (Sheaffer *et al*, 1990). Does better at more northerly latitudes and requires careful pest management (DTI, 2006), especially during establishment (Sheaffer *et al*, 1990). Seed into a well prepared damp seed bed prepared to a fine tilth, with an even surface[16].
Hemp	Prefers loamy soils with approx. pH 7[35]	Phosphorous (P) 25-35 kgP/ha; K: 40-80 kgK/ha; 30-60 kgN/ha Fertiliser is best applied to the seedbed[17].	1 year	Seed rate approx. 25kg/ha with drill depth 2.5cm, with row spacing approx. 18 inches. Seeds should be sown from mid April to end of May, giving a mid August to early September harvest. Crop is harvested using a standard combine Little weed control is required as plant is fast growing[17].
Linen (Linseed)	Suitable to a range of soil types[17].	Compound fertiliser applied in March followed by N fertiliser in April[36]. N 60-90 kg ha with maintenance dressings of phosphate and potash[17].	Annual crop (spring sowing)	In the UK populations of around 550 plants per square metre are normally established from sowing rates of around 700 viable seeds per square metre. Best seed emergence results from a fine tilth seedbed. Careful weed management is required during establishment of young crops[37]. Land ploughed in November for March cultivation and April drilling. Weed control usually required in May. Crop desiccated pre-harvest in August for harvesting in September[38]. Harvesting of desiccated crop is done using a combine harvester with specially adapted stripper

34 www.walesbiomass.org

35 http://www.york.ac.uk/org/cnap/oilcrop/cropsind/linseed_agro.htm

				heads[19].
Nettle[39]	Moist soils. Nettles are not tolerant to dry and light soils or prolonged periods of moisture.	Currently unknown for cultivated plants however fertilisation requirements are likely to be further investigated.	>7 years with optimal yields after 3 years. Yield increases with time.	Cuttings planted in May-June or Sept-Oct using cabbage planters. Cuttings are placed in rows ~ 0.75m apart.
Barley[40]	Medium to high grade agricultural quality soil pH Max. 6.5 (MAFF, 1988)	Winter barley (spring dressing) 160 kg ha N on mineral soils, 90 kg ha N on organic soils (MAFF, 1988). Spring barley 125 kg ha N on mineral soils, 70 kg ha N on organic soils (MAFF, 1988). For 10 t ha yield, require 130 kg ha P_2O_5 and 110 kg ha K_2O (MAFF, 1988).	Annual crop (1 year, winter and spring sowings)	Direct drilling, pest and weed management, May fertiliser addition, combine harvesting
Maize	Medium to high grade agricultural quality soil PH-Value 5.5	60 kg ha N (applied to sed bed), 80 kg ha P_2O_5 and 180 kg ha K_2O (autmn application primarily for maintenance as response is small) (MAFF, 1988).	Annual crop (1 year, winter and spring sowings)	Direct drilling, pest and weed management, May fertiliser addition. Mechanised harvesting of maize is done with corn-pickers, corn-shellers or combine-harvesters[41]
Oil seed rape (canola)	Medium to high grade agricultural quality soil pH Max. 6 (MAFF, 1988)	Spring sown: 187 kg ha^{-1} N and has little requirement for K (Holmes and Ainsley, 1977). High potash demand in spring (may	Annual crop (1 year, winter and spring sowings)	Direct drilling, pest and weed management, May fertiliser addition. Oil seed rape may be harvested by desiccation (spraying to kill the plant evenly), swathing/windrowing (cutting the plant and

36 http://www.ukagriculture.com
37 http://www.ienica.net/crops/linseed.pdf
38 http://www.ukagriculture.com/production_cycles/linseed_production_cycle.cfm
39 Nettle cultivation for biofuel is currently under development in Germany. For information, visit the translated web page:
http://translate.google.com/translate?hl=en&sl=de&u=http://www.nettleworld.com/page.php%3Fid%3D14&sa=X&oi=translate&resnum=9&ct=result&prev=/search%3Fq%3DNettle%2Btextiles%26hl%3Den%26lr%3Dlang_de%26client%3Dfirefox-a%26channel%3Ds%26rls%3Dorg.mozilla:de:official%26hs%3DSol%26sa%3DG%26pwst%3D1
40 Agricultural crops such as wheat, barley, sugar beet etc are typically grown in rotation, so that several crops are grown on the same area of land over succeeding years to reduce problems with pest and weed management
41 http://www.fao.org/docrep/T0522E/T0522E05.htm

		reach 12 ka ha^{-1} day) (PDA, 2006) Winter oilseed rape (spring dressing) 200-240 kg ha N on mineral soils, 100 kg ha N on organic soils, 100 kg ha P_2O_5 and 90 kg ha K_2O (MAFF, 1988). Spring oilseed rape 150 kg ha N, and 75 kg ha for P_2O_5 and K_2O (MAFF, 1988).		leaving it on the stubble to dry) or direct cutting with a combine harvester[42].
Sugar Beet	Medium to high grade agricultural quality soil pH Max. 6.5 (MAFF, 1988)	125 kg ha N on mineral soils, 75 kg ha N on organic soils, 100 kg ha P_2O_5 and 200 kg ha K_2O (when applied with Na, otherwise 300 kg ha) (MAFF, 1988).	Annual crop (during spring to autumn) – crop rotation with Winter Wheat	Seeds are sown from early March in rows 50cm wide with typical spacing of 18cm at depths 2.5-3.0cm in the soil[43].
Wheat	Medium to high grade agricultural quality soil pH Max. 6 (MAFF, 1988)	Winter wheat (spring dressing) 175 kg ha N on mineral soils, 90 kg ha N on organic soils (MAFF, 1988). Spring barley 150 kg ha N on mineral soils, 70 kg ha N on organic soils (MAFF, 1988). For 10 t ha yield, require 130 kg ha P_2O_5 and 110 kg ha K_2O (MAFF, 1988).	Annual crop (1 year, winter and spring sowings)	Direct drilling, pest and weed management, May fertiliser addition, combine harvesting

[42] http://www.farm-direct.co.uk/farming/stockcrop/rape/

[43] http://www.ukagriculture.com/crops/sugar_beet_farming.cfm

In some cases the marginal land will not have a functioning soil, in which case a series of "soil forming" interventions will need to be carried out. Soil-forming materials substitute for, or supplement, natural soils in the course of land reclamation. The material should, with appropriate surface treatment and the use of amendments as necessary during the period of aftercare, be capable of sustaining the required vegetation beyond this term by the implementation of normal management practices. Soil forming requirements will be site specific but may include the need for addition of stony or aggregate materials or other major mineral components, and/or organic matter (Bending *et al.* 1999, Foot and Sinnett 2006). For example a landfill surface may have been completed using clay rich subsoil which will not only have poor nutrient status, but may also prevent the physical growth of plant roots and may also have very poor drainage. In this circumstance it may be necessary to "form" distinct subsoil and topsoil layers. The top soil is of course not fully formed, as this process occurs only over time as a result of the effects of cultivation and plant growth. However, the surface must be capable of supporting adequate plant growth in the first instance. Physical interventions may also be necessary to deal with compaction problems in the subsoil, which has a particularly deleterious effect on tree growth (Defra 2006c).

Landfill surfaces are a special case as it will also be important that the biomass crop does not damage the landfill cap and create a migration route for hazardous levels of methane to the surface (US EPA 2006). However, a good restoration will be protective of the cap, preventing desiccation and erosion, and also promoting the oxidation of any fugitive emissions of methane. Biomass production (as SRC) has also been used as a means of treating landfill leachate, with water removal by transpiration and treatment of leachate substances within the biomass root zone. The regulatory context for this form of leachate treatment is complicated as it is affected by several EU Directives (Environment Agency 2008a).

Where compost or recycled organic matter is being used for soil forming or soil management, it is important to ensure that it is fit for purpose, and that any potential contaminants (such as toxic elements, trace organics, sharps, weed seeds or pathogens) are properly managed and considered in the overall risk management of the site being used for biomass (discussed below). Using recycled materials that comply with nationally recognised quality standards minimises both any potential organic matter risk management needs, and also to secure regulatory advantages (such as PAS-100 in the UK[44] - WRAP 2005, or the Swedish Waste Management quality label SPCR 152 - SP Technical Research Institute 2007). For example in the UK PAS-100 composts can also be eligible to comply with a "Quality Protocol" (WRAP 2007b) which means that they are no longer regarded as a waste and so are free from waste permitting and licensing requirements.

A biomass crop will impact the water environment. For example, some biomass crops may have heavy water demands (Dominguez-Faus *et al.* 2009) which may affect groundwater or surface water recharge, or indeed require water resources for irrigation. Biomass production may also impact groundwater and surface water by changing inputs of plant nutrients (see Section 4.2.6). Water balance and quality are important considerations in terms of environmental impact and overall sustainability. SRC willow has a very high water demand (Hall 2003). In most cases irrigation is not feasible so planting needs to be in locations where there is adequate rainfall, or readily available soil water, or both. However, evapo-transpiration demand may also be exploited in some circumstances for risk management. For example, poplar trees have been used for the removal of volatile organic compounds from groundwater (US EPA 2003), although this effect might be seasonal. Willow SRC irrigation has been used for landfill leachate treatment (Duggan 2005). Untreated sewage sludge has also been used to support biomass crop production (BIOPROS Consortium 2006). The use of renewable energy crops for wastewater polishing (removal of nitrogen and phosphorous) is also under investigation (Sugiura *et al.* 2008).

4.2.3 Risk management

The redevelopment of brownfields into greenspace, for example for amenity purposes, is well established, with a wide range of guidance available (e.g. Doick and Hutchings 2007). The redevelopment process involves the identification, evaluation, and – where necessary – management of pollutant linkages as part of the development process. Use of a site conceptual model is recommended to support this risk assessment and management activity (Nathanail and Bardos 2004).

Table 4.4 lists examples of possible sources of risk, the major classes of pathway and the types of receptor that may need to be considered. Table 4.5 overviews the most commonly used risk management methods

[44] PAS-100 is currently out for review (2009)

and their general applicability. Germany, Sweden and the UK have all produced extensive guidance about the management of land historic contamination (e.g. Environment Agency 2004 and 2009d, Franzius *et al.* 2008, Swedish Environmental Protection Agency 1999).

There are a broad range of risk management interventions that may be necessary for a particular area of marginal land. Risk management needs will depend on the exact circumstances; for example methods needed to deal with a contamination “hot spot” such as a former processing area in a mine site, will be different to those needed to deal with (say) more extensive but lower level contamination of groundwater from a mine site (US EPA 2007).

Crop cultivation and soil improvement such as the addition of organic matter and cultivation may be necessary to support biomass production. These may also provide part of the management of pollutant linkages, for example because added soil and vegetation prevent direct contact with on-site contamination and reduce dust blow as a pathway (AEA and r3 2004). The establishment of most crops will serve a risk pathway management function through containment, by covering and preventing dust blow off-site, which may be mitigating an important pollutant linkage to off-site receptors. The addition of organic matter and rooting habit of some crops may assist the generation of a new “clean” soil horizon and provide further containment and rooting zones may support enhanced microbial activity leading to contaminant degradation and immobilisation, for example the immobilisation of PAHs in humus. Cultivation and soil management may be combined with risk management interventions addition of sorbents to soil to provide *in situ* stabilisation of PTEs, using, for example, biochar[45] or bone-meal (Hodson *et al.* 2000).

Conversely, the use of the biomass produced on site, may potentially introduce new pathways by which site contaminants may reach receptors, for example increasing contaminant mobility by chelation with dissolved organic matter. These effects appear to be site and circumstance specific (Bardos *et al.* 2001, CL:AIRE 2008, Hartley *et al.* 2009, Nwachukwu and Pulford 2008, Padmavathiamma and Li 2009), depending on site conditions such as the nature of the contamination, pH and redox conditions, soil texture and sorptive capacity and the impacts of plant roots. It could well be important to either be able to demonstrate by bench and field trials that immobilisation rather than mobilisation is taking place.

Risk assessment for biomass production therefore needs to be iterative, considering both the initial conditions of the site, and also the impacts of any changes brought about by biomass production, whether deliberate such as phyto-remediation, or consequential such as contamination of biomass. For some countries (see Section 4.2.6) it may be important to select risk management strategies that do not result in accumulation of contaminants in any biomass harvested from the site.

In practice the soil and risk management and crop and its use will form an integrated system, where particular interventions may serve more than one purpose. This strategy provides flexibility in both the types of risk management interventions that might be considered, and the type of vegetation cover that might be grown.

[45] UK patent PCT/GB2008/002612. Metal adsorbing charcoals.

Table 4.4 Example sources, general pathways and key receptors for biomass on marginal land projects

Example Sources	General Pathways	Key Receptors
Former use of the site (e.g. landfill, mining etc). Extensive information is available in the UK from the DoE Industry Profiles[46] and the Model Procedures (Environment Agency 2004). In Germany information is available via the contaminated site land register of the Federal States (Federal Ministry of Environment 2004) and in Sweden from the Swedish Environmental Protection Agency (1999) Organic matter addition or use of other site amendments (see Chapter 5): • Biological risks (e.g. form animal pathogens • Chemical risks (e.g. from potentially toxic elements - PTEs or persistent organic pollutants - POPs) • Physical risks (e.g. from litter and sharp objects)	Direct contact with soil and dust Via air (including via dust) Via water Via biomass Via consumption	Water (groundwater, surface water) Products (biomass) Ecological (e.g. conservation areas., habitats) Human health (e.g. site workers, visitors, neighbours) Built constructions and services

Biomass and water can be considered both as a pathway to a downstream receptor, but also as a resource worthy of protection in their own right.

[46] Available from http://www.environment-agency.gov.uk/research/planning/33708.aspx

Table 4.5 Contaminated land risk management methods – (Nathanail *et al.* 2007, Franzius *et al.* 2008, Swedish Environmental Protection Agency 2008)

Engineering and excavation methods	**Broadly *in situ* techniques**	**Broadly *ex situ* techniques**	**Gas control measures**
Cover systems – *containment of site surfaces for example to prevent the upward migration of contaminants* Excavation and related materials handling – *removal of soils to the surface for screening and pre-processing prior to disposal or ex situ treatment, for example prior to bioremediation of PAH and hydrocarbon contaminated soil* Infilling - *re-use of treated soils or other factions (such as stones, gravel etc) to fill in void space from previous excavations or level a site, or similar use of imported materials* Off-site disposal of contaminated soil – *removal of soil and other materials to a licensed waste disposal site, for example highly contaminated tarry debris* Vertical barriers – *containment of sites to prevent off-site movement of contaminated groundwater*	Air sparging and biosparging – *injection of air into an aquifer to volatilise contaminants and stimulate* in situ *biodegradation in the saturated zone (below the water table)* Electro-remediation - *use of electric fields to collect or manage contaminants in saturated ground* *In situ* flushing (including *in situ* bioremediation) *extraction of groundwater and treating/conditioning it* ex situ *above ground, before re-injecting it into the aquifer to simulate a treatment effect* in situ *such as biodegradation* *In situ* oxidation techniques – *injection of strong redox agents into the ground to chemically oxidise or reduce contaminants* *In situ* stabilisation – *use of chemical agents that reduce the availability and accessibility of contaminants, for example use of bone charcoal or beringite* *In situ* thermal – *use of heating (for example electrically or with steam) to volatilise contaminants so that they can be recovered by venting* Monitored natural attenuation (MNA) – *exploitation and monitoring of naturally occurring processes to manage risks, primarily in groundwater*	*Ex situ* bioremediation – *engineered systems to biodegrade contaminants in excavated soil* Soil washing and related *ex situ* treatments– *engineered systems to remove contaminants from excavated soil using physical and or chemical means* Solidification/stabilisation – *mixing of amendments with soils to reduce their accessibility (solidification) or availability (stabilisation) – may also be used to improve materials handling properties (e.g. of tars_ prior to disposal* Thermal treatments – *use of heat to remove and then combust contaminants in excavated soil* Vitrification – *use of high energies to convert excavated materials into a glassy solid with very low contaminant availability (and thermally destroy organic contaminants)* *Ex situ* groundwater and vapour treatment – *a range of physical treatments (such as filtration) and chemical treatments (such as precipitation) to remove contaminants*	Dilution and dispersion of gases for buildings – *building measures such as ventilation* Dilution and dispersion of gases in-ground – *natural attenuation processes, for example methane oxidation by soil micro-organisms* Gas barriers for buildings – *impermeable membranes or other barriers that prevent the migration of gas* Gas barriers in-ground – *impermeable membranes or other barriers that prevent the migration of gas* Long-term post-construction monitoring for gases – *buildings on areas at risk from methane or radon may require regular gas monitoring*

	Permeable reactive barriers – *engineered* in situ *treatment zones to manage contamination problems in groundwater* Phytoremediation – *use of plants to achieve remediation see Table 4.1* Pump and treat - *extraction of groundwater and treating it* ex situ *above ground* Redox amendments for enhanced bioremediation – *agents injected into the ground to stimulate either aerobic or anaerobic biodegradation* in situ Soil vapour extraction/venting and bioventing - *extraction of air from soil to volatilise contaminants and stimulate* in situ *biodegradation in the unsaturated zone (above the water table)*		

4.2.4 Biomass Utilisation and Renewable Energy

Types of biomass that might be produced on marginal land will fall into one of these categories, depending on what can be produced:

- Woody materials, e.g. wood chip from SRC, forestry residues, Miscanthus
- Grains, e.g. wheat, barley, oil seed rape
- Straw and fibre, e.g. switch grass, straw, hay, fibre crops such as nettle or hemp

The principle fates of biomass are for energy or as a feedstock. Direct conversion to energy is typically to electricity and/or heat, but potentially also methane gas for distribution national networks (National Grid 2009); or via conversion to a fuel (Davies 2009). Biomass is seen as a reliable form of renewable energy compared with options such as wind (House of Lords 2008). Biomass may also be used as a feedstock for some form of manufacturing process (Evans 2009, Hatti-Kaul *et al.* 2007, HGCA 2009). Downstream manufacturing may be as raw materials for conventional manufacture, such as fine and bulk chemicals, bio plastics and oleo chemicals. Biomass conversion may also generate byproducts which may be used for energy recovery, as soil improvers or in some cases as agricultural animal feeds. Downstream processing can also include energy recovery and biochar production, which has generated great interest as a means of carbon sequestration (Lehmann and Joseph 2009).

There are two main biofuel products: alcohols which are used as substitutes for or amendments to petrol, such as bioethanol and lipids which are used as substitutes for or amendments to diesel, such as biodiesel produced from oil seed rape oil. Biofuels are described as primary or secondary biofuels (Royal Society 2008). First generation (or primary) biofuels generally use an existing agricultural commodity such as a grain or sugar beet which can also be used as foods. They are now reasonably well established products. Often they have developed from initiatives to maintain markets for food crops in the absence of other types of structural support or subsidy, for example for maize in the USA and sugar beet in the UK (Evans *et al.* 2007). Second generation (or secondary) biofuels are those where the total plant biomass is converted, e.g. production of bio-ethanol from wood chip. These are currently less well established products (OECD and IEA 2008). The OECD has suggested that governments should also boost the so-called second generation biofuels that do not use food crops (de La Hamaide 2008). As second generation biofuels are derived from residues such as straw or the entire crop biomass, e.g. including lingo-cellulosic components, they are seen as offering higher energy yield per unit land area with lower environmental impacts.

