

Biomass for heat and power in the UK

A techno-economic assessment of long term potential

Final report

1st December 2003

E4tech

E4tech (UK) Ltd was commissioned within the Renewables Innovation Review to undertake a techno-economic assessment of the potential for biomass energy in the UK to 2020. The assessment explains the potential for stationary heat and power from biomass, should fuel chains develop favourably . The assessment intentionally does not attempt to predict the likelihood of this development, nor does it address all of the practical steps required to bring this about.

This report was developed by for the purposes of the DTI Renewables Innovation Review. The report and its supporting model were developed over the period September-November 2003, based upon best available information. E4tech (UK) Ltd is not responsible for use of the report or the accompanying model for purposes other than those specifically of the Renewables Innovation Review.

E4tech (UK) Ltd would like to acknowledge the input of the many organisations that contributed to this report.

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Biomass energy could deliver substantial benefits to the UK

- Biomass fuel chains have the theoretical potential to provide up to 21% of UK electricity demands in 2020 at a viable cost. In practice this would be constrained by the rate at which plants could be built, though the total could still reach 13%, saving 19 million tonnes of CO₂ in the year 2020.
- This can be achieved through four primary chains, each of which can be based on more than one conversion technology, including smaller scale CHP technologies. These are:
 - Short rotation coppice willow, through both combustion and gasification
 - Miscanthus and straw, through both combustion and, by 2020, gasification at large scales
 - The organic fraction of municipal solid waste, through gasification, anaerobic digestion and combustion
 - Sewage sludge, through gasification, anaerobic digestion and combustion
- The UK could build internationally competitive industries in several areas of biomass energy such as in energy crop breeding, in established combustion and process engineering sectors, in novel gasification and small-scale generation technologies and in large scale biomass project engineering. These industries would support the UK fuel chains above and contribute to exports.
- Factors such as non-CO₂ emissions and other technology benefits do not create strong distinctions between energy crop chains, but can be more significant in the case of waste chains, where an appropriate solution for each waste management situation is needed.

Numerous barriers must be overcome to unlock this potential

- In energy crop chains, there is limited UK experience with feedstock growing and supply. This is mainly a result of little demand for feedstocks, since conversion technologies suffer from high costs and high technology risk for advanced technologies, particularly at small scales.
 - Other fuel chains can support development of these chains by helping to establish markets for biomass feedstocks, by contributing to fuel security, and by providing experience with conversion technology, helping to build investor confidence.
 - However, supporting chains alone are not sufficient to remove barriers entirely, and so to achieve significant biomass potential. This will require a coordinated package of supply and demand side measures, which simultaneously promote innovation and provide economic incentives for fuel chain development. A series of regionally-focused programmes involving feedstock market development, deployment of proven technologies and demonstration of novel technologies should be used to support energy crop based fuel chains.
- Energy generation from waste and sewage sludge must be considered as part of an integrated waste management policy to find the best disposal and energy generation solution for each situation. The main barriers to this are a lack of demonstrated advanced technology in the UK, coupled with a lack of understanding of, and priority for, energy recovery by key stakeholders.
- Central to development of all the chains is coordinated provision of policy support and information to actors in the fuel chains.

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The overall aim is to assess how to bring about biomass fuel chains which have the potential to viably reduce CO₂ and offer competitive advantage

Main questions

1. Could any biomass fuel chains make a material impact upon renewable energy generation and CO₂ reductions at costs which are competitive with limited support?
2. Are there any other important considerations which might favour certain fuel chains?
3. What barriers might fuel chains face and how could they be overcome?

Supporting questions

- Which individual fuel chains could provide >0.2% of UK electricity in 2020?
- Could these chains generate heat and/or power at costs which compete under existing support frameworks?
- How much CO₂ would these fuel chains avoid?
- Could a sustainably competitive UK biomass sector be based on any of the chains?
- Might any of the chains cause other unwanted consequences?
- Which other fuel chains could support the primary chains?
- What is the best mix of mechanisms to overcome barriers?

NB This assessment is intended to provide a view of what could happen under favourable biomass sector development conditions. Where data is available in ranges, the optimistic (but realistic) end of the ranges is used.

Approach to the modelling of potential penetration and costs (question 1)

1. Devise fuel chains in terms of resources, conversion technologies and end uses
2. Eliminate those chains where resources are very unlikely to be available or material
3. Apply resource and efficiency data to each stage of the fuel chains to determine the energy that each could supply in 2010 and 2020.
 - Compare with UK energy forecasts for 2010 and 2020 and calculate potential biomass penetration by fuel chain
 - Calculate penetration potential with and without constraint on the build rate of plants
4. Apply emissions factors to each chain to determine how much CO₂ would be emitted and compare this with electricity generated by CCGT (lowest emission fossil fuel option).
5. Apply cost and efficiency data to each stage of the fuel chains to calculate the generated energy cost for each fuel chain in 2010 and 2020
 - Compare with current cost of nearest competing fossil option, taking renewable energy incentives into account
 - For leading options, calculate cost reduction potential to 2050 based on learning curves
6. Those chains which can deliver >0.2% of UK energy in 2020 and compete with fossil energy are deemed to be the 'primary fuel chains'

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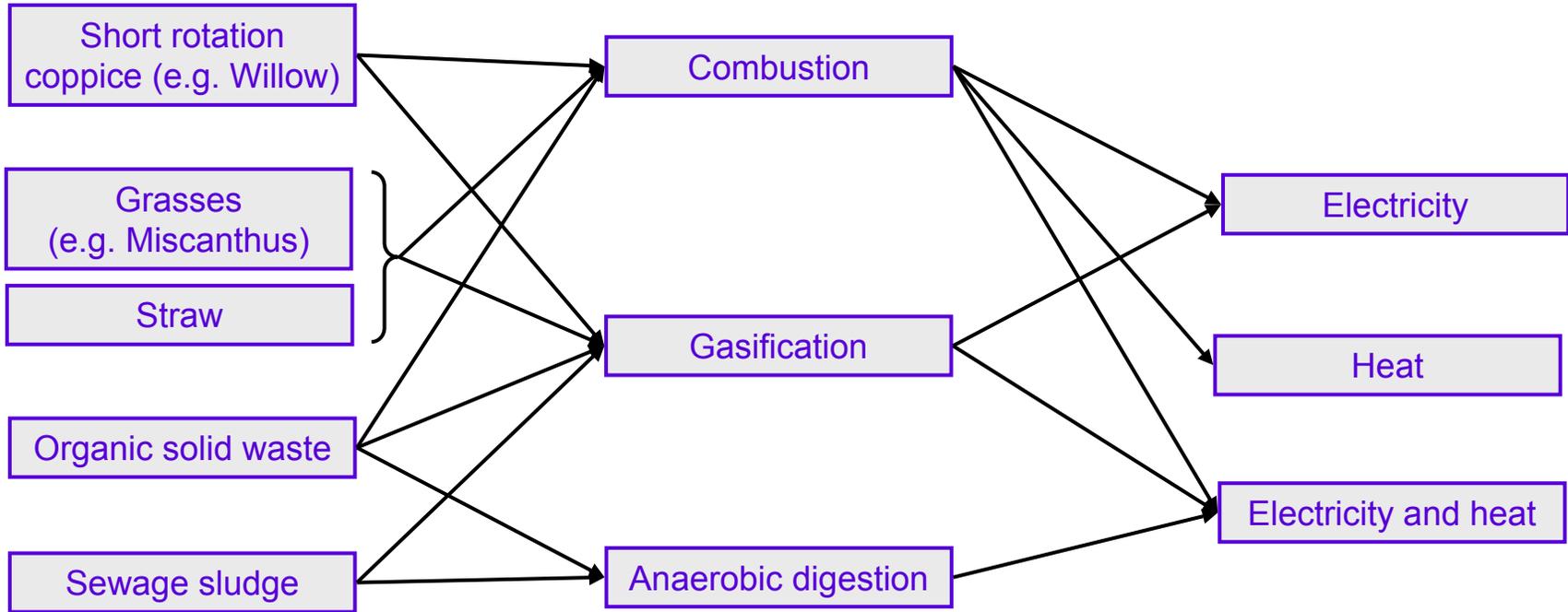
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There are four primary fuel chain groups which could make a material contribution to UK energy demand in 2020

Primary fuel chains for electricity and heat in 2020

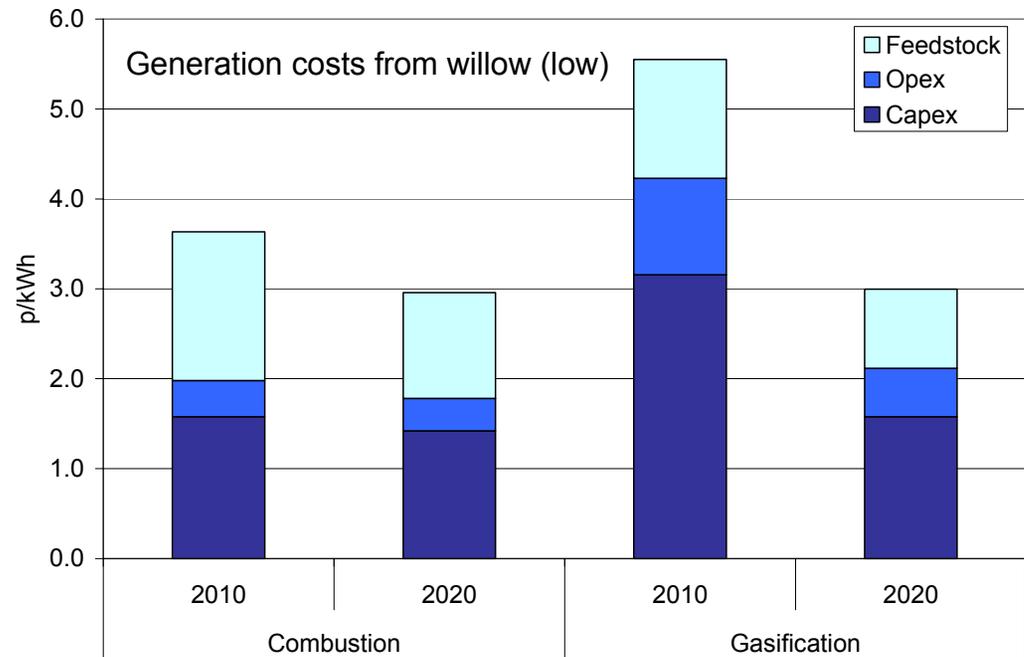


- Other potential feedstocks include: forestry residues, woodland management, wood processing wastes, food wastes, farm wastes. These could each contribute less than 0.2% of UK energy demand in 2020.
- Note that plants based on the same conversion processes may differ significantly in design based on the feedstock, and may not be able to accept a mixture of feedstocks - e.g. willow and miscanthus are not gasified together
- For definition of technology scales, applications and products, see appendix 1

Willow could provide significant penetration of UK electricity at viable costs if used in large scale power plants

Utility scale power

- At the large scale, willow-based fuel chains could provide a significant proportion of the UK's electricity, with a positive forecast of potential reaching as much as 8.8% of the 2020 total. In practice, the rate at which plants could be built is likely to constrain this to the range 0.6-1.2% by 2020, depending upon the choice of technology (gasification or combustion).
- Penetration projections are highly dependant upon being able to plant coppice at large scale. This projection assumes that by 2020, 1 million hectares of land are planted with willow. For reference there is currently a total of about 18 million hectares of agricultural land, including 5 million hectares of arable land of which 0.5 million hectares are under set-aside, making this optimistic but feasible under the right conditions. To 2010, it is assumed that 125,000 hectares are planted.
- Combustion and gasification are both technically suited for this scale. Both are competitive under the RO/CCL, with generation costs as low as 3.0p/kWh in 2020. However, generation costs are not competitive for gasification or for the majority of combustion plants in 2010.
- In the very long term (2050) energy costs using willow are similar for combustion and gasification, but gasification has higher efficiency.