Some forms of biomass conversion may take place on-site or close to the area of production, but other opportunities may require transportation of biomass. The choice between on-site or off-site conversion will depend on the specific circumstances of the site, for example whether the site and its surroundings can produce sufficient biomass to merit investment in an onsite facility, whether the site is suitable, whether an on-site facility is more profitable than off-site sales and on the interests of the project team. Profitability of an on-site facility may be strongly dependent on the proximity of a customer for heat to allow combined heat and power solutions (CHP). Finding a use for by-produced heat from biomass conversion is seen as integral to maximising GHG emission savings, and to the long term viability of biomass conversion (Environment Agency 2009a and 2009b). The availability of off-site markets and their potential revenue generating potential will be key drivers in this decision (taking into account in particular transportation distances and costs), but also the national and policy regulatory context. For example in Sweden, support is available to promote more efficient energy and renewable energy resources, as well as climate investment programs and obligations to provide renewable fuels[47].

There is increasing interest in the use of microgeneration (including from the biomass sources) as means of supplying heat and energy to buildings or groups of buildings (NHBC Foundation 2008, RAB 2007). For marginal land restoration projects which include some built development this could create the opportunity for an “internal” biomass market. This can support aims of “zero carbon” or “carbon neutral” developments, through linkage to the biomass based re-use of the remainder of the site (for an early example see AEA Technology and r3 2004). There are also two wider synergies that projects could consider, both of which may be important in *adding value* to a marginal land re-use project (see Chapter 6).

1) Built development is often a driver for land re-use, but in some cases the built development will only occupy a portion of the site area. Using a biomass approach to provide restoration of the remainder of the site can improve the landscape surrounding the built development and hence its marketability.

[47] SFS 2005:1248)

2) Other options for renewable energy (for example wind energy) *may* be able to be situated on the same site as is being re-used for biomass production, providing a greater renewable energy opportunity overall.

The impacts of the biomass to energy conversion process need to be taken into account. For example, an emerging issue in the UK is that a proliferation of wood fuelled boilers might degrade local air quality (AEA Energy & Environment 2008a, Defra 2009d). This might lead to some conversion approaches being favoured over others, for example tending to favour biomass conversion with a high degree of emissions control, depending on the site circumstances (DECC 2009b)..

4.2.5 Sustainable Development

The overall sustainability of such schemes needs to be clearly demonstrated as part of the project preparatory process and linked to the sustainable development strategy for the particular locality the site is situated in. The rationale for growing biomass on marginal land is to provide environmental, economic and social benefits. Hence it is important that each of the components of the project (crop cultivation, soil management, risk based land management and biomass utilisation) can be shown to be sustainable, preferably individually as well as in combination. For example, issues that a project might seek to avoid are water impacts from crop cultivation and production of a biomass that is contaminated and so cannot be economically put to use. Equally, for each project there may be opportunities that could greatly improve its sustainable development value, particularly in the context of local development.

For example, a UK master-planning project for growing SRC willow on a former coal mining area identified a range of linkages which improved the projects attractiveness to funding agencies and the local authority, and also created new revenue opportunities (AEA and r3 2004). These included:

- Use of the wood chip in “wood heat” scheme to provide heat to local schools
- Development of a visitor centre (heated by wood heat)
- Linkage to green waste processing to compost on-site
- Linkage to the creation of sheltered employment opportunities by charities also making use of coppice materials and the restored site
- Improvement in local amenity and tourism by opening up a walking trail as a segment of a long distance footpath
- Managing the restored landscape as a mosaic of grassland, woodland and willow coppice to improve its amenity and habitat value (this of course reduces the available area for biomass production); and
- Links to local secondary and tertiary education for developing skills in the environmental sector.

The business model for a biomass on marginal land scheme should be wide ranging at least in its initial considerations to maximise its potential value to local sustainability, its acceptability to stakeholders and its revenue-generating potential.

4.2.6 Regulatory Domains

Biomass cultivation on marginal land is likely to engage with as many as five regulatory domains: contaminated land, waste management, water resources, agriculture and biomass conversion.

The *contaminated land* domain encompasses both environmental protection and planning controls on changed land use. The site and its biomass end-use will have to comply with the prevailing national or regional contaminated land risk management regime. However, not all marginal land will be classified as contaminated land, even although it may have been previously developed. Some examples follow.

- In the UK, restored land over a former municipal waste landfill site may be designated as previously developed land, but will not necessarily be regarded as contaminated; or agricultural land contaminated by diffuse pollution from mining or smelter fallout may not be classed as previously developed or brownfield land.

- In Sweden any land with concentrations over background level polluted by a point source is a contaminated area according to risk assessment practice. Thus, treated landfill and treated contaminated sites with pollution left in the soil are included, but not areas from mining or smelter fallout, unless they pose a significant risk to human health and are defined as contaminated area according to the Environmental Code[48].

- In Germany polluted areas are considered as contaminated if they cause harmful soil changes or other hazards for individuals or the general public. Harmful soil changes are harmful impacts on soil functions that are able to bring about hazards, considerable disadvantages or considerable nuisances to individuals or the general public. (Federal Ministry of Environment 2004).

- The Environmental Liability Directive (2004/35/EC) sets out the liabilities of those carrying out activities that may cause the threat of environmental damage, specifically damage to species and habitats, damage to water and damage to land. Mismanaged biomass use of land could risk causing environmental damage that would fall under the remit of the Directive. However, the scale of impact of this Directive is not yet known (Defra 2009b).

The Waste Framework Directive (2000/76/EC) applies to the re-use of organic matter on land across the EU, if it is considered as waste from a regulatory point of view. The Waste Framework Directive may also apply to supplementary biomass from off-site that is included in a project, for example woody wastes collected from residential and industrial sources. Not all recycled organic matter and not all biomass will be classified as waste, and this will depend on the prevailing national or regional regulatory regime. The Waste Framework Directive has recently been revised (Directive 2008/98/EC) and the implementation of this revised Directive is underway (Defra 2009e)

- For example, in the UK composts complying with the Compost “Quality Protocol” (WRAP 2007b) will be products, i.e. outside waste management regulations (as mentioned above), and certain kinds of supplementary biomass, in particular those of agricultural origin such as straw or residues from forestry are not classified as wastes.

- Sweden was among the first countries in Europe, together with the Netherlands and Austria, to establish targets or obligations for bio-waste to be composted (EC 2006b).A product can be granted permission to display the quality label of Swedish Waste Management. For decomposed material the quality certification system is called SPCR 152. The certification involves verification that the product fulfils applicable requirements in respect of standards, codes of practice for the sector concerned, regulations etc., and that there is verified and approved continuous inspection of the product ("SPCR 152, Certifications rules for compost", SP Technical Research Institute of Sweden, 2009).

- All EU Member States have implemented the Water Framework Directive – WFD (2000/60/EC) and the Nitrate Directive (91/676/EEC) which intend to control (or will control) emissions of nitrate and phosphorous, as well as other impacts such as changes in the biological oxygen demand of surface water, from agriculture. These will affect the cultivation and use of fertilisers and organic matter on marginal land used for biomass, depending on whether the marginal land being considered falls under areas regarded as sensitive catchments for surface and ground water resources. For example, in the UK sensitive areas designated under the Nitrates Directive are known as “Nitrate Vulnerable Zones - NVZs” and have limits on the amount of nitrogen that can be applied to them (Defra 2008g).

A recent study indicates, for example, that preparation of soil for willow SRC, and removal of SRC leads to nitrate release. However, during cropping, including harvesting, levels of nitrate release are low, even with annual additions of 100 kgN / ha as fertiliser. In the UK, restored land over a former municipal waste landfill site may be designated as previously developed land, but will not necessarily be regarded as contaminated; or agricultural land contaminated by diffuse pollution from mining or smelter fallout may not be classed as previously developed or brownfield land. Furthermore, over the entire crop cycle (15 to 30 years) nitrate release overall from SRC is much lower than for conventional arable crops (Goodlass *et al*, 2007).

Some types of marginal land may currently fall outside these Directives as implemented in particular Member States, for example depending on its previous development or for use such as a restored landfill surface. However, the scope of implementation for both Directives is changing, so this may not always be the case.

[48] SFS 1998:808

- The UK provides a range of guidance on the forestry and agricultural use of land such as the Defra Code of Good Agricultural Practice (Defra 2009a). This code takes into account the current regulatory circumstances, but also goes further in proposing a sustainable use of soil, water and air under the Defra Nutrient Management Programme[49]. Part of this approach is not to over-apply fertiliser inputs whatever the circumstances. If managers of biomass on marginal land projects over-apply fertilisers (including organic matter) over and above crop requirements for nutrients, they are likely to trigger a view that this use of organic matter is a waste management operation. Larger amounts of organic matter may be needed for soil forming and improving soil condition, if the need is *clearly* demonstrated. For the ongoing crop production the amounts of organic matter and fertiliser being applied should be strictly in line with the crop requirements and *demonstrable* soil and risk management needs.

- In Sweden forestry is one of he largest economical sectors. The Swedish Forest Agency is the Government's expert authority on forests and forest policy with the mission to work for a sustainable utilisation of the Swedish forests, in accordance with the guidelines given by the Parliament and the Government. For example In Sweden the forest's natural productivity shall be protected by management practices that are adapted to local site conditions, and by maintenance of the natural functions and processes of forest ecosystems (Swedish Forest Agency, 2005 and 2008).

- The legislative approach in Germany is based on protecting "compartments". This means soil and groundwater are seen as receptors (Franzius *et al.* 2008). This results in a prevention driven soil and groundwater management. Land management in Germany is impacted by the Soil Protection Act (Federal Ministry of Environment 2004) and other major regulative drivers, such as the Groundwater Ordinance (Federal Ministry of Environment 1997), the Water Supply Law (Federal Ministry of Environment 2008) and the Fertilisation Ordinance (Federal Ministry of Environment 2007).

In 2006 the EC published the *Thematic Strategy for Soil Protection* (EC 2006a). The UK, Sweden and Germany have national *soil protection* strategies. In England the *draft* Defra Soil Strategy (Defra 2008d) has set priorities for preventing the pollution of rural land (by recycling materials at rates and times that deliver improvements in soil quality and agronomic benefits whilst not impairing the long-term functioning of the soil or presenting a risk to human health or the environment) and on climate change (addressing the decline in soil carbon and identifying best practices to reduce losses and increase soil carbon where appropriate). Germany established an initial Soil Protection Act in 1998 which addresses protection against harmful changes to soil and the rehabilitation of contaminated sites (see above in this chapter). It is supported by the Soil Protection and Legacy Ordinance (Federal Ministry of Environment 2004b). This ordinance rules amongst others the investigation and assessment of potentially contaminated areas, sets requirements for remediation and addresses the prevention against harmful soil changes.

Biomass conversion may take place at an on-site or off-site facility, for example a generation plant that buys biomass as a feedstock. The onus for regulatory compliance – if the biomass is not a waste - will be on the customer – including the on-site user, who will likely impose quality specifications on the biomass input. Biomass that is seen as a product and not a waste will find the easiest route to market, with the widest availability of possible end uses.

Some jurisdictions may also have concerns about use of biomass containing potentially toxic elements accumulated from marginal land[50]. If the biomass harvested and collected is designated as a waste then it will fall under the Waste Framework Directive. In this case the biomass producer will be under a "Duty of Care" to ensure that the biomass is sent to a suitably licensed or permitted waste management facility.

It has been suggested that thermal conversion of biomass containing elevated levels of metals from a contaminated site, such as combustion or gasification, could recover the metals in recyclable amounts, but the practical feasibility of this has not been shown (Baker *et al.* 1994, Environment Agency 2002). Such operations would almost certainly be a waste management process. Biomass conversion may take place at an on-site facility as part of the project. Such a facility would need to comply with the national implementations of the Integrated Pollution Prevention and Control Directive (2008/1/EC), depending on its size.

- The UK has a formal biomass strategy (Defra, DoT and DTI 2007) – although this is silent about biomass production on marginal, previously developed or contaminated land. Major biomass fired power stations for electricity generation are being developed in the UK. The UK's largest power

[49] www.defra.gov.uk/farm/environment/land-manage/nutrient/index.htm

[50] Personal communication, Federal Environmental Protection Agency, Germany 2009

station, Drax at Selby in Yorkshire, aims to increase biomass co-firing to reach 12.5% of its power output, using some 2 million tonnes of biomass a year. This is equivalent to 500MW installed capacity. Drax also intends to build three 300MW biomass power plants nearby (Anon 2009a). A 350MW electricity from biomass plant will be built in Port Talbot, South Wales, by 2010. A large amount of the biomass will be imported, and there is limited re-use of waste heat, which is seen as making these ventures effectively short to medium term projects (Environment Agency 2009a). It has been difficult to develop UK supply chains, although this may be because of the low price per tonne paid for woodchip and other biomass (Anon, 2007a, 2008a, 2009a). Bio-electricity options for the UK were recently reviewed by Thornley *et al.* (2009).

- In Sweden there are several such ongoing activities (Andersson-Sköld *et al.*, 2009). For example Göteborg Energi offer district heating, ready heat, and gas. The Göteborg Energi gas products are natural gas, biogas and city gas. Another example is the production of electricity and heat at the Riskulla, kraftvärmeverk, KVV power station, located at the south border of Göteborg. The plant which will be a biofuel based district heating, electricity and heat production plant will start operations in 2009/2010. A similar district heating plant is to be started in Sundsvall. The Sundsvall district heating plant (Fjärrvärmeverk, Sundsvall Energi), will be fuelled by pellets made of forestry residues or other biomass materials. More details and further examples are provided in Andersson-SKöld *et al.* (2009.)

- In Germany biomass power plants with a total capacity of 480 MW have been installed. They require 4.7 million tpa biomass, mainly scrap wood. The most powerful biomass power plants provide around 20 MW electrical power. An additional 190 MW nominal power has been installed in biogas power plants which consume around 0.55 million m^3 of biogas. The fuel basis for these plants is liquid and solid manure with addition of co substrates. (Institute for Energy and Environment 2004)

Table 4.6 summarises the regulatory regimes that apply to these domains in Germany, Sweden and the UK.

5 The significance of organic matter as a resource

Edere dag een draadje is een hemdsmouw in een jaar. (A thread per day makes a sleeve per year: a comment on slow accumulation of resources from the Netherlands)

5.1 For soil improvement

The benefits of compost use in soil are well established (EC 2003): they improve the carbon pool and organic matter content of soil, they supply valuable plant nutrients, they improve soil processes of fertility, they improve the condition of soil for plant growth for example by enhancing their ability to store and supply water and their structure and the resilience of that structure. Even for biomass crops that are conventionally regarded as "low input" such as SRC willow, organic amendments such as sewage sludge have been found to improve yields (e.g. Adegbidi *et al.* 2003), and is certainly important in the establishment of biomass crops on marginal land, as described in Section 4.3. In addition, the European Commission believes that enhancing organic matter input to arable soil on a long term managed basis may assist the offset of GHG emissions by sequestration of carbon in soil organic matter (Marmo 2008). Interestingly, there is some concern that the removal of biomass from arable systems for biomass (e.g. straw as well as grain) may have a long term negative impact on soil quality and productivity (Lafond *et al.* 2009). This may indicate a more direct need for organic matter from wastes, such as compost, to provide organic matter return to biomass areas, at least for arable crops. It would be interesting to know, in a strategic sense, what the carbon impact and productivity benefits might be of improving soil organic matter content in marginal land areas, where soil quality is often low.

Table 4.6 Regulatory regimes and policy links in Germany, Sweden and the UK. *(Footnotes may be on following pages)*

	Contaminated land	Organic matter re-use (for composts and sewage sludge)	Water, soil and agriculture	Biomass use
Germany	Federal Soil Protection Law (Federal Ministry of Environment 2004)	Sewage Sludge Ordinance (Federal Ministry of Environment 2006a)	Federal Soil Protection Law, Drinking water Ordinance (Federal Ministry of Environment 2006b)	Federal Law of Renewable Energies (Federal Republic of Germany 2009) The 2010 targets for Ethanol and Biodiesel use in Germany under the EU Biofuels Directive (2003/30/EC) are 3.6 and 6.17% respectively (House of Lords 2006).
Sweden	Environmental code (MB, 1998) Risk assessment practice (SEPA, 2008c) Plan and Building Code (Plan och bygglage,, PBL, 1987) (National environmental targets – sub target 6.2, SEPA, 2009)	Environmental Code (MB, 1998) Guidelines (Jordbruksverket, 2009, SEPA, 2008d, bioenergiportalen, 2008)	Environmental Code (MB, 1998) Plan and Building Code (Plan och bygglage, PBL, 1987) Risk assessment practice (SEPA, 2008c)	Environmental Code (MB, 1998) Aids for more efficient energy and biofuel and renewable energy resources (Swedish Parliament, 2006) Climate investment programs (Swedish Parliament, 2006) Obligation to provide renewable fuels (Swedish parliament, 2006, Act (2005:1248) The 2010 target for biofuels in Sweden is 5.75% under the EU Biofuels Directive (2003/30/EC) (House of Lords 2006).
UK **England and Wales**	Contaminated land legislation (Part 2A of the Environmental Protection Act 1990) was introduced in 1995. It came into force in 2000 following the publication of accompanying "statutory guidance". Sites may be regulated under environmental protection regulations or through the planning process depending on	Recently regulatory controls for the re-use of waste on land have been incorporated into a new Environmental Permitting system. This is still being developed (Defra 2007a and 2008b). The key features are that some composts meeting the *PAS-100* specification and the *Compost Quality Protocol*	A national package of advice and support for farmers preparing for the new Nitrate Pollution Prevention Regulations has been launched by Defra. The regulations came into force on 1 January 2009 and update the UK's implementation of the 1991 EU Nitrates Directive[57]. WFD	The EU Biofuels Directive (2003/30/EC) sets reference values for the EU market share of biofuels. Each Member State has a particular target. The UK target for biofuel use in 2010 is 3.5%. (House of Lords 2006). The Biomass Task Force was designed to help the Government

	Contaminated land	Organic matter re-use (for composts and sewage sludge)	Water, soil and agriculture	Biomass use
	the context (Defra 2006b, DCLG 2004-2008, WAG 2006). Detailed technical guidance is available from the Environment Agency[51]. The identification and subsequent remediation of contaminated land falls under the Contaminated Land (England) Regulations (2006) and the Contaminated Land (England) Amendment Regulations 2001. These Regulations set out provisions relating to the identification and remediation of contaminated land under Part 2A of the Environmental Protection Act 1990. There is also ongoing attempts to produce an EU Soil Framework Directive, however the outcome is currently unknown[52]. The planned Soils Directive is likely to emphasise on contaminated and brownfield land, however this may also have an effect on surrounding water, soil (and air) environments.	will no longer be considered a waste and will be considered a product. A Quality Protocol is also being finalised for anaerobic digestates and is being developed for top soils, linked to an existing British Standard (BSI 1994, WRAP 2005 and 2007, WRAP and Environment Agency 2008). Otherwise materials re-use on land will be dealt with by an "exemption", a "standard permit" or a "bespoke permit" depending on the potential level of risk and amount of regulatory effort they are perceived to carry by the regulator[53]. CLOs are seen as carrying a higher level of risk than composts produced from materials separated at source (Environment Agency 2008c, Purchase 2009). Currently, spreading of CLOa can be achieved under paragraph 9A of the Waste Management Licensing Regulations if the result is deemed to be 'ecological improvement', but this is under review[54]. The Waste Framework Directive 2006/12/EC is implemented in the UK through the Environmental	implementation is being undertaken separately by England, Wales, Scotland and Northern Ireland. However all countries are implementing the Directive in similar ways and are collaborating via the WFD United Kingdom Technical Advisory Group (UKTAG)[58]. UK TAG links to all implementation guidance, regulations and UK Draft River Basin Management Plans. It is planned for the current Groundwater Directives to fall under the WFD in 2013. The Groundwater Directive regulates pollution discharges to groundwater, and controls discharges of some pollutants by permits. In 2006, the Groundwater Daughter Directive (2006/118/EC) was introduced as an offshoot of the WFD. Discharge limits for pollutants are not specified as it was deemed to be the responsibility of the Member States. The UK Environment Agency also identifies Source Protection Zones (SPZs) to identify risk of contamination around sources of drinking water (such as	and the industry develop biomass energy in support of renewable energy targets and sustainable farming and forestry and rural objectives. Summaries of the proposed task force and governmental response can be accessed following link[59]. The UK Biomass Strategy was published in 2007 (Defra, DoT and DTI 2007) In 2008 the Renewables Advisory Board published its views on how the UK can meet its 2020 target of 15% renewable energy (RAB 2008a). In 2009 the Welsh Assembly Government published a bioenergy action plant consultation. A progress report was recently published by the Department of Energy and Climate Change – DECC (2009b), and also a "road map "towards a low carbon future" by the Royal Society (2009). Recently a revised UK renewable energy strategy was published (DECC 2009c). Policy on biofuel use for transport is set out by DfT 2009. Support for biofuel production and setting up of biofuel infrastructure is available in England through Defra[35] Energy

51 www.environment-agency.gov.uk/clea

52 http://www.defra.gov.uk/ENVIRONMENT/land/soil/europe/

53 Current situation described at http://www.environment-agency.gov.uk/business/topics/permitting/34782.aspx

	Contaminated land	Organic matter re-use (for composts and sewage sludge)	Water, soil and agriculture	Biomass use
		Protection Act (1990), the Control of Pollution (Amendment) Act (1989), the Waste Management Licensing Regulations (1994) and the Controlled Waste (Registration of Carriers and Seizure of Vehicles) Regulations 1991. The legislation requires that anyone who treats, keeps, deposits or disposes of waste needs a waste management licence (unless exempt or excluded), which is issued by the Environment Agency[55]. Sewage sludge use on land is also regulated by a Code of Practice (DoE 1996). Sewage sludge falls under The Sewage Sludge Directive (86/278/EEC) is implemented in the UK by the Sludge Regulations 1989, IPPC and the Waste Management Licensing Regulations. The EC is currently assessing whether the current Sewage Sludge Directive should be reviewed (and the extent	bore holes, wells and springs). Defra issued a public consultation on the draft Soil Strategy for England on 31 March 2008 (Defra 2008d). Defra have also issued a *Farming: Code of Good Agricultural Practice* to protect air, soil and water (Defra 2009a). This aims to limit diffuse pollution of excess nutrients from agricultural land, prevent unnecessary accumulation of excess nutrients in the soil and reduce the risk of GHG emissions.	Crops Scheme; part of the Rural Development Programme England 2007-2013[60] (Defra 2004b) and the Bioenergy Infrastructure Scheme and Bioenergy Capital Grants Scheme (for end users)[61]. A list of the current grant schemes available in the UK is provided at the following link pages[62].

54 The Environment Agency suggest that large scale use of CLO's for biomass crops will likely require a bespoke permit in future (Personal Communication June 2009)
55 http://www.wasteonline.org.uk/resources/InformationSheets/Legislation.htm#75442
56 http://ec.europa.eu/environment/waste/sludge/index.htm
57 Available from http://www.defra.gov.uk/environment/water/quality/nitrate/nvz2008.htm
58 http://www.wfduk.org/
59 http://www.defra.gov.uk/farm/crops/industrial/energy/biomass-taskforce/index.htm
60 http://www.naturalengland.org.uk/ourwork/farming/funding/ecs/default.aspx
61 http://www.bioenergycapitalgrants.org.uk/
62 http://www.biomassenergycentre.org.uk/portal/page?_pageid=77,15133&_dad=portal&_schema=PORTAL

	Contaminated land	Organic matter re-use (for composts and sewage sludge)	Water, soil and agriculture	Biomass use
		of the review if agreed it should occur)[56]. The Sewage Sludge Directive is currently being reviewed (first consultation due to be released April 2009). The Safe Sludge Matrix also lays down strict rules on sludge application timing and the crops grown on the land to which it is applied. The Safe Sludge Matrix is a voluntary agreement led by the UK consultancy company, ADAS, and is supported by Defra, Environment Agency, British Retail Consortium, National Farmers Union, the water industry and the Food Standards Agency (ADAS *et al.* 2001).		
Scotland	Contaminated land legislation in Scotland is broadly in line with the rest of the UK. Sites may be regulated under environmental protection regulations or through the planning process depending on the context (Scottish Executive 2006a) Part 2A under The Environment Protection Act (1990) is implemented in Scotland through:	Waste regulatory approaches in Scotland are broadly similar and are also currently under review (Scottish Government and Scottish Environmental Protection Agency 2008). The Scotland and Northern Ireland Forum for Environmental Research have recently carried out a risk assessment for sewage sludge re-use on forestry and for restoration of derelict land (SNIFFER 2008), which is being used to support the development of a *Code of Practice on the Use of*	Both the WFD and Nitrates Directives are implemented in Scotland in a largely similar way to the rest of the UK. Control over nitrate leaching, pesticides, soil erosion and agricultural waste in Scotland lies broadly in line with the rest of the UK[65]. Since the Waste (Scotland) Regulations were published in 2005, Scottish farmers have a 'Duty of Care' to ensure they do not treat, keep or dispose of	Refer to England/Wales for EU Biomass Directive. Scottish Biomass Action Plan has been instigated by the EU Biomass Action Plan. It aims to develop the biomass sector in Scotland. Using biomass for heat and electricity, and transport fuel will be included in the Scottish Biomass Action Plan in order to develop a sustainable biomass industry[71].

	Contaminated land	Organic matter re-use (for composts and sewage sludge)	Water, soil and agriculture	Biomass use
	Contaminated Land (Scotland) Regulations (2000)[63]. Contaminated Land Regulations Amendment (2005)[64].	*Sludge, Composts and Biowastes for Land Restoration* over 2009. Compost re-use in Scotland also uses the PAS-100 standard. However the Compost Quality Protocol does not apply. Instead the Scottish Environmental Protection Agency released a position statement regard compost re-use in 2004. Refer to England/Wales for Sewage Sludge.	agricultural waste in any way that may cause detriment to the surrounding environment or human health[66]. SEPA monitor the state of Scotland's water environment and have published the reports, including river basin planning, significant water management issues and water characterisation reports[67]. The WFD in particular is implemented in Scotland through the Water Environment and Water Services (Scotland) Act (2003). This Act gave Scottish ministers power to introduce regulatory controls over water activities, to ensure Scotland's water environments (wetlands, rivers, lochs, estuaries, coastal waters and groundwaters) are protected and used in a sustainable way[68]. Discharges, disposal (to land), water abstraction, impoundments and engineering works are controlled by SEPA by The	Refer to England/Wales for a link to a current list of grant schemes available in the UK.

63 http://www.hmso.gov.uk/legislation/scotland/ssi2000/20000178.htm
64 http://www.opsi.gov.uk/legislation/scotland/ssi2005/20050658.htm
65 http://www.sepa.org.uk/land/agriculture/arable.aspx
66 http://www.sepa.org.uk/land/agriculture/agricultural_regulation.aspx
67 http://www.sepa.org.uk/water/water_publications.aspx
68 http://www.opsi.gov.uk/legislation/scotland/acts2003/asp_20030003_en_1

	Contaminated land	Organic matter re-use (for composts and sewage sludge)	Water, soil and agriculture	Biomass use
			Controlled Activity Regulations (CAR) (2005)[69]. The Water Environment (Diffuse Pollution) (Scotland) Regulations, in the form of the 'General Binding Rules' were also published by the Scottish Government in 2008 and are an amendment to the CARS (2005)[70].	
Northern Ireland	Part 3 of the Waste and Contaminated Land (Northern Ireland) Order 1997 contains the main legal provisions for the introduction of a contaminated land regime in Northern Ireland. The Order was enacted in 1997 but the Contaminated Land Regime is not yet in operation (DoE NI 2006). The Regime will contribute to the principle objectives of the WFD.	The Waste and Contaminated Land (Northern Ireland) Order 1997), was introduced in Northern Ireland as a result of the Waste Framework Directive (75/442/EC) (as amended by 91/156/EEC and 91/692/EEC), The Hazardous Waste Directive (91/689/EC) and The Landfill Directive (1999/31/EC) which set legal standards and responsibilities for the deposit, treatment, keeping or disposal of waste. The Northern Ireland Environment Agency (NIEA) is responsible for the delivery and regulation of waste activities in Northern Ireland. The re-use of materials on land is regulated via a Waste Management Licensing system (including exemptions for the re-use of certain materials for particular purposes, for example	Implementation of the WFD is the responsibility of the Department of Environment in Northern Ireland. The implementation of the WFD will be similar to the rest of the UK by involving the development of monitoring programmes, further characterisation of water bodies and the development of programmes of measures, which will be summarised in river basin management plans[73]. The Department of the Environment and the Department of Agriculture and Rural Development have joint statutory responsibility for implementation of the Nitrates Directive[74]. The Nitrates Directive is implemented through the Nitrates Action Programme Regulations (Northern Ireland) 2006, and the	Refer to England/Wales for EU Biomass Directive. Like Scotland, Northern Ireland will fall under the UK-wide Biomass Action Plan. Refer to England/Wales. Refer to England/Wales for a link to a current list of grant schemes available in the UK.

69 http://www.netregs.gov.uk/netregs/legislation/current/63590.aspx

70 http://www.opsi.gov.uk/legislation/scotland/ssi2008/pdf/ssi_20080054_en.pdf, also see Scottish Government, 2008b

71 http://www.scotland.gov.uk/Publications/2007/03/12095912/0

	Contaminated land	Organic matter re-use (for composts and sewage sludge)	Water, soil and agriculture	Biomass use
		the re-use of composts for the improvement of PDL[72]. Refer to England/Wales for Sewage Sludge.	2008 Amendment to this regulation and the Phosphorus (Use in Agriculture) Regulations (Northern Ireland) 2006. The EC Groundwater Directive is also implemented in a similar way to the rest of the UK. Northern Irelands aquatic environments are the responsibility of the Water Management Unit of the NIEA[75]. Similar to the rest of the UK, the WFD is implemented through river basin management plans, and are currently out for consultation until June 2009. Discharges are regulated under the Water (Northern Ireland) Order 1999, which requires permission from the Department of Environment to discharge any potential pollutants.	

72 http://www.ni-environment.gov.uk/waste/authorisation/exemption.htm

73 http://www.doeni.gov.uk/index/protect_the_environment/water/water_framework_directive_.htm

74 http://www.doeni.gov.uk/index/protect_the_environment/water/nitrates_.htm

75 http://www.ni-environment.gov.uk/water.htm

There is a wide range of potential organic matter inputs which could act as renewable sources of soil improvement and fertiliser. This includes: organic matter from municipal sources, residues from arable agriculture and horticulture, residues from livestock, residues from forestry, treated soils and wastes such as gravel / sand extraction residues or “inert” wastes received at landfill sites and a range of industrial wastes such as food processing wastes and fermentation residues. This report focuses on organic matter from municipal sources: sewage sludge (BIOPROS Consortium 2006), source segregated wastes such as garden and food wastes (WRAP 2009), and mechanically processed mixed wastes produced at “mechanical-biological-treatment” facilities – MBT (Cameron *et al.* 2008). These are sometimes known as “Compost Like Outputs” or CLOs, in order to distinguish them from composts produced from materials separated at source which tend to be of higher quality. The relative strengths and weaknesses of different organic matter types for supporting biomass production on marginal land are summarised in Table 5.1. Within England and Wales, the Environment Agency has set out a series of position statements regarding the appropriate management of biowaste, and in particular the use of CLOs which the Agency see as carrying higher inherent risks than the use of composts made from source segregated materials (Environment Agency 2008b and 2008c). Their views are reflected in statements at a European level (Council of the European Union 2009).

As well as the benefits of organic matter use, their inappropriate use may cause adverse impacts. Risks can be categorised as originating from biological, chemical and physical causes. The severity of any impact is related to the composition of the organic matter added, the requirements of the soil and its application and the sensitivity of the land, for example its proximity to water resources and its capacity to buffer inputs such as nitrogen and phosphorous. Standards and quality protocols are used (as described in Section 4.2.6) to minimise risks from for example biological and chemical contaminants in composts, and codes of practice are used to minimise impacts from inappropriate use, for example to prevent excessive introduction of plant nutrients. However, the combination of issues present on marginal land, for example soil contamination and requirements for water protection, the sensitivities of particular biomass crops – such as poplar to rusts, or prevention of exposure of workers to dusts from organic matter stockpiles mean that a holistic impact assessment should be undertaken for projects.

- ***Potential biological hazards:*** Many plant pathogens are destroyed during the composting process although some parasitic organisms may persist (Noble & Roberts 2003). Human and animal pathogens are likely to be rare or absent in properly made and matured composts derived from municipal solid waste[76] (MSW), if produced in accordance with the Animal By-product Regulations (Defra 2008a). Where large volumes of organic materials are used, mechanical agitation may create a localised risk of dispersal of bioaerosols. Advice of the assessment of bioaerosols is provided in Environment Agency 2009c.

- ***Potential chemical hazards*** One concern is the possibility that increasing amounts of organic matter return to land may increase PTE loading in soil (Defra 2007b). Levels of many PTEs, in particular arsenic, cadmium, copper, lead, and especially zinc, tend to be elevated in CLO and sewage compared with soils (Bardos 2005, Defra 2007b). It is understood that in England soil metal limits will be developed which will be applicable generally to the return of organic materials to land. There are also concerns that CLOs and sewage sludge may contain persistent organic pollutants (POPs) at unacceptable levels, although not all authors agree that this is a cause for concern (Amlinger *et al.* 2004, Smith 2009). A recent review of the potential risks of the use of CLO on land has been published by the Environment Agency (2009f) which raised concerns about impacts from cadmium, chromium, zinc and several organic pollutants. In the UK (England and Wales) both the Code of Practice for the Agricultural Use of Sewage Sludge (DoE 1996) and the quality protocol for composts (WRAP 2007b) require soil testing for PTEs where organic matter is to be used.

  The plant nutrient components of compost can also have negative impacts on ground and surface water if applied to excess (see Section 4.2.2) and the decomposition of the organic matter added may cause changes in soil pH and redox conditions (Inbar *et al.*, 1990). Conversely decomposition of organic matter added to soil may cause temporary immobilisation of nitrogen, and reduction in its availability to plants, if the compost has a high carbon to nitrogen ratio (Rahn, 2000). The availability and transport of nitrogen to groundwater and surface water will need to be assessed and, if necessary, mitigated.

[76] Solid waste collected by local authorities from households and other sources such as road sweepings

- ***Potential physical hazards*** Depending on the substance in question, inert materials such as stones, glass, metal, sharp items and plastic pose a variety of problems in compost and more particularly for CLO's; in particular the visual appearance of soils treated with CLOs may be affected (Bardos 2005, Kendle, 1990,). There is potential for harm to wildlife or domestic animals (via the ingestion of plastics for example (Mays *et al.*, 1973). In the UK (England and Wales) the Compost Quality Protocol sets out specific requirements to minimise physical contamination of compost (WRAP 2007b).

Table 5.1 Strengths and Weaknesses of Different forms of Organic Matter for Soil Formation or Improvement on Marginal Land

Type	Description	Strengths	Weaknesses
Source segregated – "green waste" compost	Material produced by composting or anaerobic digestion from separately collected materials from private and public gardens and parks (including leisure facilities such as golf courses).	Material contains useful amounts of stabilised organic matter and plant nutrients. Properly treated materials should be sanitised of animal pathogens and most plant pathogens. Materials may have a protective effect by: liming (increasing pH, immobilising toxic substances and reducing the effects of some plant pathogens). Some jurisdictions may have quality standards for these composts which offer element of quality assurance, and these materials may be seen as "recycled" and hence no longer under waste regulations. Generally source segregated materials are well perceived.	Materials may command a price per m^3, unless processed on-site from green wastes (in which case revenue generation may be possible). These materials may contain hazardous materials, albeit at lower levels than for most mixed waste composts. Unstabilised material is highly odorous and may also carry wider public health / nuisance risks. Stored materials may pose risks from some micro-organisms such as *Aspergillus fumigatus*.
Source segregated – food waste compost	Material produced by composting or anaerobic digestion from separately collected materials from private kitchens and/or catering operations or commercial food producers / processors.	Properly treated materials should be sanitised of animal pathogens and most plant pathogens. Materials may have a protective effect by: liming (increasing pH, immobilising toxic substances and reducing the effects of some plant pathogens). Note: under European law all such material has to have a minimum treatment to sanitise animal pathogens (Regulation EC 1774/2002). Some jurisdictions may have quality standards for these composts which offer element of quality assurance, and these materials may be seen as "recycled" and hence no longer under waste	Materials may command a price per m^3, unless processed on-site (in which case revenue generation may be possible). These materials may contain hazardous materials, albeit at lower levels than for most mixed waste composts. Unstabilised material is highly odorous and may also carry wider public health / nuisance risks. Stored materials may pose risks from some micro-organisms such as *Aspergillus fumigatus*.

Type	Description	Strengths	Weaknesses
		regulations. Generally source segregated materials are well perceived. .	
CLO	Material produced by composting or anaerobic digestion from mechanically processed fractions of mixed municipal (household) waste; or other similar collected wastes from commercial sources (Cameron *et al.* 2008).	Material contains useful amounts of stabilised organic matter and plant nutrients The material may be available at low or zero cost, or potentially in some regulatory jurisdictions its use could command a gate fee. Properly treated materials should be sanitised of animal pathogens and most plant pathogens. Note: under European law all such material has to have a minimum treatment to sanitise animal pathogens (Regulation EC 1774/2002). Materials may have a protective effect by: liming (increasing pH, immobilising toxic substances and reducing the effects of some plant pathogens). Some jurisdictions may have quality standards for mixed waste composts which offer an element of quality assurance. Stabilised material is generally free from odour.	Mixed waste composts tend to contain higher levels of inert materials (e.g. plastic traces) and hazardous materials than some other forms of organic matter: for example, PTEs, POPs and sharps such as glass fragments. The best mixed waste composts are likely to have PTE levels similar to poorer source segregated materials. Mixed waste composts may suffer from a poor perception by some stakeholders and a more stringent regulatory regime than some other forms of organic matter. Unstabilised material is highly odorous and may also carry wider public health / nuisance risks. Stored materials may pose risks from some micro-organisms such as *Aspergillus fumigatus*.
Sewage sludge "biosolids"	Residues remaining after treatment of human effluents at a municipal scale. Untreated dilute sewage fractions have been used to irrigate energy forestry.	Very high levels of usable organic matter and plant nutrients. Potentially available at low or zero cost	Untreated materials will pose materials handling difficulties as well as problems of odour and potential microbial risks. They are likely to require special handling. Sewage materials tend to contain higher levels of inert materials (e.g. plastic traces) and hazardous materials than some other forms of organic matter: e.g. PTEs, POPs.