Willow also has potential for high levels of penetration at low cost using several smaller scale technologies

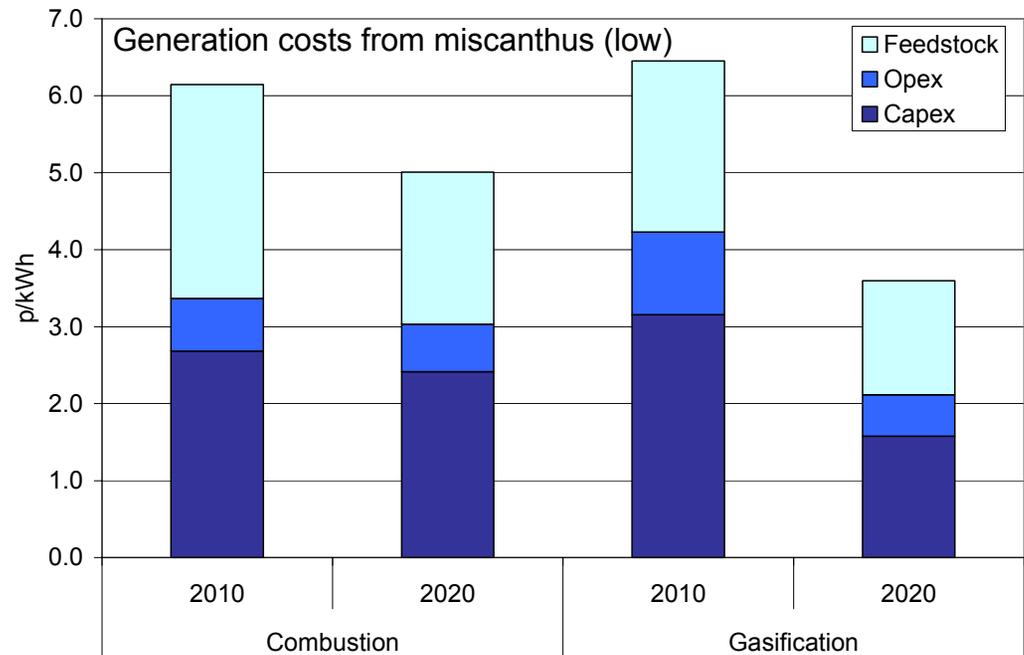
Smaller scale electricity and heat

- Willow-based fuel chains could contribute significantly to UK energy, with unconstrained potential up to 5.5% depending upon application. Build constraints limit this to 1.0-2.0% by 2020.
- Smaller scale technologies also compete well with fossil electricity under the RO/CCL with lowest costs forecast in the range 1.9-2.5 p/kWh by 2020. Generation costs in 2010 are also competitive for the majority of plants. Note, however, that small scale gasifiers are at an early stage of commercialisation worldwide.
- Willow chips and pellets are suitable fuels for heating systems at a range of scales, and there is the potential to produce heat at a cost of 0.8-2.5p/kWh_{th} in 2020. The low end of this range represents using wood chips in industrial scale applications, where the price point is estimated to be around 0.5p/kWh_{th}. The high end represents use of pellets in domestic scale systems, where the price point is 2.5 p/kWh_{th}. Heat generation is therefore only competitive in 2020 for small systems, but could be viable for some larger systems where alternative heat costs are greater. Heat costs in 2010 are not yet competitive, at 1.0-3.1p/kWh_{th}.
- Pyrolysis fails to give a material contribution based on penetration levels by 2020, which is a function of the low overall fuel chain efficiency and low build rates as the technology is at an earlier stage of development than the other considered. However, some pyrolysis development may occur based on the demand for biologically-derived specialty chemicals.

Together, miscanthus and straw have very high ultimate potential, though their economics are less attractive than willow

Utility scale power

- Miscanthus is a high-yielding crop and, if planted at scale and converted efficiently in large scale gasifiers, it could provide up to 11.8% of UK electricity in 2020. In practice, technology development needs and plant build constraints reduce this figure to only 0.6% (gasification) or 1.3% (combustion). Straw has a lower ultimate potential (around 3.2%) due to the smaller resource potentially available for energy uses.
- Miscanthus penetration projections are highly dependant upon being able to plant at large scale. This projection assumes that by 2020, 1 million of the current 5 million hectares of arable land are planted with miscanthus. The use of mixed straw and miscanthus plants would help to build technology experience whilst miscanthus availability is developed. To 2010, it is assumed that 125,000 hectares are planted.
- Gasification offers lower electricity costs than combustion, particularly with a potentially higher cost miscanthus fuel. By 2020 optimistic costs (in the order straw-miscanthus) are forecast in the range 3.3-3.6p/kWh for gasification and 4.6-5.0p/kWh for combustion. In 2010, all low-end costs are above the 5 p/kWh price point.
- In the very long term (2050), gasification is over 1p/kWh cheaper than combustion, and has a higher efficiency.



Miscanthus and straw are attractive as fuels for smaller scale CHP, but less so for heat

Smaller scale electricity and heat

- Straw and miscanthus are feasible at medium scale for combustion CHP, with a potential of 2.0% by 2020, based on build rate constraints. The lower end costs of electricity generated are 4.6-5.1p/kWh - below the 6.4p/kWh price point. However in 2010, only plants using straw are competitive (5.0-5.8 p/kWh), with miscanthus costs at 6.6-9.7 p/kWh.
- Small scale gasification and pyrolysis of both fuels are unlikely to be able to make a material impact on UK electricity demand by 2020, particularly in view of the relatively low level of technology development with these fuels. Breakthroughs in development of these technologies could allow for increased build rates, increasing this potential, and possibly lead to lower costs.
- Both miscanthus and straw have potential to contribute as heat fuels, though their use will be limited as a result of low energy density of the baled feedstock, and therefore difficulty in transport, and inconvenience of storage and feeding compared with wood chips . Penetration of this market is expected to be able to reach only 0.2-0.6% by 2020. However, 2020 generation costs are competitive for smaller users, with straw costs at 1.0-1.4 p/kWh_{th}, and miscanthus at 1.2-2.2 p/kWh_{th}.

Organic solid waste (OSW) has a significant electricity potential via several technology options at very low cost

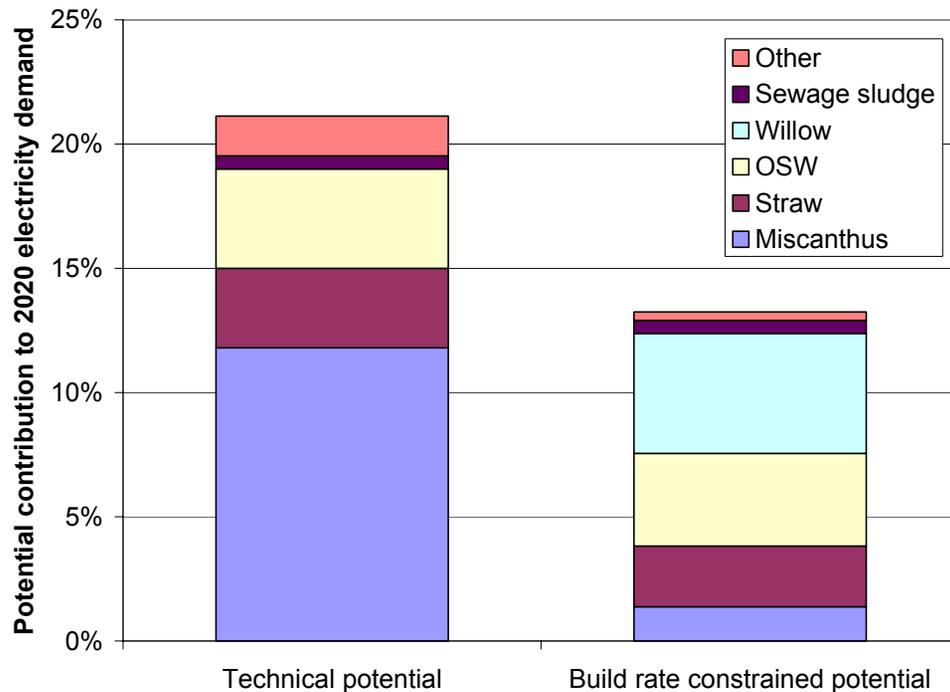
- The organic fraction of municipal solid waste (OSW) could provide around 2.2% of the UK's electricity by 2020. A significant contribution could also be made in the shorter term, with up to 0.6% able to be generated by 2010. This is as a result of the wide resource availability, and the ability to use existing technologies, at a variety of scales, even when build rates are constrained. The potential in 2020 with no build rate constraints is 4%.
- Use of OSW relies on effective waste separation – either through source separation or in centralised facilities. The gate fee has been reduced by £8/t in the model to allow for source separation costs. Other centralised options are assumed to be available at a lower cost once fully proven.
- Gasification, anaerobic digestion, and combustion are all viable options for energy from OSW. The choice of technology will vary depending on local conditions and desired inputs and outputs.
 - Gasification is likely to be most efficient for electricity generation, and is available at a range of scales, but is the least proven technology. Small scale OSW gasification plants are unlikely to generate at a viable cost in the short term.
 - Anaerobic digestion is an established technology, that produces a biofertiliser. AD is viable at small scales, and therefore is the lowest cost option for energy from waste at small scales in the short term. Some AD processes can also accept wetter, mixed wastes.
 - Combustion is currently available, and feasible at large scale, but may have higher pollutant emissions, low public acceptability and long planning times.
- The lower end electricity 'costs' for large scale gasification, combustion and AD are all negative in 2020 (as a result of the gate fees received for waste treatment, which are high as a result of the increasing landfill tax), with all high end costs below 5p/kWh. In 2010, low end costs are also negative, but high end costs are only competitive for combustion and AD. Small scale gasification is not competitive in 2010, and only competitive at the low end of the cost range in 2020 (1.7-7.8p/kWh).

Sewage sludge has a lower electricity potential, but energy generation could give low cost electricity, and a low cost sludge disposal route

- Electricity from sewage sludge could provide up to 0.5% of the UK's electricity requirement in 2020. This assumes that there are no build rate constraints from 2010 to 2020, and that energy is produced at the wastewater treatment works.
- The primary conversion technology in the short term is anaerobic digestion – a proven technology, already widely used for sewage sludge in the UK. This could provide 0.4% of electricity in 2010. Gasification technologies are at the demonstration stage for sewage sludge.
- In the longer term, gasification is likely to be the most efficient option for electricity generation, and give lower costs than other options, including sludge incineration. Before the avoided costs of alternative sludge disposal are considered, electricity costs from gasification in 2020 are around 9p/kWh. As the costs of alternative methods in 2020 are likely to be high (at least 50% more than the cost of gasification) this implies that electricity could be sold at a competitive price. In 2010, the costs are around 14 p/kWh.
- Achieving these build rates and costs will depend on adoption of new technologies, including anaerobic digestion with more efficient energy generation, by the wastewater industry. At present the industry is not focused on energy production from sludge treatment and disposal processes.
- The greenhouse gas reduction potential from avoided energy use in sludge treatment, and reduced methane emissions from existing AD plant could be greater than the reduction potential through fossil energy displacement

When the maximum biomass potential is constrained by build rates, the remaining potential of 12.9% by 2020 is still material

- The total constrained electricity potential from these primary chains cannot simply be calculated by adding the constrained potentials from each chain, as there is overlap in terms of plants built and land used. Instead, chains have been added so as to achieve the largest possible potential.
- Miscanthus and straw are assumed to use the same plants. As straw does not compete for land use with willow, it is assumed to be used first. The total build rate constrained potential (3.8%) is therefore supplied mostly by straw (2.4%) and by some miscanthus (1.4%).
- For willow the total build rate constrained potential is 4.8%.

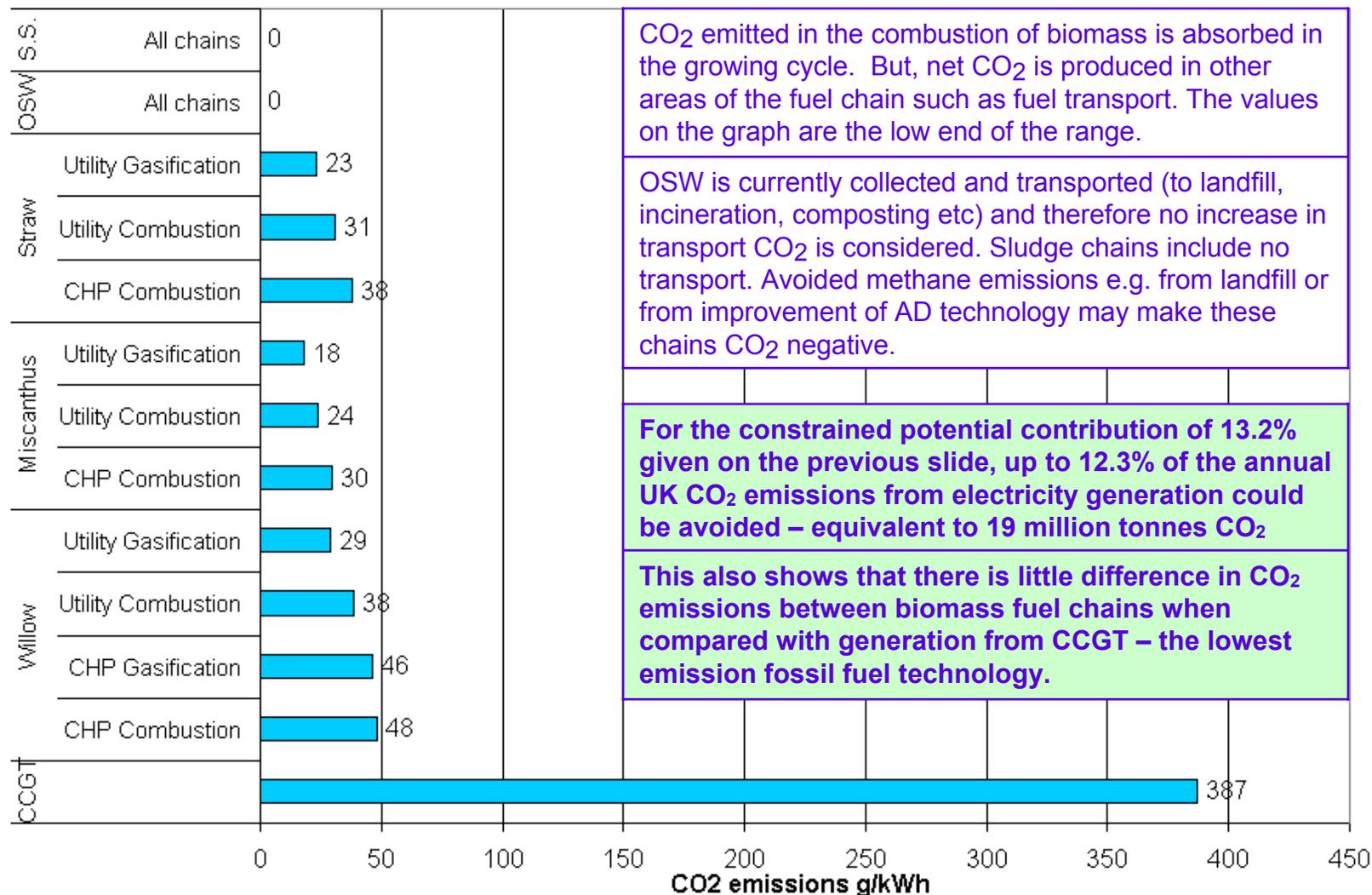


- The OSW potential is 3.7% - all gasification plus a proportion of combustion plants
- The sewage sludge potential is unconstrained in 2020 – 0.5%
- This gives a total potential of 12.9% from the primary chains.
- This is increased to 13.2% if supporting feedstocks are used

This represents a significant source of non-intermittent, dispatchable renewable electricity

The annual CO₂e savings from the constrained potential of all biomass fuel chains could be up to 19 million tonnes in 2020, when compared with CCGT

Low end CO₂ emissions from primary electricity-producing fuel chains in 2020



Using imported fuel more than doubles biomass fuel chain emissions, but still gives significantly lower emissions than CCGT

- Chains involving imported feedstocks will have higher CO₂ emissions as a result of transport.
- For wood chip import from Baltic countries, the energy use in transport is estimated up to 10% of the feedstock energy content. (Utrecht University)
- If this energy use is assumed to be from heavy fuel oil, with a carbon intensity of 0.26 kg CO₂ /kWh (LCIP), the CO₂ emissions are increased by 26 g CO₂ /kWh biomass input.
- When plant efficiencies are included, this increases the fuel chain emissions by up to 90g/kWh electricity, giving up to 138g/kWh in total (for willow combustion CHP). This assumes emissions from road transport once the feedstock is in the UK are the same as for domestic feedstock-based chains.
- This is a significant increase compared with use of domestic resources, but is still just over a third of the emissions from CCGT (387 g/kWh).

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There are a number of areas in which the UK has the potential to build competitive advantage

Plant breeding

- Energy crop plant breeding, growing and harvesting practice are areas that require improvement and where the UK has strong capabilities.

Small scale generation equipment

- The development of small scale generating equipment associated with combustion systems is an area where the UK has activity and that is of interest to improve viability of small scale systems.
- Utility scale combustion technologies need to be optimised for use with biomass feedstocks, particularly energy crops, and the UK has a solid base of equipment manufacturers. There appears to be little opportunity to build advantage in waste combustion.

Small gasification technologies for wood and wastes

- The UK has a handful of innovative small wood gasifier companies in a sector where no dominant design has emerged and there is a large potential market. Gasification requires further development, some of which plays to the strengths of the UK's research and development base. The UK also has strong technology in waste and sewage sludge gasification, particularly at the smaller scale. The UK has a strong potential market for these technologies, and there is a large worldwide market. However, the gasification technology area also has strong international competitors, particularly at larger scale.

Systems integration

- UK companies are adept at integrating diverse technologies for energy systems. The UK also has a number of global scale companies involved in power engineering and equipment service.

Other factors do not create strong distinctions between energy crop chains, but can be more significant in the case of waste chains

Emissions of regulated pollutants

- Emissions of regulated pollutants are not significant from biomass fuel chains using modern technologies and are also not a distinguishing feature between chains.

Crop choice

- Willow, miscanthus and other crops could contribute to UK biomass energy. Different types of land and climatic conditions will be suitable for each, for example, willow's high water consumption is not suitable for dry areas, but could be beneficial in wet areas. Miscanthus' annual crop cycle may also be more suitable in some cases.

Other technology benefits

- Comparison between waste conversion technologies needs to take account of the balance of priorities between waste disposal and energy and the different by-product stream values. An integrated waste management approach would use the best appropriate technology for the waste input, location, and product priorities.
- Similarly, for sewage sludge, technology choice will also consider factors such as plant scale, heat demands, and product use/disposal

All of these resources could also be used to produce transport fuels, and so potential interactions should be predicted and built into policy directions

- There may be competition for resource or land use with resources for transport fuel production. There is no reason that fuel chains for electricity, heat and transport could not co-exist, but the interactions between the chains, in terms of regional resource availability, stability of feedstock markets and feedstock prices must be considered in policymaking.
- Current UK biodiesel production is low, and predominantly uses esterification of waste vegetable oils, giving little interaction with electricity or heat chains.
 - Rapeseed and sunflower are the principal potential source of biodiesel using this fuel chain in the near term, which could lead to some competition in land use with electricity/heat chains. This process is used commercially in several European countries.
 - Diesel could be produced from lignocellulosic biomass, including SRC, wood wastes, energy grasses, straw and OSW via gasification and conversion in a Fischer-Tropsch (FT) process. This technology is at the pilot plant stage. **This could provide significant competition for resources**, however FT reactors also produce lighter gaseous hydrocarbons, which can be used to generate heat and electricity.
- There is currently no bioethanol production in the UK.
 - Production of bioethanol from sugar beet and wheat grain is a well developed process, and would be possible using UK resources.
 - In the future, technology development could allow production of bioethanol from lignocellulosic biomass. This technology is currently at the pilot plant stage worldwide, with the first commercial plant not expected in the UK until 2012-13. The first plants are expected to use straw, which could provide significant resource competition, with **competition for all resources in the longer term**.
- **Any of these feedstocks could also be used to produce hydrogen** – for example through gasification, anaerobic digestion with biogas reforming, or fermentation. Large-scale demand for hydrogen is expected to develop after 2020.