5.2 Supplementary biomass

Some organic byproducts and wastes are a biomass source in their own right (AEA Energy and Environment 2008b, Defra 2004a, 2005a, 2005b 2008c and 2009c, Leible *et al.* 2007, WRAP 2007a). From the standpoint of a biomass on marginal land project, integration of biomass with these other materials as a supplementary source of biomass may be an important means of increasing the energy capacity and scale of any related on-site bioconversion project, or indeed off-site export of biomass materials. Materials that might be compatible with biomass on marginal land projects include: agricultural residues (like straw), forestry residues (like tree trimmings), commercial and industrial wastes (like waste paper / card) and municipal wastes (like wood, or refuse derived fuel). Table 5.2 summarises the strengths and weaknesses of these sources of biomass as project opportunities. In all cases a potential opportunity is to negotiate long term supply contracts that are in line with the lifetime of, for example, SRC (AEA and r3 2004).

Table 5.2 Organic Materials as Sources of Supplementary Biomass

Type	Description	Strengths	Weaknesses
Agricultural Residues (e.g. cereal straw, oil seed rape straw).	Post harvesting residues.	Not regarded as a waste, so easier regulatory compliance. Ash or biochar may be recyclable.	Low bulk density, seasonal supply, bulky for storage, vulnerable to moisture over storage, cost of materials, and may already be existing uses.
Forestry Residues (trimmings etc).	Residues produced by forestry management and timber processing.	Not regarded as a waste, so easier regulatory compliance Ash or biochar may be recyclable.	Possibly seasonal supply, in some areas may already be used for established markets e.g. as chipboard, and so cost of materials may need to be met.
Commercial and industrial Waste (waste paper, card, rags, food processing residues).	Accumulated waste of business activities collected by waste management organisations.	Potential for fairly uniform materials. Potential to command a gate fee (for waste treatment). Year round availability.	Regarded as a waste, some types may contain contaminants requiring additional ash or emission treatment. Some waste types may have alternative uses and established prices. Some types may not be readily storable.
Municipal Waste (wood – e.g. separately collected or from green waste oversize, cooking fat, refuse derived fuel).	Waste streams collected by local authorities (or their contractors).	Potential to command a gate fee (for waste treatment). Usually year round availability.	Regarded as a waste, some types may contain contaminants requiring additional ash or emission treatment. Some waste types may have alternative uses and established prices. Some types may not be readily storable.

5.3 Availability of organic matter for soil improvement

5.3.1 Germany

2009 data from the Federal Statistical Agency[77] indicates that around 1.4 million tonnes per year of sewage sludge are produced in Germany, and about 8.5 million tonnes of green waste are collected per year by public authorities. This includes 3.8 million tonnes per year of household biowaste, 4 million tonnes per year of wastes from green areas and parks and 0.7 million tonnes per year of food waste. An additional 5 million tonnes per year of green waste are thought to be composted at home (EPEA 2004). Around 5 million tonnes per year of biowaste waste are thought to be included in the collection of other wastes and which are either landfilled or incinerated (EPEA 2004).

[77] https://www-genesis.destatis.de/genesis/online/online;jsessionid=43F223005C61932F13707374A9CBE5C3.tcggen3?operation=abruftabelleBearbeiten&levelindex=2&levelid=1242724972979&auswahloperation=abruftabelleAuspraegungAuswaehlen&auswahlverzeichnis=ordnungsstruktur&auswahlziel=werteabruf&auspraegungen3=ausw%C3%A4hlen

5.3.2 Sweden

Approximately one million tonnes of sewage sludge is produced per year in Sweden from municipal sewage treatment works, 240,000 tonnes dry weight, with an organic content of 50% on a dry matter basis) These figures exclude sludges produced from privately operated facilities. Currently around 5-10% of this sludge is recycled to arable land or forests. The rest is incinerated or used in construction works, for example sound barriers along motorways (Avfall Sverige 2007).

For 2007, the total amount of biologically treated waste in Sweden was about 870,000 tonnes. This includes 561,000 tonnes household waste (around 11% of the total household waste), and 167,000 tonnes of waste from the food industry. This led to the production of 336,100 ton of digested organic material from sources other than sewage sludge. Its dry matter content is estimated as 30%. Treated organic matter is seen as a long-term soil improver and it is often used in gardens, parks and in different land constructions. The material can be certified through SPCR 152 and SPCR 120 (Avfall Sverige 2007).

Almost all of this treated waste is at present recycled back to arable land or to gardens. The Swedish municipalities aim to double the capacity for biological treatment within a few years. A national objective is that 35% of all household waste should be treated biologically in the year 2010 (Avfall Sverige, 2007), so the amount of organic material available for soil improvement will increase.

In Sweden about 21 million tonnes of livestock manure are produced every year from livestock housed indoors, around 84% from cattle and 13% from pigs. Two thirds of the stable manure is pumpable (liquid manure and urine) and one third is solid manure (SCB and Jordbruksverket 2008). This manure is reused directly in agriculture and: consequently, this organic matter resource is not at present readily available for supporting biomass on marginal land in Sweden.

5.3.3 United Kingdom

Table 5.3 and Figure 5.1 summarises the amounts of compost from source segregated green and food waste produced in the UK, amounts of sewage sludge and CLO. The predicted amount of MBT processed organic matter (MBT-OM) is not as large as the volume of production of source segregated composts, but is nonetheless a sizeable amount. All of these waste sources are dwarfed by agricultural waste arisings It is estimated that in the UK, around 90 million tonnes of manures (45% solid, 55% liquid) per year are generated as a result of livestock production and applied to agricultural land. Livestock manures are applied to 16% of UK tilled land and 48% of the UK grassland (Defra 2008e).

UK information on municipal materials treated by composting, digestion or MBT is compiled through the *WasteDataFlow* reporting system[78] which collects returns from individual local authorities. Each of the UK countries produce national statistics from the WasteDataFlow collated by the Department for Environment Food and Rural Affairs, Welsh Assembly Government, Northern Ireland Environment Agency and the Scottish Environment Protection Agency. The most survey of UK composting for 2006/7 was published in 2008 by AFOR (2008) which found that approximately 3.6 million tonnes of source-segregated feedstock was composted in 2006-2007, of which 82% was municipal waste. This is a 5% increase from 2005/2006.

Information in Table 5.3 on sewage sludge has been collected primarily from Water UK. Current annual sludge production for the whole of the UK is 1,785,000 tonnes dry weight. An estimate of amounts for each country has been made for Table 5.3 by assuming the same proportions of sewage sludge between countries as in 2004 data from Defra[79]. The majority of sewage sludge produced in the UK (1.785 million tonnes) is applied to land (Water UK, 2008), often with prior treatment that may reduce its total mass.

[78] www.wastedataflow.org/
[79] http://www.defra.gov.uk/environment/statistics/waste/download/xls/wrtb11-12.xls.

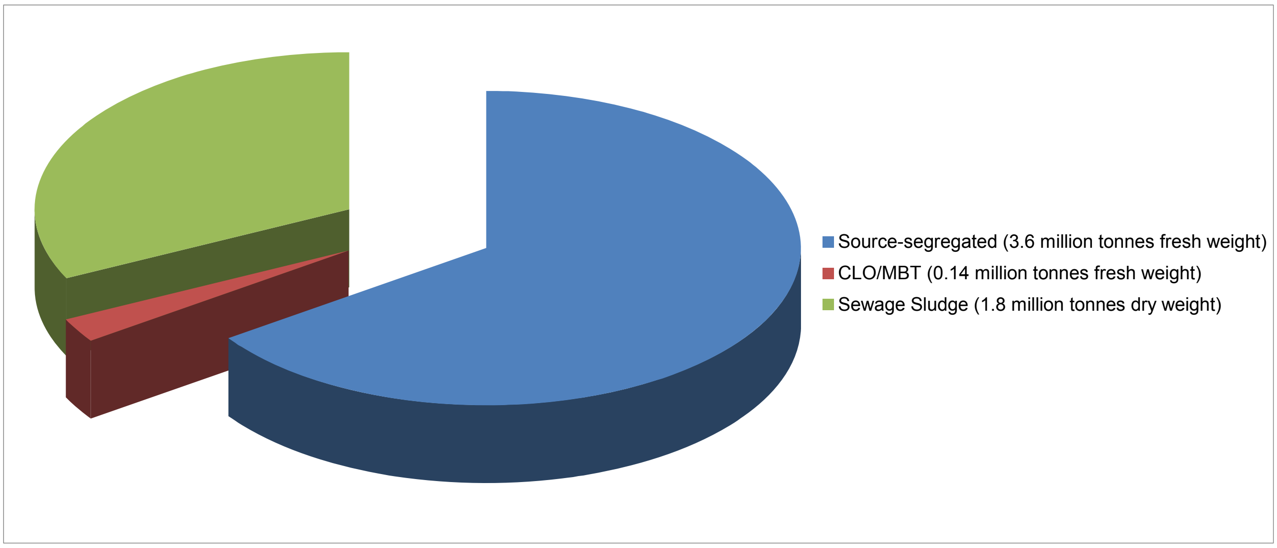


Figure 5.1 Relative proportions of organic matter available for re-use

Table 5.3 UK Annual Arisings of Composts, CLOs and Sewage Sludge (in thousands of tonnes)

	Fresh or Dry Weight basis	UK Overall	Wales	England	Scotland	Northern Ireland
Source segregated / green waste compost	Fresh	3,600 *	193	~2,880[80]	352	114
MBT processed materials	Fresh	~260[81]	30	121	108	Not determined
Sewage sludge[82]	Dry	1,785 #	1,558		183	44

Notes:

- Data sourced from AFOR 2008, Defra 2008f, SEPA, 2008 and Water UK 2008 and also from the Environment Agency[83] and the Northern Ireland Environment Agency[84]. Most of the data were summarised from WasteDataFlow[85]; except for * AFOR 2008 and Water UK 2008.
- 2007/8 data except for AFOR and Scotland where data is for 2006/7
- See also footnotes

6 A decision making framework for biomass production on marginal land

It seems difficult to determine the approaches that will be taken to biomass production, soil management and risk management simultaneously, yet all of these strategies interact. One way of dealing with this dilemma is to take a project management approach, considering decisions that are easy to take and limiting on

80 AFOR (2008) suggest 80% of the total compost production figure they calculated originates in England

81 AFOR (2008) estimated 140,000 tonnes compost from mixed waste feedstock

82 Water UK report a national increase of 37% of sludge production from 2005 to 2008 (11.1% pa) http://www.water.org.uk/

83 http://new.wales.gov.uk/topics/environmentcountryside/epq/waste_recycling/?lang=en

84 http://www.ni-environment.gov.uk/waste/municipal_data_reporting.htm

85 http://www.wastedataflow.org/

subsequent more difficult decisions, to make the overall planning more manageable. The most logical starting point is to draw up a short list of possible biomass crops and uses. Some biomass crops will be discounted immediately on the basis of their climatic or topographical requirements as not matching the marginal land in question. Others may be discounted as not being readily usable. It is important that this consideration begins from a clear view of the objectives for the marginal land area. For example, it is important to decide at an early stage if there is a possible appetite and opportunity for on-site biomass conversion, or will only off-site biomass be considered. This may depend strongly on the preferences of individual project teams. For example, a farmer considering how to better use land contaminated by diffuse metal pollution may prefer to produce commodity biomass products that can be sold to a third party.

Once a short list of possible biomass options has been determined, the next logical step is to consider what the management needs are for the marginal land in order to grow and process the crop where on-site conversion is being considered. If a crop cannot grow, then there is no biomass and hence no project. Therefore the starting point for the site management step is to consider what soil management is necessary, taking into account both soil forming and ongoing maintenance once a biomass use is established. The short list of biomass types can therefore be converted into a list of biomass types and their associated soil management requirements. It is possible that some biomass types will be discounted at this stage because the soil management required for them is not considered feasible. This consideration also needs to take into account the biomass crop impacts on the local water resources, and be based on existing guidance for good practice for the crop concerned in that regard (e.g. as in Tables 4.2 and 4.3).

Where on-site conversion is being considered it will also be necessary to develop a site management strategy for the conversion facility, including any infrastructure that might be needed such as for services and access, along with the environmental impacts of any conversion and their mitigation.

With a short list of options for biomass and their associated soil management needs, there is a better defined set of scenarios for risk assessment, taking into account the possible site end use scenarios for a practical range of biomass production options. Some biomass production scenarios will be discounted at this stage because the environmental risk management required for them is not considered feasible. The outcome will be a shortened list of options for biomass with their associated soil and risk management requirements for the marginal land being considered.

The overall outcome at this stage of decision making is a short list of biomass and site management options which are sufficiently well elaborated to be costed, and assessed for sustainability, for example considering biodiversity and ecological impacts and public amenity values (such as landscape and accessibility). For most projects some form of cost benefit appraisal will be undertaken, and direct project value will need to be greater than direct project costs. Additionally, particularly where public investment is being sought, it is necessary to show that the wider benefits for a project merit investment and any wider impacts to economy, society or the environment. Opportunities will need to be assessed for their likely levels of profitability, levels of project risk, know-how requirements, compatibility with other forms of reuse (such as built development) and amenity.

Consequently the best “value” biomass on marginal land option for a particular area will be a function of a direct cost benefit appraisal and a wider sustainability appraisal (SA). Linking the biomass project to wider initiatives may improve value. For example, an opportunity for improving value might be to combine biomass production with reuse of locally produced secondary biomass. For example woody residues or straw, or use of the site for additional forms or renewables in parallel with biomass could improve value. Also important in terms of wider value will be consideration of linked initiatives that improve local value, as mentioned in Section 4.2.5. Not all possible options will deliver sufficient value. The outcome of this stage will be one or two viable project opportunities which can be taken forward for detailed project appraisal to identify and mitigate any significant project risks (such as those relating to the status and verifiability of the different project components, detailed engagement with stakeholders and due diligence for financial resources).

Regulations governing restoration of marginal lands using organic waste materials vary from country to country, but two considerations will be important: the quality of the biomass produced, and the effective management of risks to human health and the wider environment.

The transfer of potential contaminants from the marginal land (or secondary organic matter inputs) to biomass needs to be avoided, or at least be limited to levels tolerable by downstream biomass use (for energy, fuel or manufacturing feedstock). This consideration is important both from a competitive product quality standpoint, and to avoid triggering a regulatory view that the feedstock generated is a waste or its use of downstream processing needs special pollution control measures. It is also likely that pragmatic risk management strategies will be adopted that will protect the feedstock and the environmental risks from the site, but not necessarily lead to removal of toxic substances (except perhaps for those which are biodegradable). Pragmatism will be driven by finding the approach that is most likely to win regulatory acceptance, and is most economically feasible, both of which are vital to securing a rapid re-use of the marginal land.

6.1 Key decision factors

Four broad stages can be used to refine choices for bio-renewables on marginal land (as illustrated in Figure 6.1).

1. Crop suitability: 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 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.

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. The output is a shortened list of crops that could be grown on-site and specification of the management interventions needed to achieve this.

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, 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 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. The output are project options that are financially viable and sustainable.

4. Project risk: once a firm project concept has been elaborated, with a value that 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. The output is a realistic appraisal of project risks and a mitigation strategy.

6.2 The decision makers (key stakeholders)

Marginal land re-use for biomass projects are likely to be considering large areas, many hectares, of land, often land that has been under-exploited. The projects will also be relatively complicated as they will be considering a range of sectors or activities, such as: risk management, recycling / re-use of materials; biomass production and use; carbon balance; wider local economic and community benefits. The project development is likely therefore to proceed from concept to a viable project as an exercise in “master-planning” (see Box 6.1).

Successful master planning will depend on reaching a local consensus between a range of actors, including those who will be the actual decision makers at the “core” of the project; and others with influential views but not directly involved in decision making. The master-planning team is likely to include members from most of the decision makers, although not necessarily from the regulatory and planning control. Regulators and those in charge of planning control are more likely to take a reactive role, waiting to be consulted by the master-planning team on specific issues and advising them accordingly.

The decision makers will include: the land owner / manager; the funders and investors – often such projects will have a public funding element; a range of service providers, both those involved in developing the project such as master-planning consultants and those who will provide services to the project development or its longer term operation; and those involved in regulation and planning control. A biomass re-use of marginal land may cross a number of regulatory domains, for example land management, waste management and water management. The service providers (consultants, contractors, vendors, biomass customers) will also come from a wide range of sectors, including: contaminated land management; agriculture and land management; soil science; organic waste processors and recyclers; biomass users and processors; and possibly the carbon finance industry.

Box 6.1 What is Master-planning?

In broad terms, a master-plan comprises three dimensional images and text describing how an area will be developed. It is more commonly applied to urban planning, where its scope can range from strategic planning at a regional scale to small scale groups of buildings. Most commonly, it is a plan that describes and maps an overall development concept, including present and future land use, urban design and landscaping, built form, infrastructure, circulation and service provision. It is based upon an understanding of place and it is intended to provide a structured approach to creating a clear and consistent framework for development (Scottish Government 2008a). Master planning is seen as particularly important for large environmental projects. Its methodology has also been successfully applied to biomass on marginal land projects (r3 and AEA 2004, Edwards *et al.* 2005).

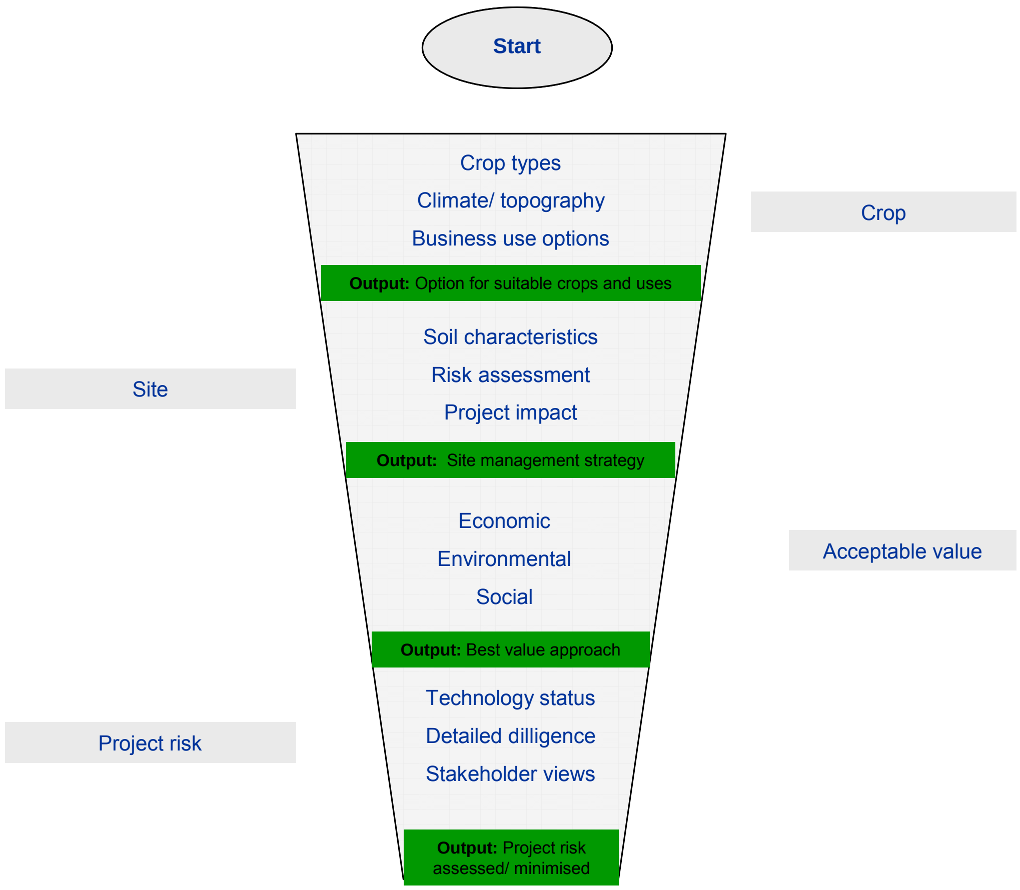


Figure 6.1 Project Development for Biomass on Marginal Land

The influencers of decisions will include most significantly local communities, indeed projects may wish to bring local community representatives into the master-planning team at an early stage to ensure a good local "buy-in"; non-governmental organisations (NGOs) such as campaigning groups; organisations which might exploit the project in a wider sense such as educational establishments or those in the "Third Sector" who might find opportunities to bolt on supplementary projects that improve sustainability – for example providing sheltered employment; and the local media.