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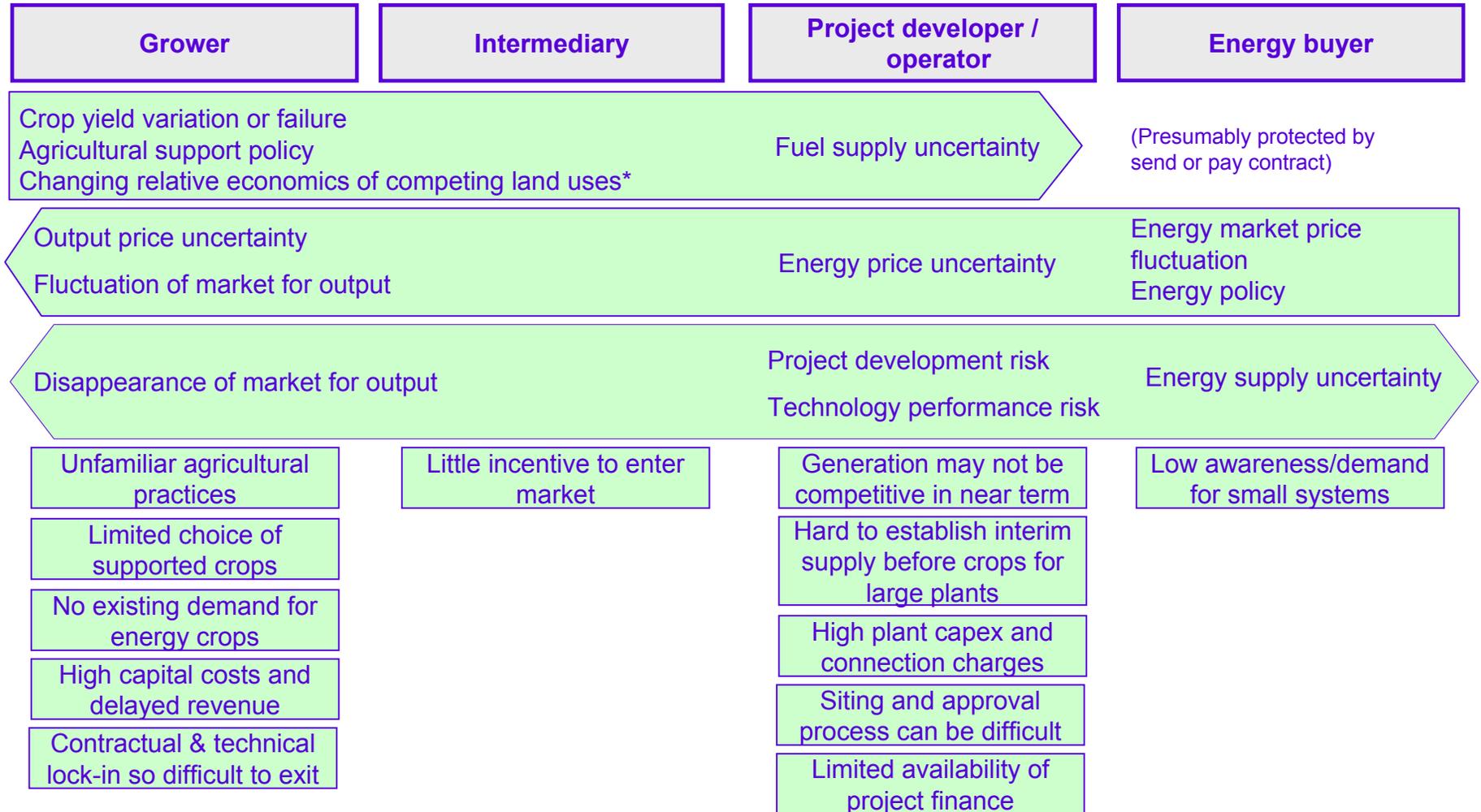
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Biomass development faces barriers at all stages of the fuel chains, which must be addressed holistically

- All fuel chains involve multiple actors, and feedstock, energy and financial flows, in a complex system. As a result, the actors are highly interdependent, and barriers to one actor will impact strongly on the others, causing systems level barriers
- This leads to fundamental problems with simultaneous lack of supply and demand (the 'chicken and egg' problem)
- In many cases, there is also a lack of a functioning marketplace, to transmit supply and demand through the chain
- The following slides show how the barriers and risks are distributed through the chains for five systems, which may overlap, but which have distinct characteristics
 - Energy crop chains for electricity or CHP
 - Straw for electricity or CHP
 - Energy crops and straw for heat
 - OSW
 - Sewage
- Note that the barriers are discussed in (approximately) the order in which they may be encountered. This is not necessarily the order of significance.
- In the following section mechanisms to address these barriers are discussed

Energy crop chains barriers and risks

Risks and barriers by fuel chain stage, with direction of influence shown where applicable



*Not necessarily a risk for growers, but contributes to risk of others

Energy crop chains – growers

- Farmers are generally unfamiliar with growing these types of crop, and therefore most have little experience of energy crop growing and management, and are uncertain as to how difficult this will be. To date there is a limited amount of wider UK experience with energy crops that farmers can draw upon
- Income may not be competitive with growing other crops
- There is currently limited demand for energy crops
- Capital costs of crop, planting and harvesting equipment are higher than for established crops
- Income is delayed for several years for non-annual crops
- The energy crops scheme limits crop choice to willow or miscanthus – other crops could be suitable for specific land types or conversion technologies
- Uncertainty over future policy support for the conversion technology and renewable energy in general leads to lack of confidence in maintaining demand, and the certainty of contracts. Failure of ARBRE has contributed to this.
- The financial returns on the crop are uncertain, as a result of
 - Difficulty in estimating costs of growing and managing the crop as a result of inexperience in estimating crop yields, input requirements and time needed for management
 - Uncertainty of the quantities of crop that can be sold each year – as there may not be flexible local markets for excess yields or crop not taken by plants
 - Uncertainty of the price that will be received for the crop, unless fixed price contracts are in place. This is exacerbated by lack of experience in energy crop markets, unlike grain markets, for example.
 - Uncertain policy-based annual income e.g. set-aside subsidies over the crop or supply contract lifetime
- Exiting the energy crop market could be difficult as a result of the need to sign long term contracts, and possible high costs of crop removal
- Growers will find it particularly difficult to deal with the risk of their market disappearing or significantly decreasing, and with changes to the financial viability of their crop in the course of the contract term e.g. from subsidy changes

Energy crop chains - intermediaries

- Intermediaries may be present in energy crop fuel chains, and would lead to a greater market liquidity and supply chain security, both to grower and technology developer, if present.
- There is currently no strong incentive to enter the market as an intermediary for energy feedstocks, and there is limited supply or demand. However, existing intermediaries for other products e.g. straw, wood wastes, could enter this market when needed.
- Large plants: Risk that plant will go under and break the contract – due to high technology risk in some cases, uncertain policy support to electricity revenue long term. Uncertainty over feedstock selling price to plant – affected by energy markets and renewable energy support
- Small plants: Lower risk of market disappearing as there are a larger number of smaller plants. However, all likely to be affected by energy markets and support, giving similar uncertainty over feedstock selling prices
- Growers: With a limited number of growers and limited import potential, poor yields could lead to a shortfall in feedstock. Changing policy support in agriculture could cause farmers to switch away from energy crops. Competing uses for land or the feedstock itself could also lead to breaking supply contracts
- Intermediaries are in the market in order to mitigate risk - but the level may be too high for them to mitigate at present, as they are exposed to a high degree of policy risk from both growers and plant developers, and as there are a limited number of players.

Energy crop chains – utility scale plant developer (1)

- There is currently very little production of energy crops in the UK. As a result, a developer would have to establish a supply base, either through an intermediary, or direct with growers. There is at least a year of time lag in this process. In the interim, other feedstocks could be used; this is relatively easy for straw, but may be more difficult with woody residues. These may be more dispersed, further from the plant, and are not currently collected and traded in such large volumes – setting up a system only to provide significant supply as an interim step may, therefore, be difficult
- Gasification technology for biomass feedstocks is at an early stage of commercialisation, and so has little proven long term operating experience. There is, therefore, a risk of lower efficiency and lower reliability than expected.
- There is also little experience in building biomass plant in the UK, which leads to uncertainty over the length and cost of construction.
- For some willow combustion plants, low cost feedstocks and low capital costs could lead to generation at a viable cost in the near term (2010). However, for all other fuel chains the costs of electricity generated is high. Therefore generation would not be economically viable, even with ROCs.
- Capital costs of plant are high per unit of installed capacity for all plants
- Interconnection costs and charges are currently high for all distributed energy technologies
- There is risk associated with receiving a reliable supply of energy crop feedstock. If the plant contracts directly with farmers, there is a risk of fluctuation in supply due to crop yields. There is also the (general counterparty) risk that individual growers may break their contracts for a variety of reasons. Supply risk is reduced by dealing with intermediaries, but is still high while there are few intermediaries and little liquidity in the market

Energy crop chains – utility scale plant developer (2)

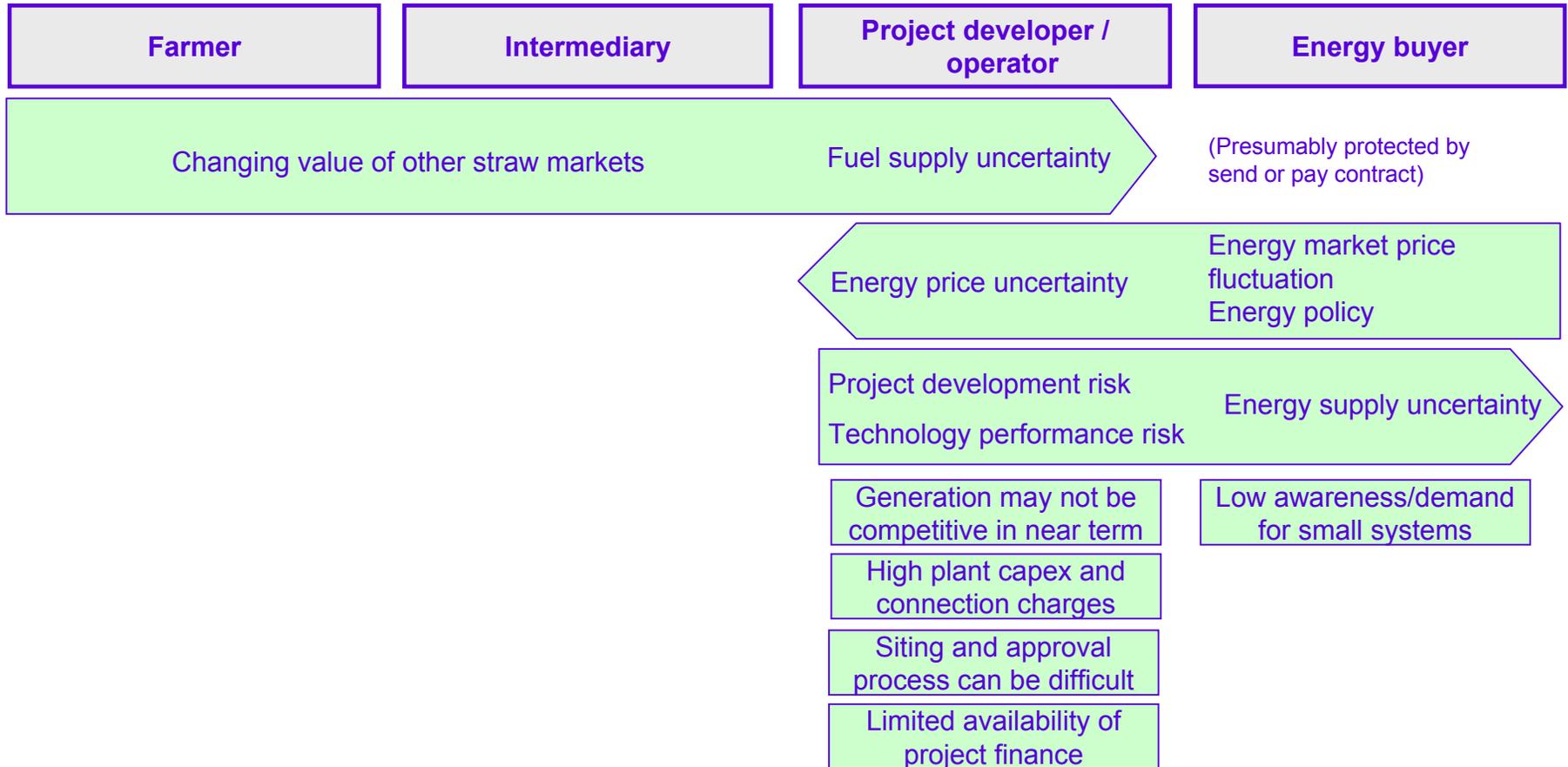
- The electricity income from the plant will vary depending on electricity markets, and on policy support for renewable generation, which is unlikely to be guaranteed over the plant lifetime
- Developers have difficulty in accessing project finance, as there are a limited number of project financiers with biomass experience, which is likely to be necessary in assessing the risks of the project
- Plant siting is a difficult process, involving determining the local resource potential (which in some cases must be able to provide more than 2.5 times the plant requirements in order to get project finance), assessing the willingness of farmers to become growers, and the acceptance of the local community
- Planning for biomass plant can be drawn out as a result of insufficient understanding of the planning requirements in each area by developers, varying planning requirements between areas, association with waste incineration, lack of public recognition of the wider benefits of biomass, and concerns about traffic flows
- Plant developers are able to support some degree of risk – though they are unlikely to be able to support both the supply and technology risks for gasification

Energy crop chains – small scale plant developer/operator and user

- The barriers to developers of small plants (1-10MW combustion CHP, 250kW-1MW gasification CHP) are similar to those for large plants, however with several changes of emphasis:
 - Technologies are less proven for combustion at under 5 MW than at larger scales, and again, gasification has little long term operating record
 - For willow based plants, low cost feedstocks and low capital costs could lead to generation at a viable cost in the near term (2010). However, for miscanthus combustion the cost of electricity in 2010 generated is above the price point, and therefore generation will not be economically viable even with industrial electricity prices+ROC+CCL
 - The plant is likely to be grid connected for increased reliability – this leads to high costs and charges for interconnection, which will have a larger effect on the economics of small plants. The price of electricity bought back from the grid is also likely to be high compared with that exported.
 - The income to the developer/operator from the plant will be less subject to variation if the heat and power are sold direct to the end user under contract (not to the grid) - however generation is not eligible for ROCs in this case
- There are also barriers to end user adoption of small scale CHP
 - Capital costs of plant are high per unit of installed capacity for all plants – this is a significant barrier as the end users are more likely to directly finance the installation for onsite CHP
 - There is little demand for small biomass CHP, as a result of both low awareness of biomass energy and low demand for CHP in general
 - The technology is perceived as higher risk than other CHP options, especially for gasification
 - End users will expect the plant developer/operator to accept all risk

Straw chains barriers and risks

Risks and barriers by fuel chain stage, with direction of influence shown where applicable



Straw chains – farmers and intermediaries

- Farmers are used to selling straw to straw companies and other users, have the relevant equipment and have alternative markets for the straw – not really barriers to energy chains
- Intermediaries are already present in the straw market, and give greater market liquidity and supply chain security, both to grower and technology developer, if present.
- Competing uses for the straw could lead to large price fluctuations and farmers or intermediaries breaking supply contracts
- There are still risks of plants breaking their contracts, however, this presents much lower risk to the intermediary as there are alternative markets for the straw

Straw chains – utility scale plant developer

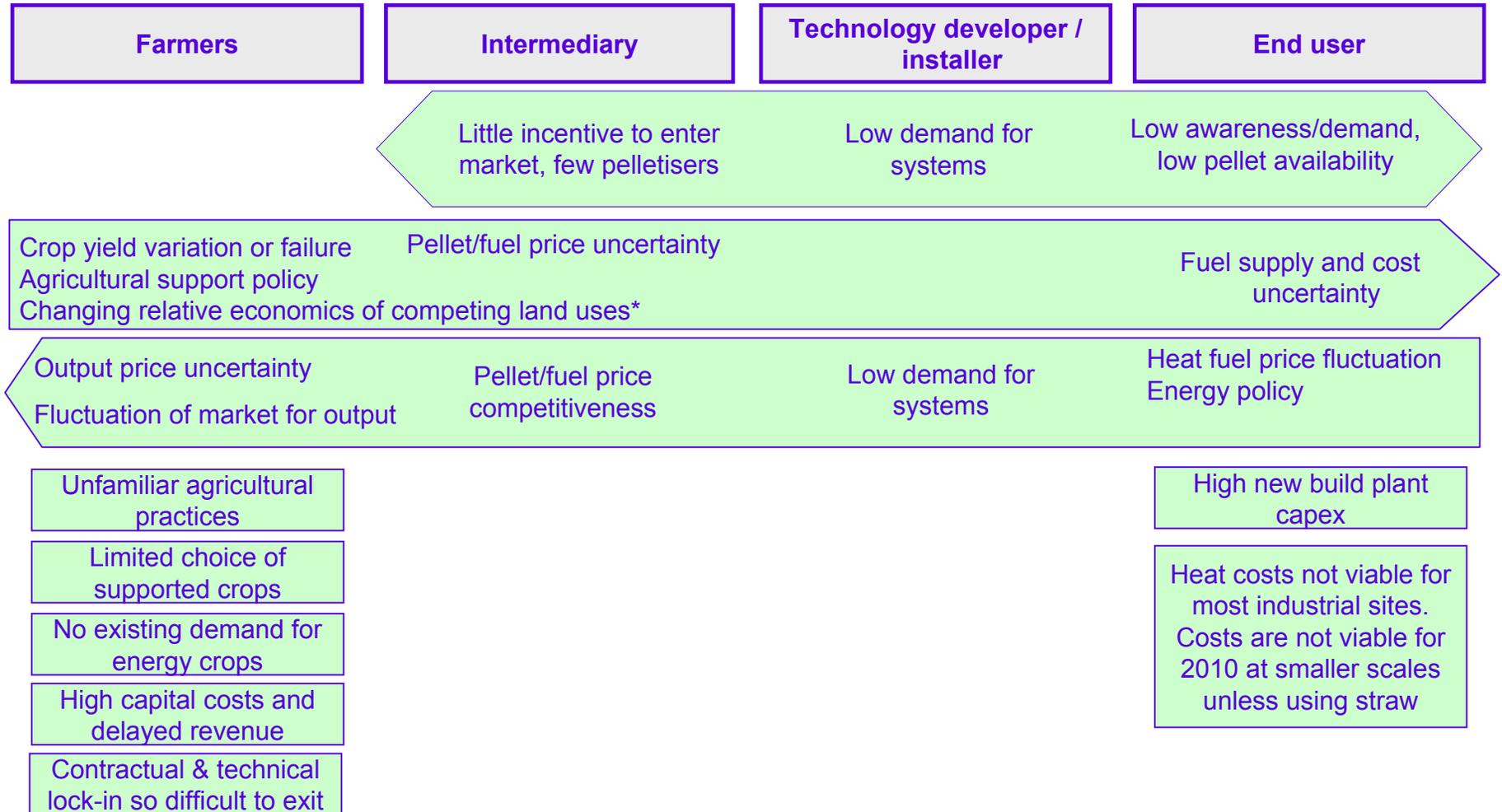
- There is already a straw market, but as before, there may be competition from other uses in some regions and at certain times
- Gasification technology for straw is at a very early stage, and therefore has little operating experience. There is a risk of lower efficiency and lower reliability than expected.
- There is also little experience in building biomass plant, which leads to uncertainty over the length and cost of construction.
- Electricity generation costs are above the price point for 2010, and therefore will not be economically viable
- Capital costs of plant are high per unit of installed capacity for all plants
- Interconnection costs and charges are currently high
- The electricity income from the plant will vary depending on electricity markets, and on policy support for renewable generation, which is unlikely to be guaranteed over the plant lifetime
- Plant siting is a difficult process, involving determining the local resource potential (which in some cases must be able to provide more than 2.5 times the plant requirements in order to get project finance) and the acceptance of the local community
- Planning for biomass plant can be drawn out as a result of insufficient understanding of the planning requirements in each area by developers, varying planning requirements between areas, association with waste incineration, lack of public recognition of the wider benefits of biomass, and concerns about traffic flows
- Plant developers are able to support some degree of risk – though they are unlikely to be able to support both the supply and technology risks for gasification