There are sectoral networks active at an EU and national level with interests in different technical and project areas that relate to biomass production on marginal land. These networks are an important means of making contact with interested and qualified partners for project planning. Table 6.1 provides a summary listing of key stakeholder networks at an EU level and in Germany, Sweden and the UK.

Table 6.1 Stakeholder networks relevant to biomass on marginal land project planning

	EU and world-wide	Germany	Sweden	UK
Contaminated land owners	NICOLE (Network for Industrially Contaminated Land in Europe) www.nicole.org Concerted Action on Brownfield and Economic Regeneration Network (www.cabernet.org.uk)	e.g. Federal Ministry of Construction www.bmvbs.de/-,2600/Klima_-Umwelt-Energie.htm Germany´s Federal State Ministries www.labo-deutschland.de/	SPIMFAB (Swedish Petrolum Industry environmental remediation fund AB) www.spimfab.se SKL (Sveriges kommuner och landsting, Swedish municipalities www.skl.se Sveriges hamnar (Swedish ports association) The Swedish petroleum industry (www.spi.se) The Swedish association of environmental managers (www.nmc.a.se) Nätverket Renare mark, www.renaremark.se	SAGTA (Soil and Groundwater Technology Association) www.sagta.org.uk LRT (Land Restoration Trust) www.landrestorationtrust.org.uk
Other land owner interests	Research Network on Recycling of Agricultural and Industrial Residues in Agriculture (RAMIRAN) www.ramiran.net	German Farmers Association http://bauernbund.info/ Association of German Farmers and land owners www.deutsche-landwirte.de/	Swedish Farmers Bio Energy Association http://www.bioagri.se/	National Farmers' Union. (NFU) - http://www.nfuonline.com/
Service Providers – Contaminated land	NICOLE (Network for Industrially Contaminated Land in Europe) www.nicole.org European Committee of Environmental Technology Suppliers Associations (EUCETSA) - www.eucetsa.com	Association of Engineers for Contaminated Sites (ITVA) www.itv-altlasten.de	Nätverket Renare mark, www.renaremark.se)	The Environmental Industries Commission (EIC) http://www.eic-uk.co.uk/main.cfm - contaminated land group
Service Providers –	European Confederation of Soil	Federal Soil Association	Agroenergi	Institute of Professional Soil

Soil Management	Science Societies (ECSSS) - www.ecsss.net/ International Union Of Soil Sciences (IUSS) www.iuss.org	www.bvboden.de	www.agrobransle.se	Scientists (IPSS) http://www.soilscientist.org/ Landscape Institute www.landscapeinstitute.org/
Service Providers[86] – Organic matter and other soil forming materials	European Compost Network (ECN / ORBIT) http://www.compostnetwork.info/	Working Group of the German Länder on Waste Issues (LAGA) www.laga-online.de	Avfall Sverige (Swedish Waste Management) www.avfallsverige.se	The Environmental Industries Commission (EIC) http://www.eic-uk.co.uk/main.cfm - Waste Resources Management group Association for Organics Recycling –(AfOR) http://www.organics-recycling.org.uk/ The Chartered Institution of Wastes Management (CIWM) - http://www.ciwm.org.uk/ Environmental Services Association (ESA) - http://www.esauk.org/ Chartered Institution of Water and Environmental Management (CIWEM) - http://www.ciwem.org/ Sustainable Organic Resources Partnership (SORP) - www.sorp.org
Service Providers[87] – Biomass production and use	European Biomass Industry Association (EUBIA) - www.eubia.org/ European Biomass Association (AEBIOM) www.aebiom.org The European Technology Platform for Sustainable		Swedenergy, www.svenskenergi.se Svebio, www.svebio.se	The Environmental Industries Commission (EIC) http://www.eic-uk.co.uk/main.cfm - renewable transport fuels group NFU Renerwable energy - http://www.nfuonline.com/x338

[86] Include consultants, contractors, vendors and suppliers

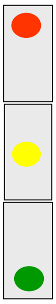
[87] Include consultants, contractors, vendors and suppliers

	Chemistry (www.suschem.org) EuPC, representing European Plastics Converters (www.plasticsconverters.eu/) IRENA, International Renewable Energy Agency (www.irena.org) World Bioenergy Association (WBA) www.worldbioenergy.org ThermalNet- the European Network for biomass pyrolysis, gasification and combustion www.thermalnet.co.uk			77.xml Renewable Energy Association (REA) - http://www.r-e-a.net/
Regulators, planners, local authorities	Common Forum www.commonforum.eu International Committee on Contaminated Land (ICCL) www.iccl.ch	Working Group of the German Länder for Soil Protection (LABO) www.labo-deutschland.de	SKL (Sveriges kommuner och landsting) Swedish municipalities www.skl.se	Environmental Protection UK http://www.environmental-protection.org.uk/ Chartered Institute of Environmental Health (CIEH) http://www.cieh.org/
Third Sector national networks (voluntary organisations with land management interests	EcoSystem Marketplace http://ecosystemmarketplace.com/index.php Part of the Katoomba Group (network) http://www.katoombagroup.org/		Naturskyddsföreningen www.naturskyddsforeningen.se	Groundwork Trust, www.groundwork.org.uk
Research and demonstration	SNOWMAN www.snowman-era.net/ BIONET - http://www.eranetbioenergy.net/website/exec/front?id=10764-6e65742e6572616e65742e50616765 Risk Based Management of	Association of Engineers for Contaminated Sites (ITVA) www.itv-altlasten.de Helmholtz Centre for Environmental research – UFZ, www.ufz.de	Värmeforsk, www.energiaskor.se Avfall Sverige (Swedish Waste Management) www.avfallsverige.se	Carbon Trust - www.carbontrust.co.uk/ Contaminated Land Applications in Real Environments (CL:AIRE) – http://www.claire.co.uk Environment KTN - http://ipmnet.globalwatchonline.com/epicentric_portal/site/IPM

	River Basins (RISKBASE) www.riskbase.info			NET/?mode=0 UK Water Industry Research (UKWIR) - www.ukwir.org/ Resource Efficiency KTN - http://www.resource-efficiency.org Waste-net http://wastenet.defra.gov.uk/
Other	Portal for soil and water management in Europe (EUGRIS) www.eugris.info			National Industrial Symbiosis Programme (NISP) - www.nisp.org.uk/ Waste Resources Action Plan (WRAP) - http://www.wrap.org.uk/

6.3 The procedure overall

The decision making procedure suggested here uses the sequence of considerations first suggested in Section 4.3 and elaborated in Section 6.1. The procedure starts with an explicit statement by the project team of their objectives for the marginal land in question, including any constraints, for example that off-site biomass re-use only is to be considered. It then proceeds through four stages considering (1) the biomass crop, (2) the site, (3) the project value and (4) the project risks to identify viable project opportunities. It uses a simple traffic light concept to describe the outcomes for project options at each stage.



No suitable biomass option for the marginal land under consideration

A suitable biomass option may exist but would require starting objectives are revisited

A viable project approach

The overall scheme is shown as a flow chart in Figure 6.2, using the traffic light colours to show progress at each of the four linked stages.

Each stage produces an interim finding or output. The decision maker proceeds through the four stages to determine a final view. The procedure is a decision support framework or tool (DST). The procedure supports but does not make the decision (Bardos *et al.* 2002). The goal of the DST offered here is to ensure a comprehensive consideration and reporting of the key decision making factors by the project team for a particular biomass on marginal land initiative. With the aid of checklists, the scheme identifies both the considerations needed at each stage and the possible site management and other interventions that might need to be considered. It uses checklists to suggest the broad types of information needed at each stage and the outputs that might be expected from each stage and how those outputs should be reported. Most of the information needed will be highly site and circumstance specific, however as far as possible this report signposts the project team to information sources.

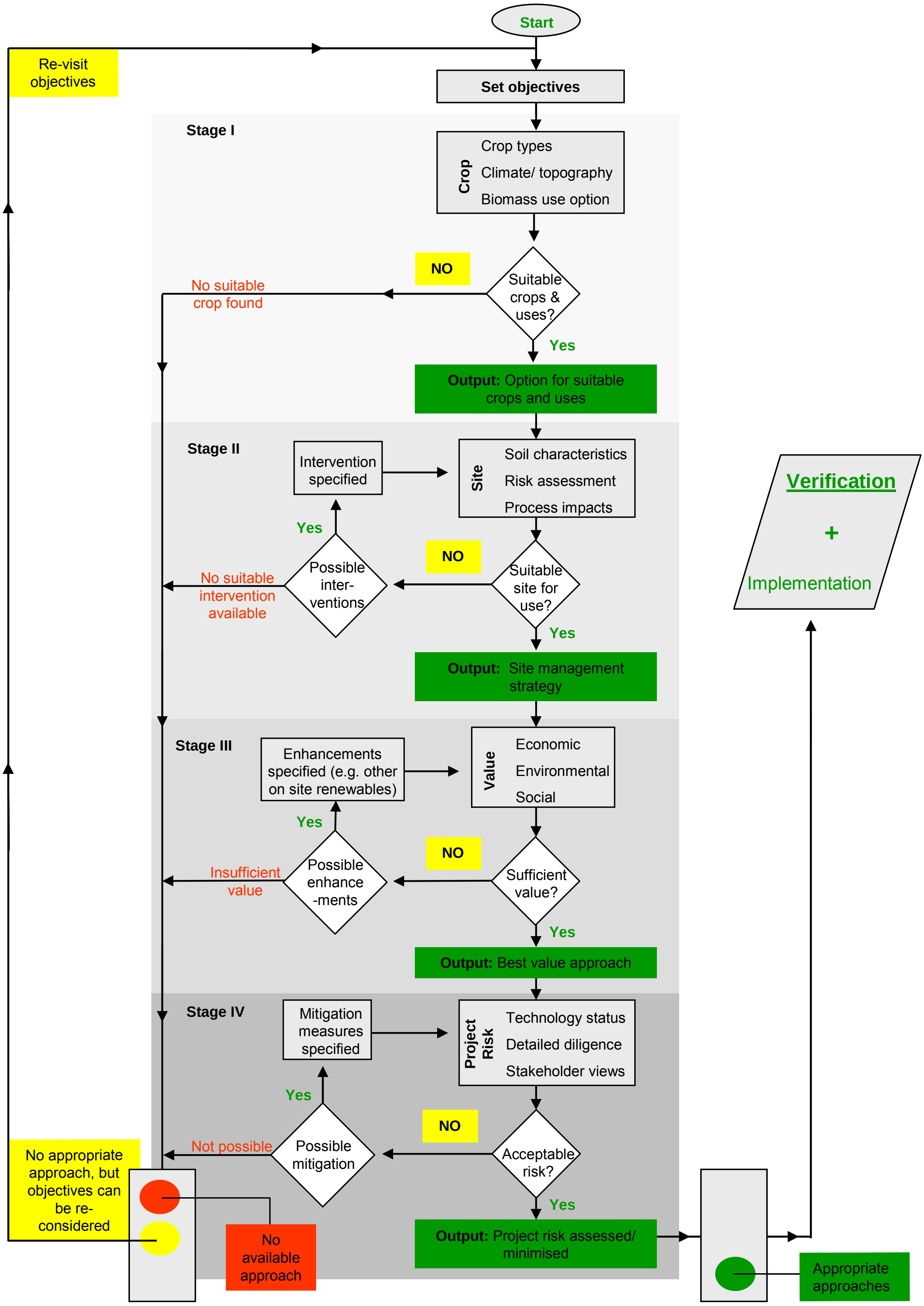


Figure 6.2 Overall Rejuvenate decision support flowchart

6.4 Step by step

6.4.1 Stage 1: Crop Types

Consideration of crop type in the Rejuvenate scheme takes place in four stages, as set out in Figure 6.3.

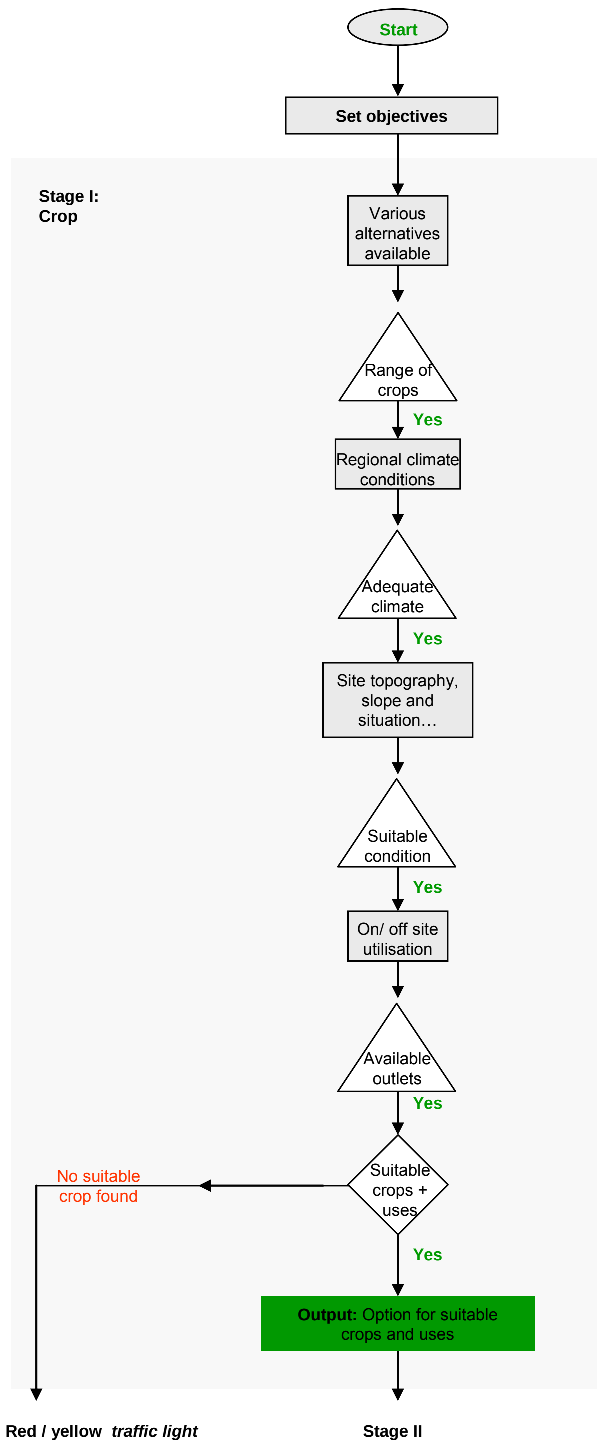


Figure 6.3 Rejuvenate DST: Stage 1: Selecting the Crops *(Note: each "triangle" is a factor which may mean no suitable crop is found)*

- ***Stage 1.1: range of crops meeting site objectives.*** This initial step is where the range of biomass crop alternatives (e.g. as summarised in Tables 4.2 and 4.3) are compared against the site objectives agreed by the project team for the marginal land under consideration.
- ***Stage 1.2: range of crops meeting local climate conditions.*** The list of biomass crops remaining after site objectives have been considered is then screened against prevailing *local* climatic conditions. For example local wind and rainfall conditions may favour some biomass crops over others. Table 4.3 provides initial screening information for biomass crops. However, the project will need to consider the micro-climatic conditions at the site.
- ***Stage 1.3: range of crops that can be cultivated on the sites topography.*** Biomass crops vary in their cultivation requirements. For example steep slopes restrict what can be grown on them. Only biomass crops that can grow under the topographical conditions of the site should be considered further.
- ***Stage 1.4: available uses.*** An initial appraisal of biomass use opportunities should be carried out for the remaining biomass crop options. Biomass use options may be present off-site or on-site, depending on project team's preferences. At this stage the decision making is concerned with the broad feasibility of use, rather than an exact calculation of revenue. However, this screening process should select only biomass crops for which *profitable* use of the biomass produced seems feasible.

The output of Stage 1 is therefore a list of feasible biomass crops able to grow under local and topographical conditions, which can fulfil the project team's objectives and for which viable end uses exist. The *output reporting* should report the option appraisal undertaken on a stage by stage basis, recording the information and assumptions used in each stage of decision making. Alternatively, if no crops are feasible, then reasons for this finding can be recorded. It may be appropriate to revisit the original project objectives, to widen the range of possible options.

Table 6.2 sets out the key considerations for Stages 1.1 to 1.4 in a checklist with a proforma for reporting the output from this stage.

Table 6.2 Rejuvenate Stage 1 Checklist and Reporting Format (shaded)

Stage	Considerations	Information needs	Decisions made
1.1 range of crops meeting site objectives	Crop characteristics related to any boundaries or preferences set by the general biomass objectives (e.g. SRC may be discounted because the site will have a limited availability in time).	List the main aims of the biomass project: for example on-site or off-site conversion processes; preferences such as whether arable crops are preferred, or that crops requiring irrigation would be preferred for landfill leachate treatment etc Also consider limitations relating to planning and regulatory consents and final allowable landform.	Removal of crops not able to meet overarching project objectives from the short list of possible crops (see Tables 4.2 and 4.3).
1.2: range of crops meeting local climate conditions	• Average temperature and range. • Sunlight hours. • Rainfall / water supply. • Elevation. • Soil temperature/thawing.	Crop characteristics to identify if their tolerable / optimal range matches local climatic conditions (note local rather than regional data may give a better basis for decision making).	Removal of crops unsuitable for local climatic conditions from the short list of possible crops.
1.3: range of crops that can be cultivated on the site land form.	• Coverage of sloping areas. • Steepness i.e. Catena effect – sequence of soil profiles and characteristics on a slope (Huggett, 2007). • Soil cover and presence of erosion gullies on steep, unstable topography. • Slope angle (i.e. North-facing). • Degree of surface heterogeneity (undulation, existing soil characteristics).	Establish the optimal and the tolerable cultivation conditions for crops remaining after Step 1.2, therefore determining profitability of potential yield.	Removal of crops that cannot be grown on gross site conditions from the short list of possible crops. *Possibly: site management interventions to improve gross conditions such as slope and topography.*
1.4: available uses	• Available biomass markets (considering revenue paid at gate and transportation needs) for crops remaining after 1.3, also taking into account the likely area of cultivation. Possible on-site conversion methods for	Initial market and technology survey. *Note: this is an initial screening assessment, detailed valuation is carried out at Step 3.*	Short list of crops that are feasible to grow on the site in question, and for which feasible options for use exist.

	crops remaining after 1.3 – unless on-site conversion was discounted at 1.1.		
Overall Stage 1 findings		***Summarise the information and assumptions used at each stage.***	***Short list of crops that are feasible to grow on the site in question, and for which feasible options for use exist, identifying decisions made at each stage.***

6.4.2 Stage 2: Site Management

Stage 2 considers the management of the site from the perspective of biomass production, and from the perspective of biomass conversion on-site options are under consideration. There are three sequential considerations for the biomass production, and two for on-site biomass conversion. While conceptually the biomass production and on-site biomass conversion are parallel considerations, in practice it may be sensible to initially consider one before the other in timing, since for example if an on-site facility is linked to a particular biomass crop that cannot be produced on the site, then it makes no sense to consider it in detail. Figure 6.4 shows the Stage 2 decision procedure, and each of its steps is described below.