Straw chains – small scale plant developer/operator and user

- The barriers to developers of small plants (1-10MW combustion CHP) are similar to those for large plants, however with several changes of emphasis:
 - Technology is less proven for combustion at under 5 MW than at larger scales
 - The generation cost of electricity is below the price point in 2010 – this is not a barrier
 - The plant is likely to be grid connected for increased reliability – this leads to high costs and charges for interconnection, which will have a larger effect on the economics of small plants. The price of electricity bought back from the grid is also likely to be high compared with that exported.
 - The income to the developer/operator from the plant will be less subject to variation if the heat and power are sold direct to the end user under contract - however generation may not be eligible for ROC in this case
- There are also barriers to end user adoption in this case
 - Capital costs of plant are high per unit of installed capacity for all plants – this is a significant barrier as the end users are more likely to directly finance the installation for onsite CHP
 - There is little demand for small biomass CHP, as a result of both low awareness of biomass energy and low demand for CHP in general
 - The technology is perceived as higher risk than other CHP options
 - End users will expect the plant developer/operator to accept all risk

Heat chains barriers and risks

Risks and barriers by fuel chain stage, with direction of influence shown where applicable



*Not necessarily a risk for growers, but contributes to risk of others

Heat chains – farmers, intermediaries and technology developers/installers

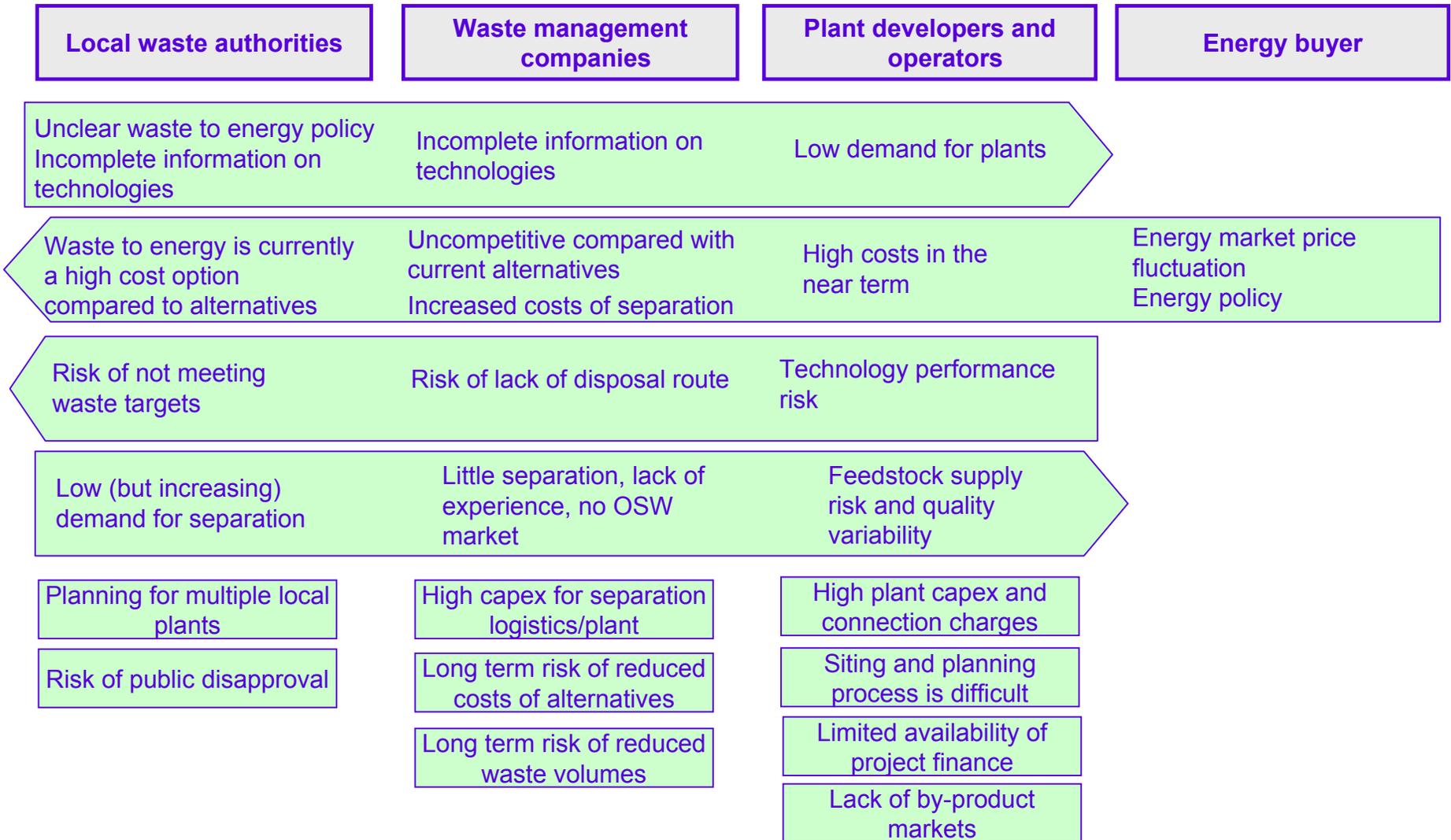
- Barriers to farmers are the same as those for electricity/heat chains
- Intermediaries will face several extra barriers related to the fuel type needed, and to the increased number of smaller plants to be supplied
 - SRC, straw and miscanthus could all be pelletised for easier transport and for smaller plants. There are currently few pelletisation plants, and therefore little UK operational experience. Similarly, there is no well-established pellet market to facilitate increased demand or supply
 - For a large number of small plants, for example at domestic scale, feedstock will not be sold through long term contracts, but through merchants, in the same way as for coal. This could lead to more variation in demand
- For technology developers and installers
 - There is little demand from end users, as a result of the barriers on the following slide

Heat chains – end users

- End-users generally own and operate the heating plant
- There is limited knowledge in the general installer community and public about the use of biomass-based heating and fuel sources – what systems are available, their benefits and economics
- Technology risk is low, with several commercial suppliers of boilers operating on wood chips, pellets or straw fuel (bales or shredded straw) – this is not a barrier, but may be perceived as one. In some cases back-up systems are installed which further increases the capital cost.
- Heat from straw could be competitive with fossil fuel counterparts for smaller scale applications, but for willow and miscanthus the economics are marginal. Pellet prices are high (~2.2p/kWh) in comparison with unprocessed fuels (~1.2p/kWh for woodchips). At the high end of the size range (3MWth) the generation cost using all feedstocks is higher than the price for industrial heat – with heat not being adequately valued, and no premium for renewable heat.
- Capital costs are higher than oil, LPG and gas fired systems (e.g. a 23kWth oil-fired boiler costs ~£3,500, pellet-fired ~£6,000 [~£4,500 after capital grant])
- The small number of fuel suppliers currently limits demand to areas that they can supply
- Users without fuel supply contracts are at risk of variation in fuel price, which may be affected by supply and demand in markets for larger scale biomass plants and other non-energy uses of biomass.
- All users, particularly those without supply contracts, are at risk of fuel supply disruption or disappearance as a result of the same range of factors as in electricity chains – varying yields, farmers exiting the market, competing uses of the feedstock, though this may be mitigated in part by the intermediaries

OSW chains barriers and risks

Risks and barriers by fuel chain stage, with direction of influence shown where applicable



OSW chains – local waste authorities

- Despite strong policy trends towards diversion of organic fraction of MSW from landfill, it is unclear how waste to energy stands in EU and UK policy priorities – it may be considered a less favourable option than other methods such as composting, which is included in recycling targets, and there may be little distinction between waste to energy options, despite different benefits. Overall, the diversity of energy, waste and environment policies creates barriers.
- Waste management companies are currently unlikely to require waste to energy in their contracts with waste management companies as:
 - OSW separation and waste to energy technology are currently more expensive than existing routes in most cases, requiring higher fees to be charged.
 - Local waste authorities may have incomplete information as to the range of technology options available, and their relative benefits, costs and environmental performance when setting contract targets
- The long term nature of waste management contracts (up to 25 years) means that many authorities are ‘locked-in’ and cannot modify their contract targets when new technologies are available
- Obtaining planning consents is also a barrier to the local authorities’ plans for waste to energy; it can be difficult to identify suitable sites for larger plants, but multiple smaller plants may be less economically viable, and impact on a larger number of local residents
- Local authorities risk public backlash if waste to energy facilities are perceived to have wasted money, imposed on residents, or caused problems such as visual disamenity or increased traffic, which are disproportionate to the perceived benefits of improved waste management and renewable energy generation

OSW chains – waste management companies

- Little OSW is separated in the UK, either through source separation or through post-collection separation. As a result there is little experience in efficient collection of source separated wastes, or in separation of OSW via technologies such as Mechanical Recovery Facilities and Mechanical Biological Treatment and their combination with waste to energy. This leads to risks of lower standards of separation (e.g. 98% biomass for RO requirements), lower throughputs, and higher costs.
- There is low demand for separation of OSW, despite policy moving towards this
- There is low demand for waste to energy projects from local waste authorities, and it is unclear to waste management companies what will be required in the future. Policy changes with respect to incineration have caused concern as to the security of future policy on other technologies.
- In the absence of strong market signals, waste management companies adopt a relatively conservative attitude with regard to waste to energy and novel approaches
- Capital costs of separation equipment/plant are a barrier (compared with using existing disposal routes)
- Gasification and AD technologies are at an early stage of commercialisation for MSW, with little UK experience. Technology risk, and other risks affecting the plant developer, lead to the risk of the plant failing, leaving the waste management company with no route, or only costly alternative routes available. They are likely to protect themselves from this risk, through contractual arrangement with the plant developer. They are also likely to fix gate fees to be paid to the plant developer through contractual arrangements
- Whilst the waste management company will be able to plan for some variation in waste volume and composition, larger discrepancies between expected and actual volumes will be difficult to deal with, once the option to landfill excess OSW is no longer available, until there are a sufficient number of OSW-using plants in the same area to allow trading.
- The need for long term contracts with plants is a barrier, as waste management companies may see falling costs of alternative disposal methods, or trends in waste volume, which may arise as a result of waste policy changes

OSW chains – plant developers and operators (1)

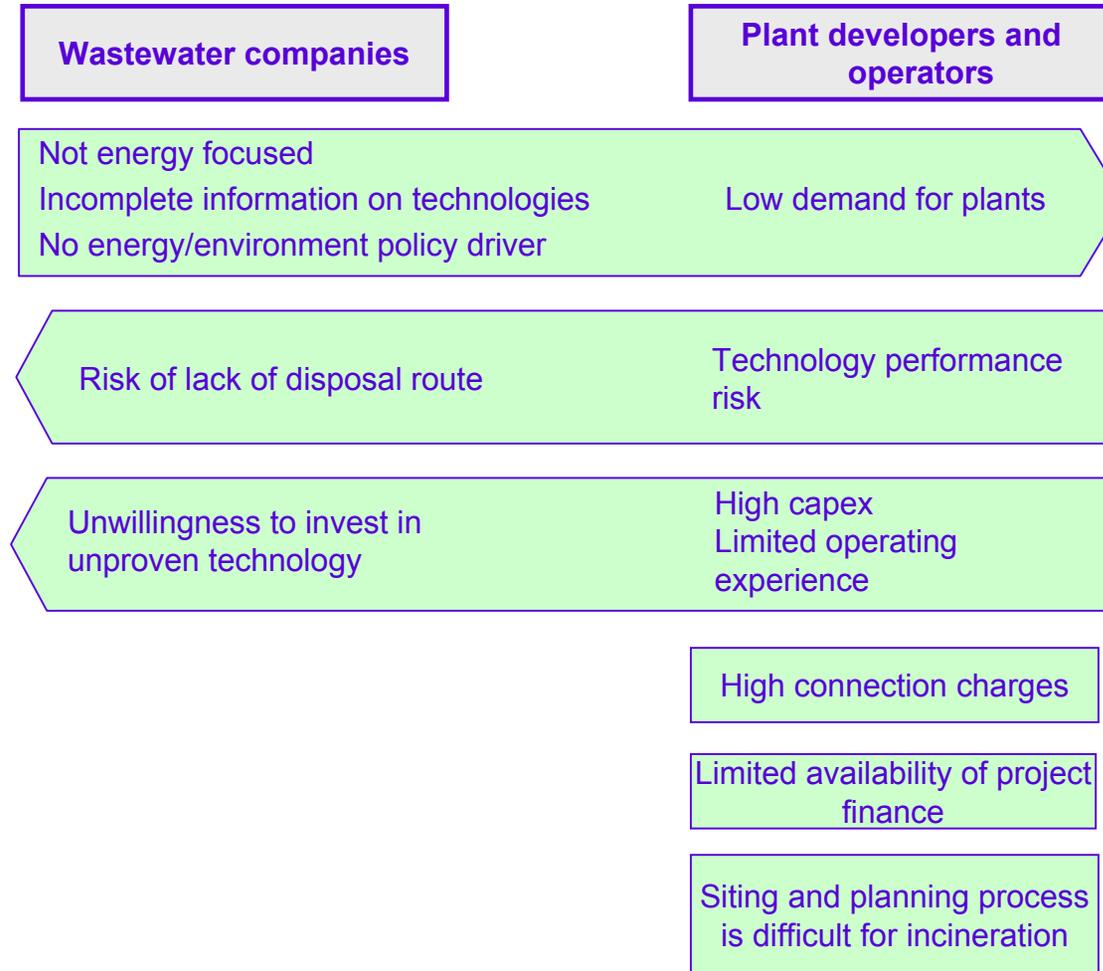
- Gasification and anaerobic digestion technologies are at the early commercial stage for MSW, and therefore there is little experience with their construction, leading to project risk, and with their use, leading to uncertain efficiencies, emissions, costs and product quality (for AD).
- Inexperience of waste management companies in separation to high OSW content plus inherent waste composition variation may lead to inconsistency in OSW input quality, and technical problems
- The economics of electricity generation for small gasification plants, and for large gasification and combustion plants where gate fees for alternative disposal routes are low, are not viable in 2010. Current gate fees for alternative routes are lower than expected for 2010, making the economics even less attractive.
- The availability of project finance is poor. Despite increased confidence as a result of new legislation, there is still confusion as to the significance of technology, supply and policy risk in waste technologies. Unsurprisingly, it is very difficult to obtain finance for technologies with no experience of reliable performance.
- Capital costs of plant are high per unit of installed capacity for all plants
- Interconnection costs and charges are currently high for distributed energy technologies, especially for small plants
- There is also little experience in building plants, leading to uncertainty on the length and cost of construction.
- Quality standards for OSW input and for outputs such as biofertiliser are not as well developed in the UK as in some other EU countries, which hinders the possibility of trading in feedstocks, and in the development of a viable fertiliser product market
- It would be difficult for plants to avoid loss of income due to lower waste volumes than expected, as a result of the initial low availability of alternative feedstocks of similar quality, near enough to the plant, and which would command a sufficiently high gate fee.

OSW chains – plant developers and operators (2)

- The electricity income from the plant will vary depending on energy markets, and on policy support for renewable generation, which is unlikely to be guaranteed over the plant lifetime
- For AD, heat and biofertiliser produced do not currently have market value
- Planning for waste to energy plants can be difficult. Combustion plants in particular have lengthy planning processes with high failure rates due to local opposition as a result of perception of health concerns. Other waste to energy plants, in particular gasification, may suffer from association with combustion, together with concerns on traffic, appearance, emissions etc and lack of recognition of the difficulty of waste disposal
- Planning for small plants is easier, as these are perceived to be more environmentally sound, but this can involve higher specific capital and operating costs. As planning requirements many vary by area, permission for subsequent small plants may not be facilitated by the first application

Sewage chains barriers and risks

Risks and barriers by fuel chain stage, with direction of influence shown where applicable



Sewage sludge chains – wastewater companies

- Wastewater companies are primarily concerned with low cost and safe disposal of sewage sludge, and do not consider themselves as energy companies – sludge is considered a problem, not a resource
- Companies have low access to information on new technologies and their real costs and performance
- There is no environmental driver within the industry for sludge treatment technologies that use less energy or emit less methane than current AD technology – increasing requirements for sludge safety are increasing energy use
- There have been several recent changes to policy on sludge quality which have required the wastewater industry to make significant investment, making them more reluctant to adopt new technologies in the near term
- Gasification and pyrolysis technologies are at an early stage of development for sewage sludge, and UK demonstrations have not performed as well as expected. Companies are unwilling to accept this level of technology risk, and have few capabilities in these technologies, so would be likely to contract plant operation to the plant developer, or potentially enter into joint ventures. They are also likely to contract out incineration.
- As wastewater companies are experienced with anaerobic digestion, they will operate the plants themselves, thereby accepting risk that the digestion and generation technology may not perform as well as expected.
- Costs of sludge treatment by these technologies are likely to be lower than for other routes, once electricity and heat income is included - this is not a barrier
- However capital costs of improved AD technology or new incineration plants are high, and capital costs of gasification and pyrolysis are both high and uncertain, as few have been built. This is a direct barrier where the company would own the plant, and would lead to high fees where e.g. the technology developer would own and operate the plant. As there are incumbent technologies, this is a considerable barrier to any new plant.
- Changing regulation on disposal of the output of the treatment technology (e.g. digested sludge) could lead to the need for further investment, changing the economics of the process. If this is thought likely, companies may defer investment in new technologies

Sewage sludge chains – plant developers and operators

- For gasification, pyrolysis and incineration, the wastewater company is likely to contract out operation of the plant e.g. to the plant developer, however for AD, they are likely to operate the plant themselves, as they are experienced in the technology
- Gasification and pyrolysis technologies are at an early stage of development for sewage sludge, and UK demonstrations have not performed as well as expected. Incineration and AD are proven, but have not been focused on energy generation. There is therefore a risk of the technology performance being lower, or costs being higher than expected.
- There is currently little demand for sludge to energy technologies from wastewater companies, and an unwillingness for companies to become involved in demonstration projects – on the grounds that they can wait and see how other demonstrations perform
- Capital costs of plant are high per unit of installed capacity for all plants
- Interconnection costs and charges are currently high for distributed energy technologies, especially for small plants
- There may be difficulties for plant developers in obtaining finance beyond what the water companies may be able to provide for technologies, for example through joint ventures
- There is still strong opposition to siting of incineration plant, which could also influence the planning process for other thermal technologies

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Other important considerations

Barriers to biomass energy

Overcoming barriers

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There are several broad mechanisms that could support many biomass energy fuel chains

Suggested mechanism	Current status	Barriers that would be addressed
Review Renewables Obligation for biomass	RO in place, review due in 2005/6	Could provides consistent long term framework with support also for off-grid and small scale technologies, and diverse waste technologies
Simplified interconnection rules and reduced charges	Review in progress for all distributed energy	Lower project costs for grid-connected technologies. Particularly valuable for smaller scale projects which currently suffer more
Consistent framework for plant planning authorisation	PPS22 consultation on renewable energy planning open until end Jan 2004	Consultation includes provisions to assist biomass and waste, but excludes waste incineration; encourages examination of benefits and impacts throughout the fuel chain; planning to be in support of national/regional renewables targets
Increased R&D support in areas where UK has potential competitive advantage	UK has strong skills in some areas, but the export potential is not yet a main focus	Development could be accelerated in the UK whilst building international competitiveness (See appendix 3&4 for more details)
Increase resources of trade association	British Biogen already active, based on membership fees	Increased activity in providing information to potential players in fuel chains; assistance in setting up demonstrations, identifying partners, understanding research needs, public outreach
Simplify access to government information – ‘one stop shop’	Numerous different initiatives at present	Assists new entrants to get consistent, impartial information and provides access to support available. Could also be valuable for end users and the general public. May be administratively simpler than current situation.
Increased cross-policy impact assessment	Several initiatives to improve this at present	Consistency of policymaking across energy, agricultural, environment, waste and transport policy

Energy crops and straw for electricity and heat should be supported by focused regional programmes

- **Establish coordinated regional programmes:** These would include all technology types (combustion and gasification, at a range of scales, and for heat only) with fuel provided by one or more intermediaries. This would help to provide technology demonstration, deployment of more mature technologies, build flexible local fuel markets, and provide supply security. Features of the programmes would include:
 - Based on areas with potential high feedstock availability and flexibility – i.e. areas where supporting feedstocks could provide a substantial proportion of demand if energy crop supply varied
 - Beginning with targeted end users for smaller scale plants. These are likely to be local authority buildings with high heat loads such as leisure centres, new housing developments, specific industrial users or organisations with multiple sites such as out of town shopping developments. Industry groups or RDAs could assist in identifying these users, who would then be provided with more information to encourage participation
 - Multiple demonstrations of smaller plant using the same technology. This gives a greater depth of experience in the technology than a scheme built from too wide a technology variation
- **Capital support for advanced technologies to be demonstrated:** To overcome perceived technology risk and high capital costs, capital grants or soft loans are needed to assist advanced technologies using energy crops e.g. small and large gasification. Support should be linked to minimum efficiency standards, proof of flexible fuel supply availability and environmental criteria. Support should be proportionately higher for small scale power technologies due to their earlier stage of technology development and potential contribution to a more liquid market.