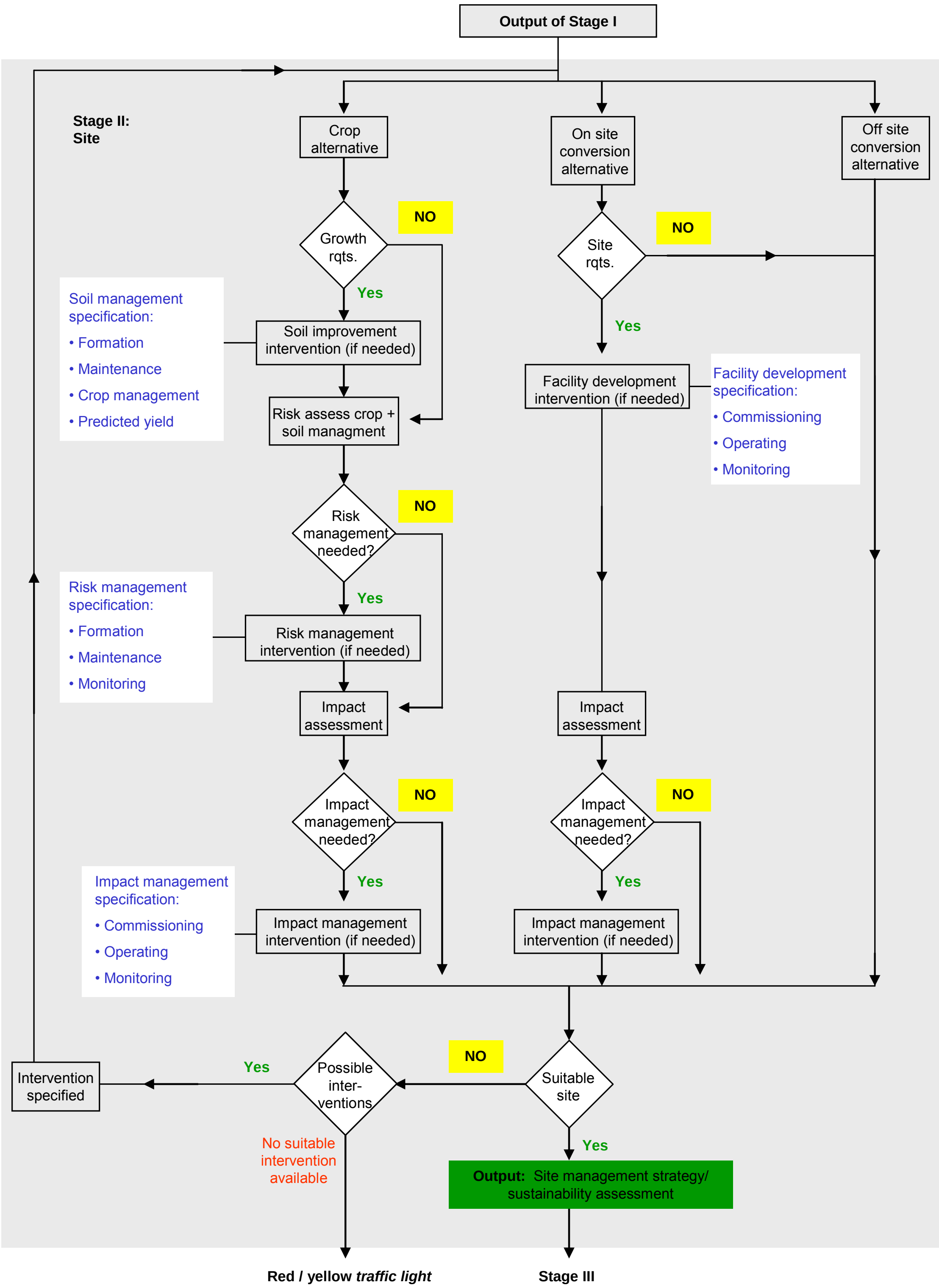


Figure 6.4 Rejuvenate DST: Stage 2: Site Management

- ***Stage 2.1: range of crops that can be grown on the site.*** The existing soil on the site is compared against the crop requirements for the biomass types short listed from Stage 1. Table 4.3 summarises soil requirements for major biomass types. This comparison will require soil compositional information for the marginal land area, in particular for chemical and physical properties, as well as information about soil depth. There are three possible outcomes from this consideration: that the soil is already suitable for a biomass crop, in which case perhaps only soil maintenance for the crop need be considered (traffic light = green); that the soil can be made suitable for crop production by soil improvement and/or soil forming measures (traffic light = yellow), or that the soil surface cannot be brought into a condition that is suitable for a particular crop type, for example because local rainfall and ground conditions mean that it will always be too wet for the particular crop type (traffic light = red). The outcome of this stage is a short list of viable biomass crop types along with their individual soil management needs (encompassing site preparation and ongoing maintenance).

- ***Stage 2.2: environmental risk management.*** The short list of crop and soil management combinations should be included as possible end uses for site risk assessment where the site is suspected as being contaminated (or organic matter inputs may contain contaminants). These end uses should be included in a conceptual site model that reviews all of the pollutant linkages that need to be considered for a site. Figures 6.5 – 6.7 show example site conceptual models for a former mining area being restored with SRC. 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. Table 6.3 shows a remediation strategy for the site considered in Figures 6.5 – 6.7.

- ***Stage 2.3: impact of interventions.*** The outcome of Stage 2.2 is a refinement of the short list of crop and soil management options to list options for which appropriate risk management exists, and which describes possible risk management interventions required. The soil management and risk management interventions may have environmental impacts. For example soil maintenance and crop production impacts on the water environment may need to be minimised. 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. This consideration, may favour particular crop alternatives, for example SRC is known to have low fertiliser requirements (and hence less nitrogen loss). Willow coppice can also improve biodiversity in marginal land contexts and supports greater biodiversity than many conventional arable crops (ADAS 2002, Haughton *et al.* 2009, Perttu 1999, Volk *et al.* 2004). The outcome of this stage will be a short list of viable biomass crops that can be grown on the site under consideration with acceptable environmental impacts. A comprehensive impact assessment system for biomass production has recently been made available in the UK (AEA Energy and Environment and North Energy 2008)

- ***Stage 2.4: facility development.*** This stage considers the feasibility of the various on-site bioconversion alternatives under consideration. Key factors will include infrastructure and service requirements (such as roadways and mains water), suitability of the site for construction (for example is it geotechnically suitable) and any risk management that might need to be undertaken to protect the facility (for example to deal with fugitive landfill gas). These considerations may mean that some conversion options will not be feasible for a particular site. The outcome of this stage will be a short list of feasible biomass conversion options and their site development requirements.

- ***Stage 2.5: facility development impacts.*** This stage considers the impacts of the facility development on the marginal land and its surroundings, for example the impact of construction work and new roadways, and any mitigation measures that need to be put in place to deal with these impacts. The outcome of this stage will be a short list of feasible biomass conversion options, their site development requirements and any mitigation strategies needed for their environmental impacts.

The output of Stage 2 is therefore a list of feasible biomass crops able to grow on the marginal land under consideration, their soil and risk management needs and their environmental impacts, along with the on-site conversion strategies for those crops if they are to be considered. The *output reporting* should report the option appraisal undertaken on a stage by stage basis, recording the information and assumptions used in each stage of decision making.

Table 6.4 sets out the key considerations for Stages 2.1 to 2.5 in a checklist with a proforma for reporting the output from this stage.

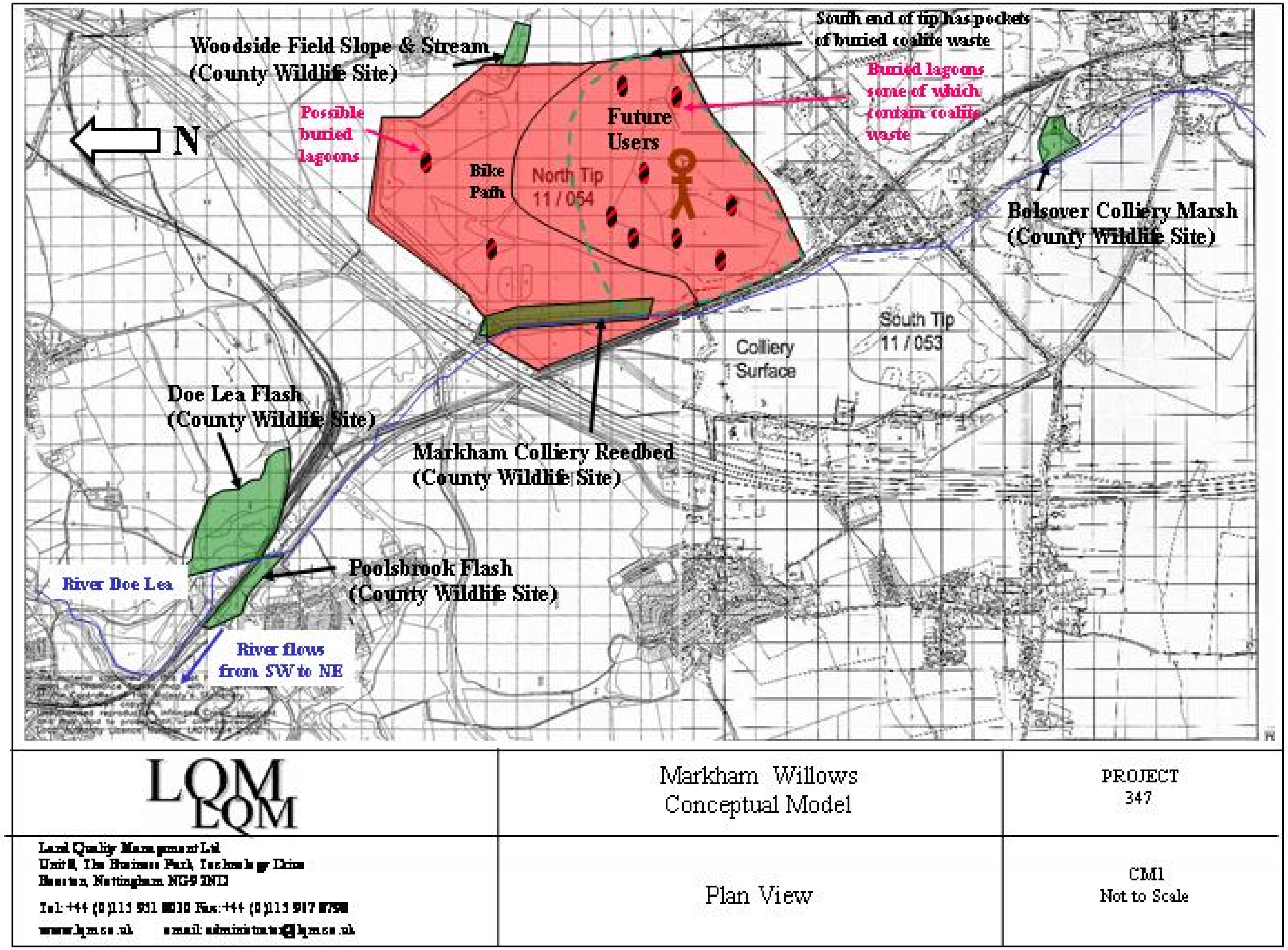


Figure 6.5 Example Site Conceptual Model Plan View (Markham Willows Site - r3 2004)

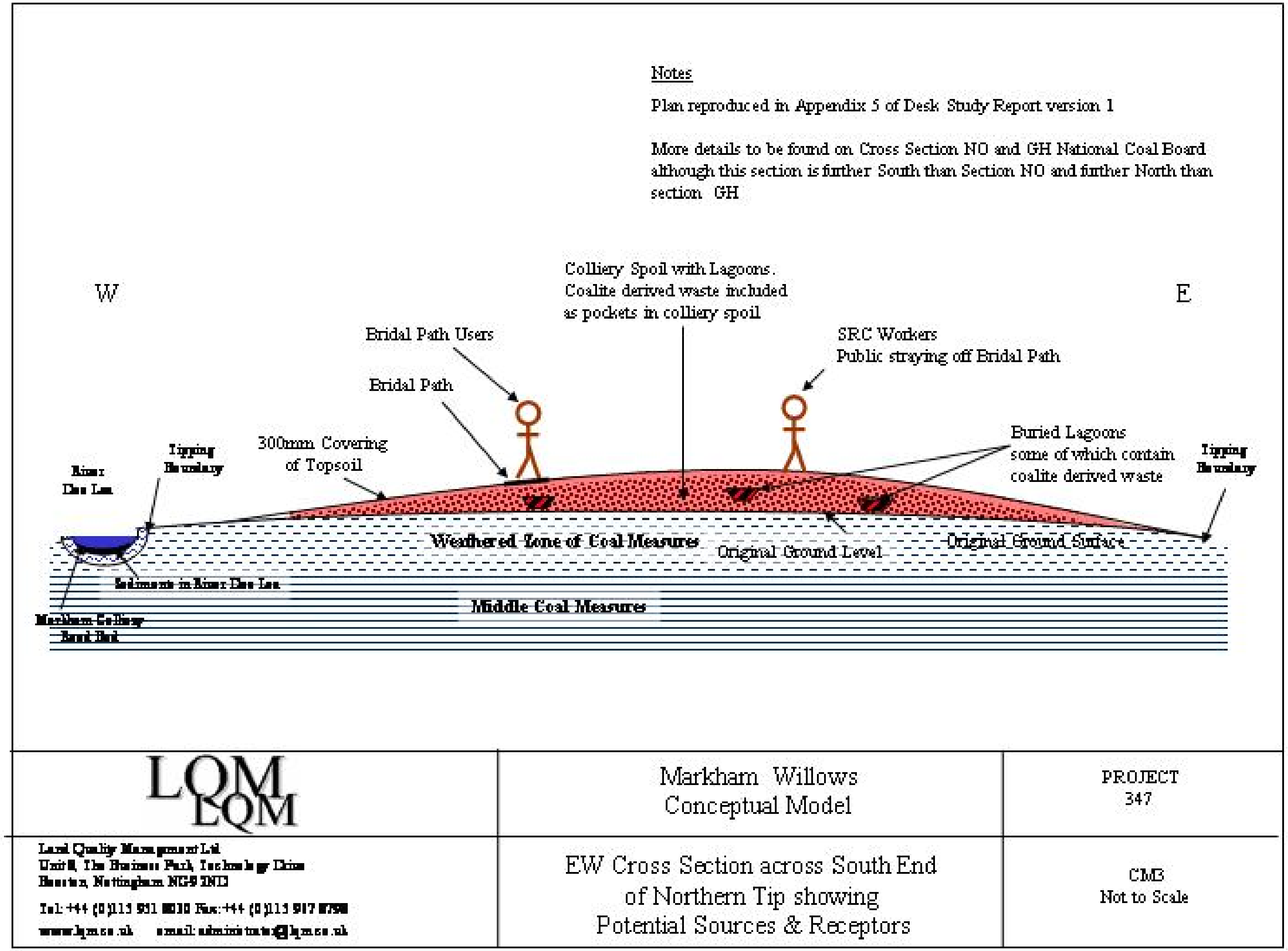


Figure 6.6 Example Site Conceptual Model Cross Sectional View (Markham Willows Site - r3 2004)

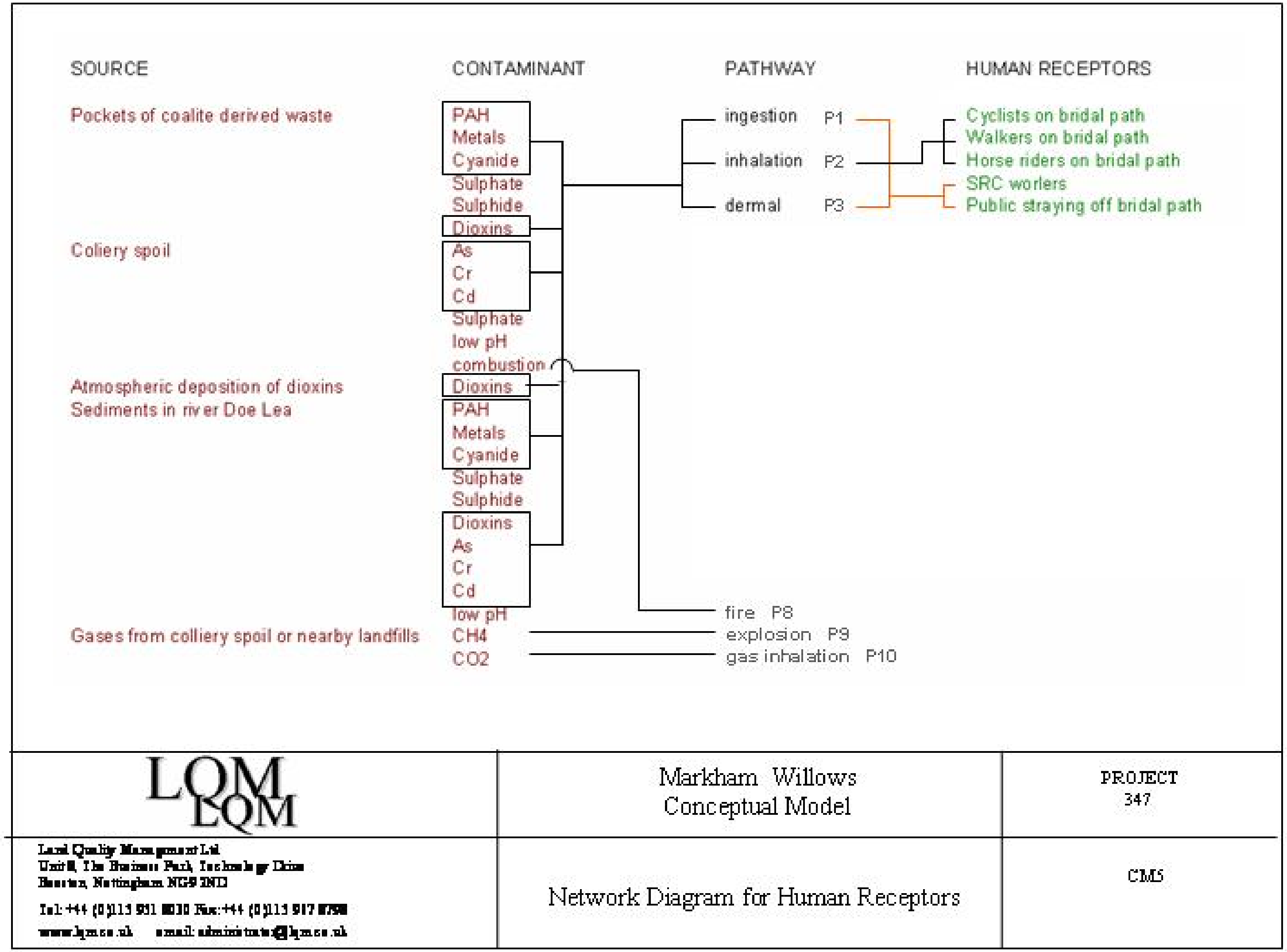


Figure 6.7 Example Conceptual Model Network Diagram for Human Receptors (Markham Willows Site - r3 2004)

Table 6.3 Integrated Remediation Strategy for Markham Willows (r3 2004)

Possible Pollutant Linkages	Remedial Objectives	Remedial Options
- Subsurface and surface contaminants - Ingestion / inhalation / dermal contact - Workers and public not on bridle paths	Prevent workers and public not on bridle paths 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. Derbyshire County Council have decided that fenced off deciduous woodland will be used for areas with elevated dioxin contamination levels.
- Subsurface and surface contaminants - Ingestion / inhalation / dermal contact - Bridle path users	Prevent bridle path users being exposed to hazardous levels of contaminants	Hotspot removal in bridle path and picnic 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 - River Doe Lea, Doe Lea Flash, Poolsbrook Flash, Woodside Field slope and stream, Markham Colliery Reedbeds, Bolsover Colliery Marsh, Coal Measures	Prevent unacceptable deterioration of the River Doe Lea, Doe Lea Flash, Poolsbrook Flash, Woodside Field slope and stream, Markham Colliery Reedbeds, Bolsover Colliery Marsh, Coal Measures	Possible remediation approaches, if pollutant linkages are significant are: - Permeable reactive barriers (including bioscreens) - Monitored natural attenuation
- Mine gas - Explosion - All users	Prevent mine gas explosions	Any buildings on the North Tip will need to be constructed with adequate measures to prevent accumulation of mine gas in enclosed volumes, for example adequate ventilation. This includes any temporary excavations, e.g. for drainage etc

Table 6.4 Rejuvenate Stage 2 Checklist and Reporting Format (shaded)

Decision	Considerations	Information needs	Decisions made
2.1: range of crops that can be grown on the site.	Site soil, hydrological and hydrogeological characteristics, matched to crop requirements from the Stage 1 short list.	Site investigation information considering: • Site hydrology information, including drainage, hydrogeological information, especially regarding shallow perched aquifers (a hydrology plan should show the current drainage regime and discharge points (and applicable consents), • Ground conditions: how any surface working such as sub soil addition or capping / covering has been carried out; consideration of possible compaction, • Soil depth across site (e.g. depth of soil cover above a landfill cap), • Soil physical conditions (texture, water holding, particle analysis – e.g. stones, wastes such as plastics, organic matter content, density), • Soil chemical conditions (pH, nutrient status, redox, content of phyto-toxic components – see also Step 2.2, cation exchange capacity, buffering capacity), • Limitations relating to planning and regulatory consents and final allowable landform. See for example Nason *et al.* 2007.	Identification of crops which can be feasibly grown on under the prevailing site conditions and/or soil management interventions needed and a consequent range of possible crop options.
2.2: environmental risk management.	Possible risks to receptors, considering sources, pathways and receptors, set out in a site conceptual model. Three models are suggested: SCM for initial conditions; SCM for	Site investigation information based on prevailing regulatory requirements / advice (see Table 4.6).	Site / project risk assessment and risk management strategy, including implementation and verification requirements (e.g. see Environment Agency 2004) →

Decision	Considerations	Information needs	Decisions made
	initial conditions plus soil management plus crop; SCM post remediation / risk management interventions including soil management and crop.		Selection of a short list of combined strategies considering: crop, soil management and risk management.
2.3: impact of interventions	Possible impacts to groundwater, surface water and air of the soil and risk management interventions proposed from Steps 2.1 and 2.2, considering issues such as N and P migration, odour, noise and nuisances.	Environmental impact assessment.	Identification of any unacceptable environmental impacts and a mitigation strategy for them, this may comprise meeting accepted codes of practice for agricultural land, even although the site in question may be brownfield or previously developed land (depending on the local regulators and planning authorities).
2.4: facility development.	(If applicable) Site engineering plan outlining infrastructure and site management interventions for example for geotechnical stabilisation.	Engineering feasibility study.	(If applicable) Identification of feasible on-site re-use options for the crop types remaining after Step 2.2.
2.5: facility development impacts	(If applicable) Possible impacts to air, water and soil of the facility development.	Environmental impact assessment.	(If applicable) Identification of any unacceptable environmental impacts and a mitigation strategy for them.
Overall Stage 2 findings		***Summarise the information and assumptions used at each stage.***	***Short list of possible biomass and site management options and specifications for any interventions required for site / soil management; risk management; on-site facility development (if applicable) and mitigation of unacceptable environmental impacts.***

6.4.3 Stage 3: Value management

Stage 3 considers the assessment of project value and its possibilities for enhancement. It includes two parallel considerations: the direct economic benefits of the project compared with its costs, the so-called "bottom line", and the wider sustainability of the project. The key factors driving costs and revenues (and also environmental sustainability impacts) will have been already been elaborated in Stage 1 and Stage 2. Stage 3 identifies the most *economically viable* option from the Stage 2 short list from the point of view of the project promoters *and also* an overall sustainability appraisal considering economic, social and environmental elements in a holistic way. Figure 6.8 shows the Stage 3 decision procedure, and each of its steps is described below.

- ***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. Where the revenue earning potential for a particular approach exceeds its costs an initial suggestion of viability is indicated. The value of linked initiatives should also be considered as part of this valuation process, and indeed the valuation process may trigger the need to identify possible linkages, for example adding other forms of renewables to the site management approach such as wind power, or linking the project to carbon offsetting or carbon neutrality for a larger regeneration initiative (See Section 2.3). This activity also includes the initial identification of possible funding streams such as grants and tax breaks, as well as potential sources of investment (and what needs must be met to secure those investments).

- ***Stage 3.2: financial viability.*** This stage considers the financial feasibility of each approach in more detail, developing a more detailed financial model and comparing it against investment thresholds set for the project, such as requirements for return on capital (see Box 2) set by investors and other funders.

- ***Stage 3.3: Sustainability appraisal.*** This stage uses qualitative 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. In the UK the Sustainable Remediation Forum (SURF-UK) has set out a framework for "sustainable remediation" which can guide this SA process[88].

Project options may also be eliminated during Stage 3 as failing to reach adequate value for the project team.

The output of Stage 3 is therefore one or may be two economically viable project concepts worthy of detailed appraisals, along with an initial sustainability assessment of them. The *output reporting* should report the option appraisal undertaken on a stage by stage basis, recording the information and assumptions used in each stage of decision making.

Table 6.5 sets out the key considerations for Stages 3.1 to 3.3 in a checklist with a proforma for reporting the output from this stage.

[88] www.claire.co.uk/surfuk

Box 2 Financial Viability

The financial measurements Net Present Value (NPV), Internal Rate of Return (IRR), Amortisation, and Annuity are used in dynamic investment appraisal. Each method is a monetary evaluation

NPV: This method considers cash in- and out-flows over a period of time and uses a Discounting Factor (DF), which brings future cash into a current value. Investment $C_0 > 0$ is an indication for the profitability of an investment.

Formula:

$$C_0 = -I + \sum_{t=1}^{T} (R_t) \cdot (1+i)^{-t} + L \cdot (1+i)^{-T}$$

C_0: capital value	I: investment	T: period of time
R: cash in-/ out-flows	L: liquidation proceeds	i: interest

IRR: This method is an estimation of the discounting factor, which projects use to consider all cash in- and out-flows. The IRR represents a minimum percentage from the investors' point of view.

Formula:

$$i^* = i_1 - \frac{KW_1}{KW_2 - KW_1} \cdot (i_2 - i_1)$$

i^*: IRR	KW_1: capital value	KW_2: capital value
i_1: interest	i_2: interest	

Amortisation: Amortisation describes the period of time needed to recover capital investment

Formula:

$$A = \frac{I}{D_a + P_{av} + i}$$

A: amortisation time	I: investment (asset costs)	D_a= annual depreciation
P_{av}: average profit	i: imputed interest	

Annuity: This measurement estimates the average active trade balance of an investment. The annuity factor is better known as the reciprocal value of the present value of annuity.

Formula:

$$ANF_{n,i} = \frac{(1+i)^n \cdot i}{(1+i)^n - 1} \qquad a = C_0 \cdot ANF_{n,i}$$

$ANF_{n,i}$: annuity factor	i: interest	C_0: capital value
a: annuity value		

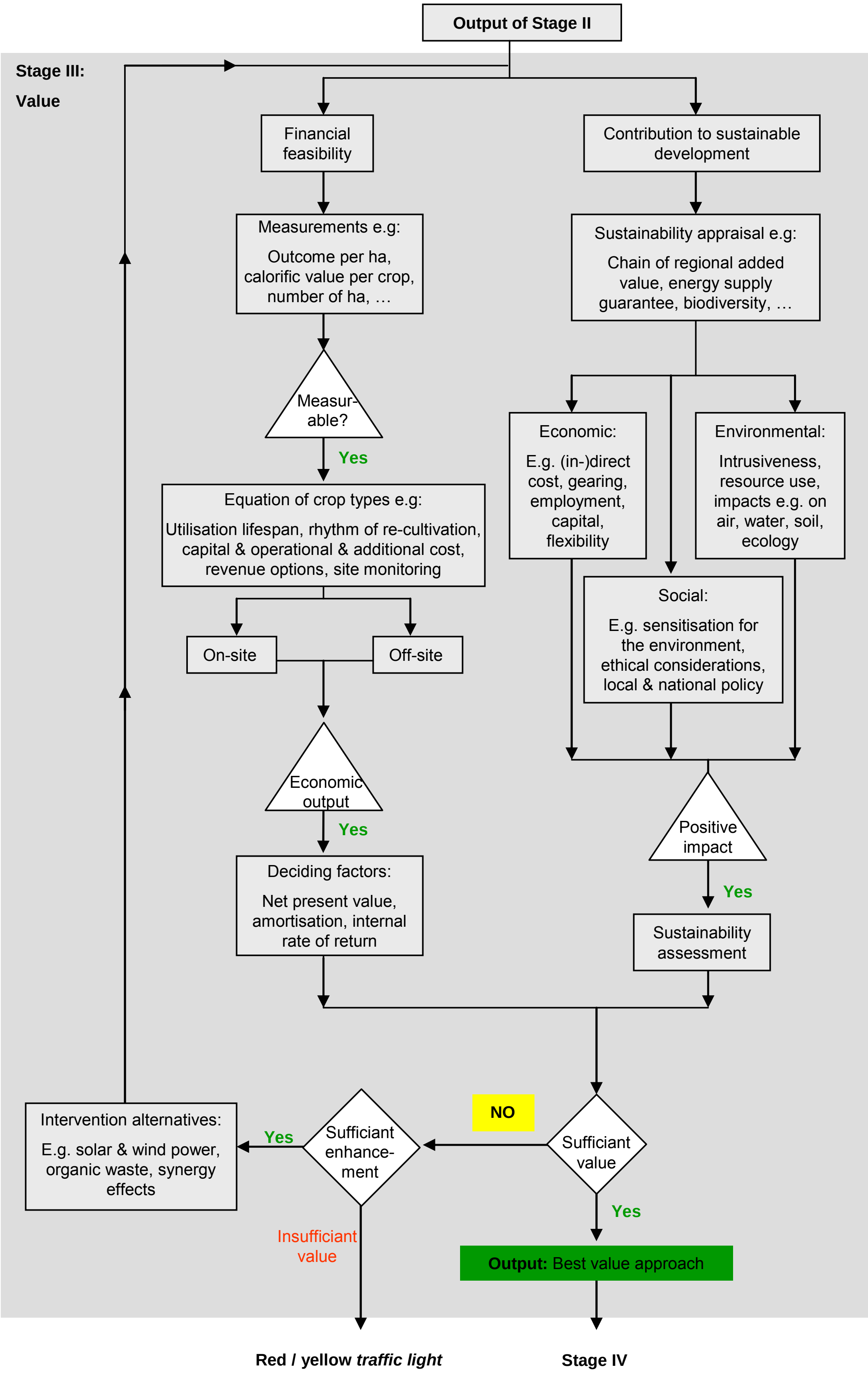


Figure 6.8 Rejuvenate DST: Stage 3: Value Management

Table 6.5 Rejuvenate Stage 3 Checklist and Reporting Format (shaded)

Decision	Considerations	Information needs	Decisions made
3.1: Financial feasibility	Profit and loss accounting.	Capital and operational cost, utilisation duration, turnover.	Identification of financially *feasible* options, and where appropriate interventions to improve financial performance.
3.2: Financial viability	NPV, IRR, amortisation, annuity.	Cash inflows and outflows over the project duration.	Identification of financially *viable* options, and where appropriate interventions to improve financial performance.
3.3: Sustainability appraisal.	A wide ranging SA, overarching considerations are listed in Table 2.1.	Qualitative sustainability appraisal (some regulators may require quantitative appraisals such as LCA, however this does not apply in the UK).	Identification of the most sustainable project option.
Overall Stage 3 findings		***Summarise the information and assumptions used at each stage.***	***The goal of this stage is to identify an option that balances economic viability against sustainability, and identify any interventions that might improve value. These interventions may mean that Stage 2 has to be reconsidered.*** ***Stage 3 sets in place the components of a business plan for the project, and – depending on funders' and stakeholders' needs, a series of wider sustainable development goals for the project.***

6.4.4 Stage 4: Project risk management

Stage 4 considers the project risks for the viable project opportunities identified at the end of Stage 3. Three broad considerations are important: technology status, detailed diligence (e.g. of financial partners and project partners) and developing a broad stakeholder consensus. Figure 6.9 shows the Stage 4 decision procedure, and each of its steps is described below.

- ***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. This stage includes seeking the necessary permissions and permits for activity from regulators and planners and engagement with the local community to involve them and other partner organisations if this has not already taken place. It also includes the confirmation of public financial support prior to step 4.2. Stakeholder engagement needs to begin at an early stage of planning, and it will be prudent to seek initial stakeholder views about the various site management interventions under consideration during Stage 2, and the Stage 3 sustainability appraisal, to reduce the risk of major surprises at this Stage.
- ***Stage 4.2: Technology status:*** this consideration is a detailed assessment of the project components, for example: will the crop really grow and provide the predicted yields, will the site really be managed, and will the conversion really work in practice? What needs to be tested before the project starts in full, what preparatory studies are needed? This stage may include detailed biomass and possibly conversion technology trials to demonstrate proof of concept. Earlier work (in Stage 2) may have included some biomass growth trials. However, it may be sensible to wait until the Stage 1 – 3 assessments are completed, to maximise chances of success, before undertaking expensive trial work. Large scale trial work may also be important in satisfying stakeholder requirements, for example building regulatory and investment confidence.
- ***Stage 4.3: Detailed diligence*** during this stage the project team seeks firm prices and makes the project business plan in detail and checking in detail that they can raise capital, employ people, are in line with environmental legislation and that the partners they wants to work with are reliable, across the whole site management and biomass production (and conversion) system. This is also the point when any investment, or public or regional funding or tax breaks have to be finally consolidated.

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 *output reporting* should report the option appraisal undertaken on a stage by stage basis, recording the information and assumptions used in each stage of decision making.

Table 6.6 sets out the key considerations for Stages 4.1 to 4.3 in a checklist with a proforma for reporting the output from this stage.

Table 6.6 Rejuvenate Stage 4 Checklist and Reporting Format (shaded)

Decision	Considerations	Information needs	Decisions made
4.1: Stakeholder views	Are there any conflicts with potential stakeholders to be expected?	Stakeholder engagement should have begun at an early stage, particularly of core stakeholders (see Section 6.2). This should be a wider consultation of approaches already agreed in principle	Whether the stakeholders involved will support a project going ahead, and if not what mitigation measures might be required.
4.2: Technology status	Do all elements of the concept work properly and in an integrated way and what are the key parameters that control this?	Detailed technical appraisal of Stage 1 and Stage 2 information Commencement of formal planning permitting and licensing negotiations	Stop / go for the project concept and whether mitigation measures are required (for example use of alterative technologies or suppliers)
4.3: Detailed diligence	Does the concept work from the legal and financial perspective?	Due diligence procedure applied to Stage 3 findings.	Stop / go for the project financing and whether mitigation measures are required (for example use of alterative investors, or revisions in project approach to provide improved investor confidence)
Overall Stage 4 findings		***Summarise the information and assumptions used at each stage.***	***Whether a viable project concept can be taken forward to implementation, and what mitigation measures may be necessary.*** ***These mitigation measures may mean that earlier stages have to be reconsidered.*** ***An important output of this stage is an agreed business plan for the project, and – depending on funders' and stakeholders' needs, agreement of wider sustainable development goals for the project.***

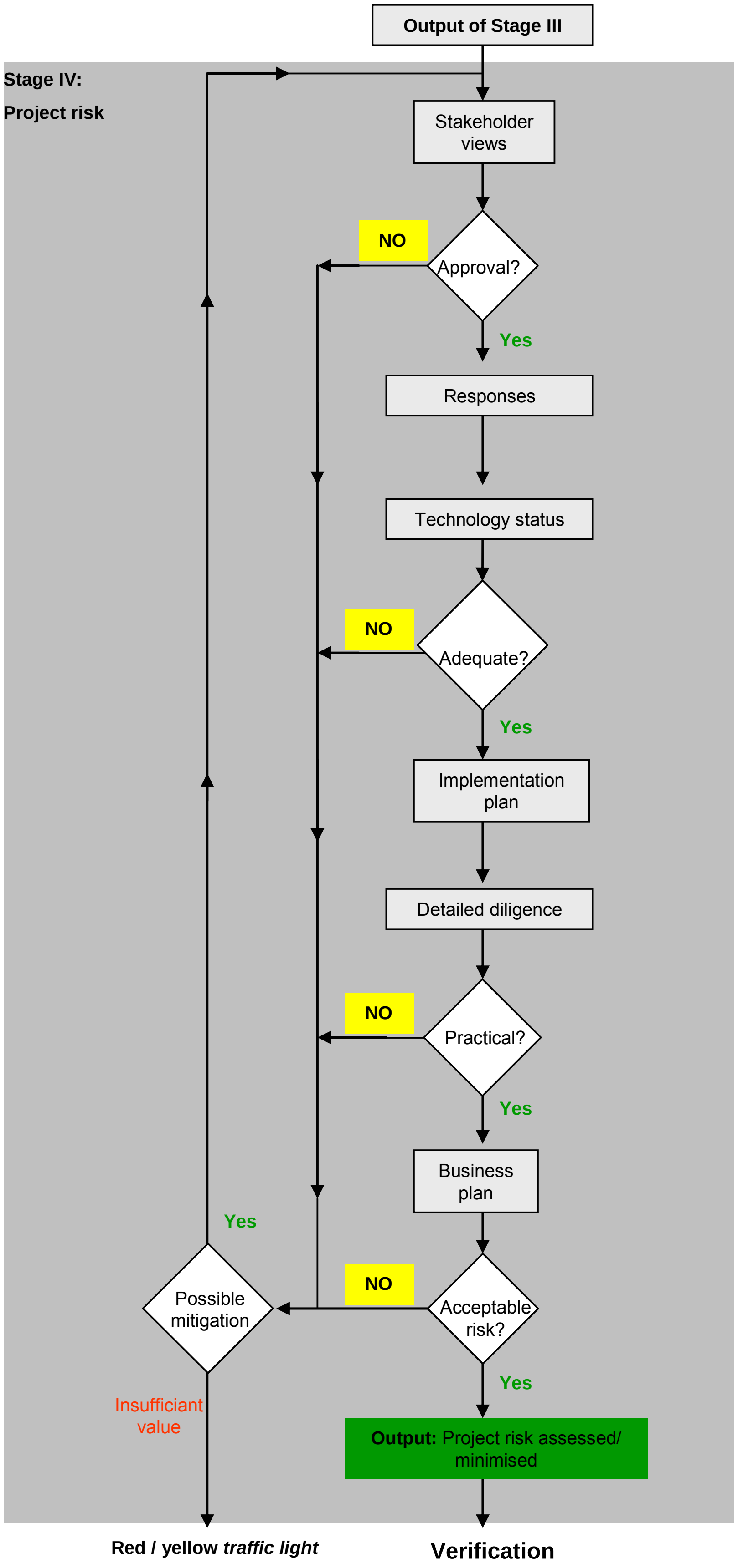


Figure 6.9 Rejuvenate DST: Stage 4: Project Risk Management

6.5 Verification of project performance

Verification of project performance will need to consider both the specific environmental project goals agreed with regulators and the project economic goals needed to achieve suitable economic performance. It will also need to consider the wider sustainable development performance of the project, in particular if sustainability goals have been agreed as a part of any public investment in the project.

Implementation and business planning information needs should largely be met by the four stages of decision making described above. *Verification* is the process by which stakeholders can be assured that the project has met its planned objectives. The project verification can therefore also follow the same structure as the four stages of decision making outlined. Additionally, verification needs to consider the following.

1. The period to be considered for verifying the project performance should be defined. Dependant on the project complexity verification can be done in a single step or in a stepwise approach, dynamically following the project start up phase. This allows the project team to identify deviations between planned and actual performance development at early stage so enabling early corrective action to be taken. It may be useful to identify milestones to ensure routine verification checks. The verification process should be linked to the site conceptual model, and the verification process will need to take into account the possibility that the SCM will need to be adapted as the site develops, and in response to changing circumstances. Hence the verification process needs to be adaptive.

2. Parameters that allow one to assess the performance related to the three categories have to be defined carefully as well as the location where and the methodology how they will be measured.

3. Verification goals/references which are the values (e.g. financial, environmental, productivity) that were planned to be achieved in the defined period. These can be compared against “control” scenarios such as an alternative use or no use of marginal land.

Three broad classes of project goals can be distinguished: environmental goals, economic goals and social goals.

Verification of project environmental goals: the project will include several environmental goals that might be explicit requirements for compliance with investment, regulations and planning constraints, and also other agreements reached with stakeholders. A key objective is likely to be that the desired site risk management is required (.e.g. that pollutant linkages are effectively managed). Wider environmental goals may relate to restoration of soil function, carbon sequestration, and improved biodiversity, as well as managing impacts, for example from N and P, on the water environment. Verification may be linked to specific measurement thresholds and an agreed environmental monitoring programme, for example for groundwater quality, as well as effective ground cover and productivity, and possibly third party verification for VER carbon financing. The verification framework should follow the assumptions and decisions made through Stages 1.1 – 1.3, 2.1 – 2.4, 3.3 and 4.1.

Verification of project economic goals: in the business plan economic goals in terms of financial feasibility and viability have to be set. In case of the implementation of supporting activities as identified in Stage 3 (value management) they have to be considered in this assessment as well. Stages 3 and 4 should be formalised in a business plan which can serve as the point of reference for economic verification, linked to project viability; and perhaps a wider range of sustainable development goals agreed in these stages for broader objectives agreed with funders and other stakeholders, such as increasing local/regional employment. The verification framework should follow the assumptions and decisions made through Stages 3.1, 3.2, 4.2 and 4.3.

Verification of social goals: a series of goals may have been established for the project, for example demonstrating stakeholder engagement and inclusive decision making as the project is implemented (and indeed while it was planned). In addition, particularly where public funding or investment has been secured, there may be wider sustainable development goals agreed, for example related to the provision of public open space and access, or linkage of the project to local education and training initiatives, or work by charities. The verification framework should follow the assumptions and decisions made through Stage 4.3.

Table 6.7 sets out an example a verification template. As criteria would vary on a case basis, a matrix would need to be refined and adapted for each specific project.

Table 6.7 Rejuvenate verification matrix template

Elements for verification	**Period considered for verification**	**Criteria to be considered for verification**	**Verification goals/ references**	**Projected values**	**Actual values**
Environmental goals					
Contaminated land risk management performance					
Organic matter re-use performance					
Wider environmental performance (soil, water and air)					
Carbon / energy balance					
….					
Economic goals					
NPV					
IRR					
Amortisation					
Annuity					
wider economic value (e.g. surrounding land values, local economic benefits etc)					
Social goals					
permission related criteria					
Community inclusion and satisfaction					
wider economic value (e.g. surrounding land values, local economic benefits etc)					

7 Decision Making Example

The Rejuvenate Project has provided a worked example to show the application of its decision-making framework. This is provided in the accompanying report: *REJUVENATE Crop Based Systems for Sustainable Risk Based Land Management for Economically Marginal Degraded Areas – A Worked Example.*

The worked example is based on a fictitious site, which is a closed colliery tip 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, open fields amounting to a 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*). However, maize was also retained for further consideration to allow a better illustration of the Stage 3. In practice it would have been ruled out in Stage 1.

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 would have been 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 and poplar with willow for the purposes of illustration, although in practice they would have been discounted already.

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 wind and solar energy were considered as project enhancements. Willow and poplar had similar financial performance, but willow is the more robust solution. Both poplar and willow were considered in Stage 4, for purposes of illustration.

The completion of Stage 4 is intended to provide a firm project concept where all associated risks are known and mitigated where necessary. The most important suggestions were to carry out a test cultivation of poplar and willow as well as early contracting to minimise potential project risks.

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.

8 Discussion

8.1 Key Messages

This study has been able to show that:

- There are significant amounts of marginal land in Germany, Sweden and the UK (as well as more widely across the EU) which are not in beneficial use, including areas that have lain unused for some time, which are hard to bring back into use by conventional means.
- There are significant amounts of organic wastes which could be used for restoration, soil improvement and as a fertiliser substitute.
- There is an increasing demand for land for biomass production (for energy, fuel and feedstock) and an increasing interest in carbon management opportunities.
- The conjunction of these need and interests could create a new opportunity for sustainable development: use of marginal land for biomass production, which may “unlock” long term problems of land degradation and dereliction.

This type of land use may also bring a wider range of sustainability benefits including biodiversity management, benefit for local communities and the generation of capital, educational value and employment. There are competing demands for marginal land, yet many large areas of land remain under-utilised. In addition, large areas of land under agricultural use suffer problems of diffuse contamination.

Furthermore this conjunction of several drivers (land restoration, organic matter re-use and biomass energy) as well as its wider sustainability benefits may make land that has been marginal over long periods very attractive for “pioneering” biomass projects, compared with the use of land previously designated as agricultural set aside. An interesting thought is that it may be both easier and faster to establish biomass projects on marginal land, than on land where the change in land use may be more controversial, since carbon effects of land use change can be a major factor in the overall effectiveness of any biomass project in achieving overall net GHG emission savings (Environment Agency 2009a and 2009b).

The study is unable to give an exact prognosis of the scale of the opportunity as the conjunction of opportunities and interests is controlled by local scale factors. Furthermore, definitions and data collection approaches vary significantly between the UK, Germany and Sweden so what is considered potentially contaminated land in one country (e.g. former mining areas in the UK) may be explicitly excluded from this category in others (e.g. mining areas in Germany) whatever the issues of land contamination actually are.

However, it does appear that some countries, in particular the UK, are collecting locally based information, which could be combined in a GIS to provide a better estimation of the scale of the opportunity at a regional level, and also assist project developers in identifying and evaluating opportunities. What is clear is that the amount of marginal land in global terms is small in comparison to the potential land demand for non-food crops if European demand for bioenergy, biofuels and biofeedstocks is to be met. However, the amount of land may be far more significant at local and regional levels. The revenue potential from non-food production on land, and perhaps even carbon off set, may be sufficient to assist the long term management of marginal land, and perhaps in some cases even generate a positive return.

This type of land use should not be seen as an “either-or” alterative to other land use options such as built redevelopment and amenity use. The Markham Willows master planning showed several years ago how biomass use of marginal land could be integrated with built and amenity development, and indeed new synergies were created by such an integrated or “mosaic” approach. The synergies include the use of the biomass on marginal land project for local energy and organic waste management solutions, as well as opportunities like local grey water management (AEA and r3 2004). More recently, with the interest in sustainable homes, particularly in terms of carbon balance, this type of integrated land use may provide new opportunities for moving towards carbon neutrality on a project wide basis.

Success will depend on whether a suitable cross-sectoral interest can be established, both in terms of approach, and the stakeholders who would be involved. Marginal land for biomass projects are increasingly being offered in studies and demonstration projects, but have yet to “break through” as a main stream activity. In part this is because the activity cuts across different sectors and interests. Consequently a project developer may struggle to create a critical mass of interest. Cross-sectoral networking activities, aimed at practioners, might be a way of assisting the development of biomass on marginal land projects, particularly if evidence can be brought to bear that they can truly generate value under the current economic climate. Project opportunities may also be supported by providing integrated information, for example biomass market, non-food crop suitability, organic resources and land bank information in a single GIS, albeit operated at regional or national levels.

A difficulty for biomass on marginal land projects is that they cut across a number of regulatory domains, for example concerned with: waste management and recycling, contaminated land management, water environment, soil protection and biomass strategy. The regulatory and planning demands may therefore be complex. Consequently Rejuvenate has suggested its integrated decision making framework, the four stages described above: crop; site; value and project risks. It is important in this decision making process that decisions are made on the least suitable information, rather than always on the basis of detail, in order to expedite projects and minimise unnecessary decision making costs. For example, where sustainability appraisal is called for, this should be qualitative unless there are specific demands that explicitly call for a quantitative approach such as LCA.

It will be important for biomass on marginal land projects to show that the biomass they deliver is fit for purpose and that environmental risks are being managed. In Sweden and Germany contamination of biomass, for example by PTEs, may trigger the need for special measures being introduced for biomass use, for example in terms of emissions control and ash re-use. The situation is uncertain and will depend on the views of the stakeholders concerned at a particular project and of the local regulator. For this reason containment and stabilisation, with a view to minimising biomass content of toxic elements, may be preferable as a land risk management approach compared with phytoextraction based approaches to biomass, particularly as the long term effectiveness of phytoextraction for metal removal from soils is unproven in any case.

Quality management will need to be an integrated activity across the project, for example considering process inputs such as organic matter used for soil forming or as a soil improver to facilitate crop growth. Project managers may greatly reduce their regulatory burden by using organic matter inputs that comply with recognised standards (such as PAS-100 in the UK), but such materials may exclude important classes of organic inputs such as CLOs. Where materials are excluded, it would seem important to develop site-specific quality standards for them to facilitate their use, particularly as such materials may be available at far lower cost to a project.

While there is a general opportunity for biomass on marginal land projects across Germany, Sweden and the UK, the nature of the opportunity is different in each country, reflecting their different contexts. For example in the UK there appears to be an appetite for integrated projects (at least conceptually) where biomass is used locally or even on the regeneration project itself. In Sweden there is far greater demand for off-site use in its existing infrastructure of biomass CHP plants. The decision making approach devised by Rejuvenate is robust as it is serviceable in all three countries.

Finally, it is not the purpose of this project to suggest an irreversible switch in land use to biomass production. However, there do appear to be carbon balance advantages in the long term management of marginal land for biomass, particularly perennial crops, with regular use of organic matter soil improvers, provided that accumulation of contaminants such as PTEs and POPs does not create new pollutant linkages. Over the longer term biomass re-use of a site may facilitate its improving functionality for other uses as its history of dereliction and impact on the local surroundings gradually diminishes. Such projects may also offer a gradual improvement in economic value along with landscape value.

8.2 The European Dimension

The requirements for managing marginal land which may have long term problems of abandonment, dereliction or under management are widespread across Europe. A major impediment to bring such land back into a chain of use is that there has been no economic driver to do so. There has always been a public and political interest in rehabilitating such land, but the rehabilitation is not a self managing process and usually requires an ongoing public investment in its maintenance. The increasing demand for biomass may provide a mechanism for generating revenue that could support the long term use of such land as well as the amelioration of environmental impacts. An unexplored opportunity is how these projects could be supported by *voluntary* carbon offset trading.

It is clear that across the EU 27 the amount of marginal land is not large in comparison with the land bank envisaged as necessary for biomass production in the future. However, it may be significant at a regional or local scale, particularly where primary extractive or secondary processing industry has been discontinued. In such areas biomass re-use of marginal land may additionally provide a range of wider sustainability benefits such as landscape improvement, creating economic activity and some job creation.

These opportunities are clearly inline with both the EU Sustainable Development Strategy (SDS), especially the objectives on climate change and clean energy and conservation and management of natural resources (Hontelez and Maria 2006) and the interest in sustainable approaches to remediation and land management in the EC Soil Strategy (2006) and the draft Soil Framework Directive.

The use of renewable sources of soil improver (and fertiliser) in the production of biomass on marginal land is in line with the Waste Framework Directive (2008/98/EC) and the EU 'Green Paper' on biowastes (EC 2008b).

There are therefore a number of common drivers across Europe for encouraging biomass based re-use of marginal land. However, it is clear from the Rejuvenate project that a “one size fits all” specification for what such a project might be is simply not possible. Each region and indeed locality will be subject to its own geological and meteorological conditions, markets for biomass and regulatory circumstances are variable. However, what also appears clear is that a set of common decision making principles could be established across Germany, Sweden and the UK, which have been elaborated in a decision making approach by the Rejuvenate project. It will be interesting to see if this common approach can have a wider applicability across the rest of the EU 27, particularly at a demonstration scale.

9 Conclusions and Suggestions for Further Activities

The use of marginal land for biomass production is a substantial sustainable development opportunity across Europe. The conjunction of these need and interests create a new opportunity for sustainable development: use of marginal land for biomass production, which may also bring a wider range of sustainability benefits, and also provide leverage to support the re-use of “hard to develop” sites. The conjunction of several drivers (land restoration, organic matter re-use and biomass energy) as well as its wider sustainability benefits may make this land very attractive for “pioneering” biomass projects. This may make a quick start more likely than for projects where the change in land use may be more controversial for example in terms of land use changes on carbon balance, but this will depend on the emergence of a suitable cross-sectoral approach.

Biomass on marginal land projects may be important in localities and regions with a history of long term land dereliction. Quality will be a determining factor from regulatory and market perspectives. Consequently the uptake of contaminants into biomass should be limited.

A decision support approach has been developed by Rejuvenate which is serviceable in Germany, Sweden and the UK. These countries have substantive differences in their land and biomass re-use contexts. However, all can make use of the set of common principles of crop, site, value and project risk management set out by Rejuvenate. This implies that this guidance and its decision-making framework should have wider applicability across the EU.

The potential opportunities for biomass on marginal land in tandem with organic waste recycling may be more easily identified using a GIS system that pools crop suitability, biomass market, and bank and organic matter resource information.

Biomass on marginal land projects cut across a range of market and regulatory sectors. It may be useful to facilitate cross sectoral network to facilitate the emergence of new projects.

It would also be interesting to know, in a strategic sense, what the carbon impact and soil fertility benefits might be of improving soil organic matter content in marginal land areas, where soil quality is often low.

At a European level (and indeed within national jurisdictions) the findings of Rejuvenate indicate that there are data gaps which a range of demonstration projects of biomass re-use of marginal land could help to fill, to take into account different regional, economic and technological aspects, and to robustly test the decision making framework presented in this report.

9.1 Research Needs

A series of research, technology and demonstration needs and opportunities are summarised below, for each of the four decision making contexts identified by Rejuvenate:

Crop (and soil system)

There is a need for better understanding of the fate of contaminants of concern in biomass crops and the elaboration of strategies for risk management that prevent the transmission of contaminants to harvestable fractions of biomass. This would imply a need for development of containment and stabilisation approaches[89], and perhaps some work related to biomass crop development for types that *exclude* rather than accumulate contaminants, combined with soil interventions such as the use of biochar to reduce metal mobility. Work is also needed to better understand the fate (and burdens posed) of contaminants that might be taken up by biomass produced on marginal land.

Site

The most urgent need is to support large scale demonstration work and the reporting of decision making process beforehand. There are a number of demonstration projects looking at biomass on marginal land to some extent, but what is needed is a holistic approach that is able to move this concept from being one of academic interest to one that is being implemented in a practical sense.

Value

The Rejuvenate approach emphasises the importance of wider sustainability. Sustainable remediation concepts are in development in Europe and sustainability based decision making should be encouraged. As the CLARINET network (Vegter *et al.* 2002) pointed out nearly 8 years ago considering the true contribution of remediation work to sustainable development is an emerging challenge at least as great in its difficulty as the development of risk based decision making, and with the same capacity to profoundly change how we manage contaminated land in the future. The long term impacts of biomass use of marginal land on the soil and water environment should be evaluated, particularly as the re-use of organic matter combined with perennial biomass crop types appear to carry benefits for soil functionality and carbon sequestration. There are also potential biodiversity advantages for biomass crops such as willow, and interestingly soil degradation (loss of organic matter) has been linked with decreased biodiversity of bird populations, as invertebrate numbers and biodiversity are reduced (Gilroy *et al.* 2008). There are also worries that removal of excessive secondary biomass from agriculture, such as straw for bioenergy, may lead to long term declines in soil organic matter content and productivity. Perhaps better soil management, including regular organic matter return, under biomass crops may have a range of broad benefits. It would be useful to understand in a strategic way how soil quality, biodiversity and biomass production might be optimised, and indeed in a systematic way come to a conclusion whether high rates of organic matter return might be beneficial, even in excess of crop N and P requirements. Any such strategy would need to carefully consider the environmental impacts of any N and P losses to the wider environment, in particular impacts on water bodies.

There is a substantial interest at present on biomass for energy. However, biomass as feedstock for industrial processes may provide both greater revenue opportunities and also a better overall carbon benefit where these feedstocks substitute for resources that are otherwise produced in a carbon-intensive manner. The most recent SNOWMAN call for proposals included an item on biomass on contaminated land for biofuel. It may be interesting for a future call to consider biofeedstock opportunities, as there are a wide range of novel non-food crops that have feedstock value.

Project risks and verification

In tandem with supporting demonstration projects, there need to be confidence building activities to encourage participation in biomass on marginal land projects. These activities might range from networking to allow the incubation of projects in a cross-sectoral way, but also other activities related to developing more holistic approaches to the regulation and permitting of projects, in particular facilitating the use of biomass products from marginal land. Where projects are taking place performance against environmental, economic and social goals should be monitored, both to show examples of good performance, and to understand causes of poor performance where it occurs.

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[89] Also considered by the SUMATECS project (SUMATECS Consortium 2008)

Overall

The decision making approach developed by Rejuvenate should be “tested” against real demonstration project activities, and also against its wider applicability in the EU 27, particularly countries with large areas of marginal land.

In an overall sense there would appear to be clear benefits from developing GIS based approaches to the assessment of potential project opportunities, both from the perspective of individual project developers being able to access consolidated local information in support of their decision making, but also to provide local, regional and national authorities with estimates of the scale of opportunities for marginal land management, organic matter re-use and biomass production. These broader assessments made on the basis of existing consolidated land bank information and general reviews or organic matter availability and biomass markets do not withstand detailed scrutiny.

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