Regional programmes should be underpinned by the development of the biomass fuel market

- **Change establishment support for farmers:** Provide equal levels of support for willow and miscanthus, as the development of both can be complementary, and miscanthus is at an earlier stage of development. Also allow other environmentally beneficial energy crops to be included, if there is a suitable local market.
- **Decrease farmers' exit cost risk:** for example through insurance schemes set up by government, or through obliging intermediaries or plants to include clauses in their contracts to pay for removal if the demand disappears or plant fails
- **Encourage the establishment of intermediaries:** Encourage new players or existing traders to enter the energy crops market through business development support and capital grants for transport and processing equipment. Link these benefits to the inclusion of a variety of feedstock sources in their business plan, showing how they can access an oversupply of feedstocks to mitigate supply risk. Farmers could also be encouraged to vertically integrate: becoming involved in cooperatives, with processing capabilities, to capture more of the value chain, and to reduce the grower/intermediary risk – for example through capital grants for transport and processing equipment.
- **Price support for energy crops products via intermediaries:** Supporting the price of willow and miscanthus at the point of delivery to the plant would provide more support to growers and intermediaries than support for renewable electricity. Similarly, it would provide a greater possibility for support to flow to the project developer than if crops were subsidised directly. The measure would target energy crops in preference to other feedstocks.
- **Continue to award ROCs for co-firing:** Co-firing of willow will assist the development of the fuel supply chain, since it creates volume demand through proven technology without siting issues. However, the fuel price support described above is not required as it is already economically viable under the RO.

A special focus is required to encourage the use of biomass for heat

- **Include heat applications in regional programmes:** The deployment schemes, together with further information dissemination (as is currently carried out by British Biogen etc) would promote awareness of the benefits of biomass heating systems, and build up local supply. They could be in same areas as electricity demonstrations if there is a heat market, to develop and rely on the same supply chains. They will need to be directed at targeted users, possibly smaller scale applications where the near term economics are better.
- **Encouraging intermediaries' involvement in pelletisation and wood chips for the heat market:** Through grants for pelletisation equipment, help in market sizing etc, and multiple demonstrations in the same area. Initial price support to pellets would enhance the competitiveness of wood pellet-based heating systems and stimulate the development of a wood pellet market.
- **Increased incentives for renewable heat:** Investigate ways to value heat generated in small plants through existing mechanisms e.g. providing some extra ROCs for heat generation

Energy recovery from OSW requires a range of support measures which should be set within a long term waste to energy policy framework

- **Clarification of policy on waste to energy:** Requires long term integrated waste and energy policy based on environmental benefits of the energy chains, to provide certainty about policy framework. It should encourage local waste authorities to consider waste to energy where possible in their waste management strategy, which could set waste to energy targets and include them with recycling and composting targets where possible – e.g. where there are volumes of OSW above a certain level, which are not already dealt with by composting
- **Increased information provision to local authorities and waste management companies:** Through central, standardised information provision on different technologies and technology developers, and through promotion of increased information sharing between local waste authorities
- **Funding to local authorities testing new separation schemes or plants:** To enable local authorities to prepare for proposed EU biowaste directive and its implementation in the UK. Support could be linked with technology support below
- **Capital grants or soft loans for demonstration plant:** To support development and early adoption of gasification and AD technology, possibly beginning with low risk feedstock supply areas, such as in the food waste industry. Then progressing to areas where separation schemes have been tested, potentially relaxing the 98% biomass constraint in the RO in the early stage of plant operation to allow for unexpected variation in input while technologies are developed. Capital support must be high enough to allow for insufficiently high landfill tax, and therefore insufficiently low gate fees available in the short term
- **Promote establishment of standards and market for waste treatment by-products and residues:** For example, for biofertiliser products from AD and residual ash from thermal treatment routes

The success of energy recovery from sewage sludge requires regulators and water companies to be convinced of the long term potential

- **Industry regulation:** Encourage industry regulators to include energy consumption and greenhouse gas emission in standards for sludge treatment, and set clear long term standards for sludge treatment, energy generation and output quality. Industry regulators could also require water companies to undertake energy and greenhouse gas audits of their processes, and then provide information on possible technologies to reduce these. Regulation could also allow for water companies to monetise the reductions in greenhouse gas emissions through emissions trading
- **Promotion of industry fora and information provision:** More efficient energy recovery from sewage requires cooperation between technology developers, water companies and the regulator, through industry fora, and centralised initial information provision on the technologies, to enable the water companies to then get further information on the most suitable systems for them
- **New technology demonstration programmes:** Each water company should be encouraged to allow demonstration of new technologies on their sites, with funding provided by the water companies, and through government support. This could be in the form of a set of demonstrations, for which consortia of water companies and technology developers bid to demonstrate a particular technology

Appendices

- 1. Scale definitions and price points**
- 2. Primary and supporting chains**
- 3. Other considerations**
- 4. Mechanisms to overcome barriers**

Plant scales used in fuel chains

Legend	Description
Combustion - Utility	10-50 MWe utility scale electricity generation
Gasification - Utility	10-50 MWe utility scale electricity generation
Pyrolysis	Pyrolysis oil production in 20MWe oil out plant and pyrolysis oil use in CHP (oil engine) for buildings in capacity range 250 kWe-1MWe
Combustion - CHP	Industrial and community CHP in the capacity range 1-10 MWe
Gasification - Small CHP	Buildings and community CHP in the capacity range 250 kWe – 1MWe
Combustion - Heat	Buildings and industrial heat production in the capacity range 10 kWth-3 MWth
Large scale gasification (OSW)	1-10 MWe utility scale electricity generation
Small scale gasification (OSW)	250 kWe-1MWe electricity generation
Large scale mixed anaerobic digestion with wet wastes	1-3 MWe CHP
Small scale dry anaerobic digestion of OSW only	< 1 MWe CHP modular
Gasification CHP (Sewage sludge)	250 kWe-1MWe CHP
Anaerobic digestion – CHP (Sewage sludge)	<10 MWe CHP

Price points used to test viability

Cost that must be beaten in 2020

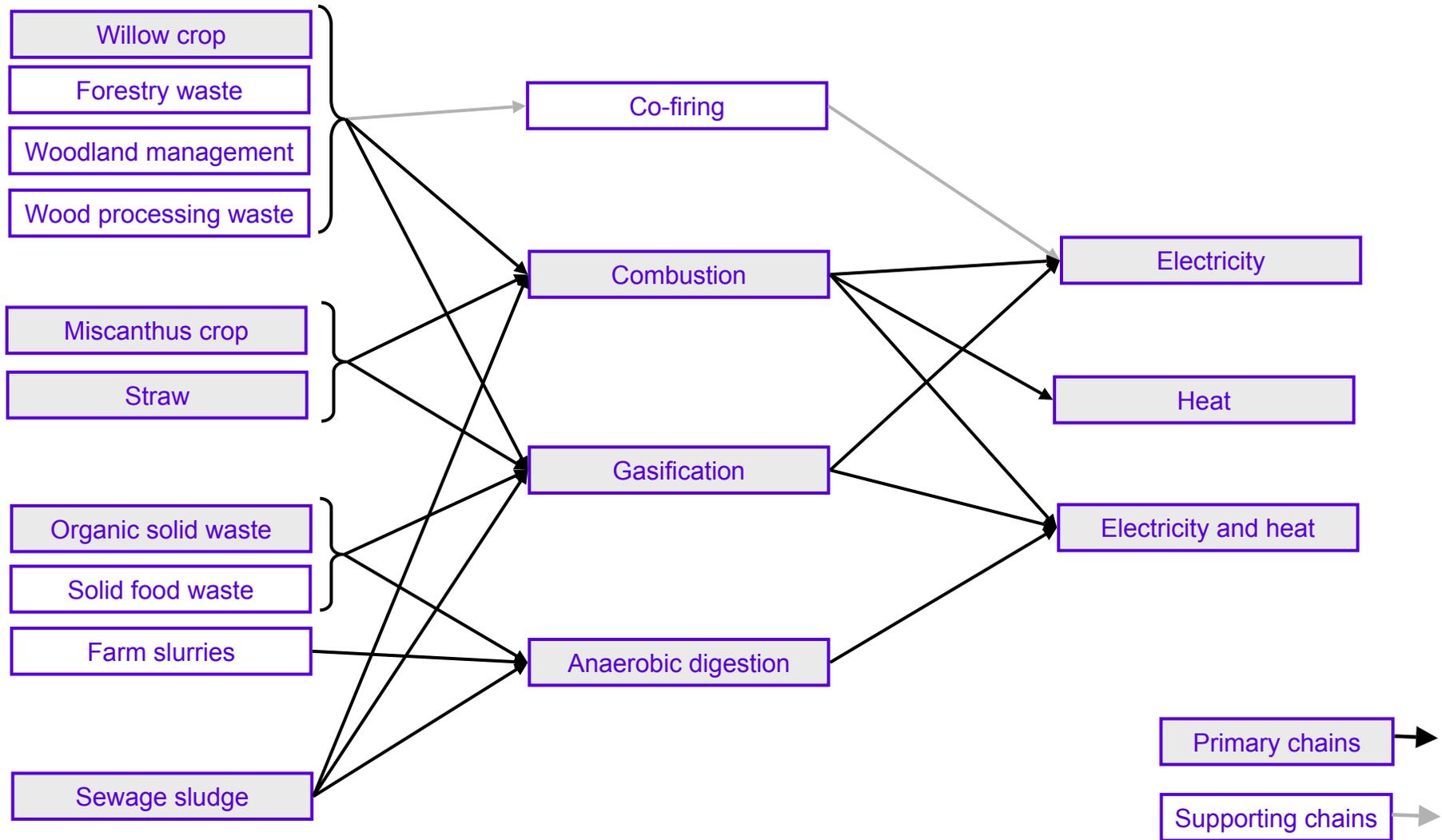


	All units p/kWh			Total	Notes
Co-firing - 5-10% of a 500MW+ coal plant	CCGT	ROC/LEC			
	1.5	3.5		5.0	
Power - utility 10-50 MWe	CCGT	ROC			
	1.5	3.5		5.0	
CHP - industrial and community CHP 1-10 MWe	Industrial tariff	CCL	ROC/LEC		CCL not paid by community so exclude to make benchmark lower. NB not calculated on heat
	2.853	0.25	3.5	6.4	
Heat - buildings and industrial 10-50 kWth approx	Residential oil price	Oil boiler efficiency	Oil boiler capex		
	2	80%	3500	2.5	
Heat - buildings and industrial 1-3 MWth approx	Industrial heat price				
	0.5			0.5	
CHP - Buildings 250 kWe-1MWe	Industrial tariff	ROC			NB not calculated on heat. No CCL included
	3.493	3.5		7.0	
Power/CHP - grid-connected DG 250 kWe-1MWe	CCGT	ROC/LEC	TUOS		From perspective of a utility purchasing DG electricity
	1.5	3.5	0	5.0	

Appendices

1. Scale definitions and price points
2. Primary and supporting chains
3. Other considerations
4. Mechanisms to overcome barriers

There are four primary fuel chain groups, each of which could be supported by several other chains



Willow coppice – primary fuel chains

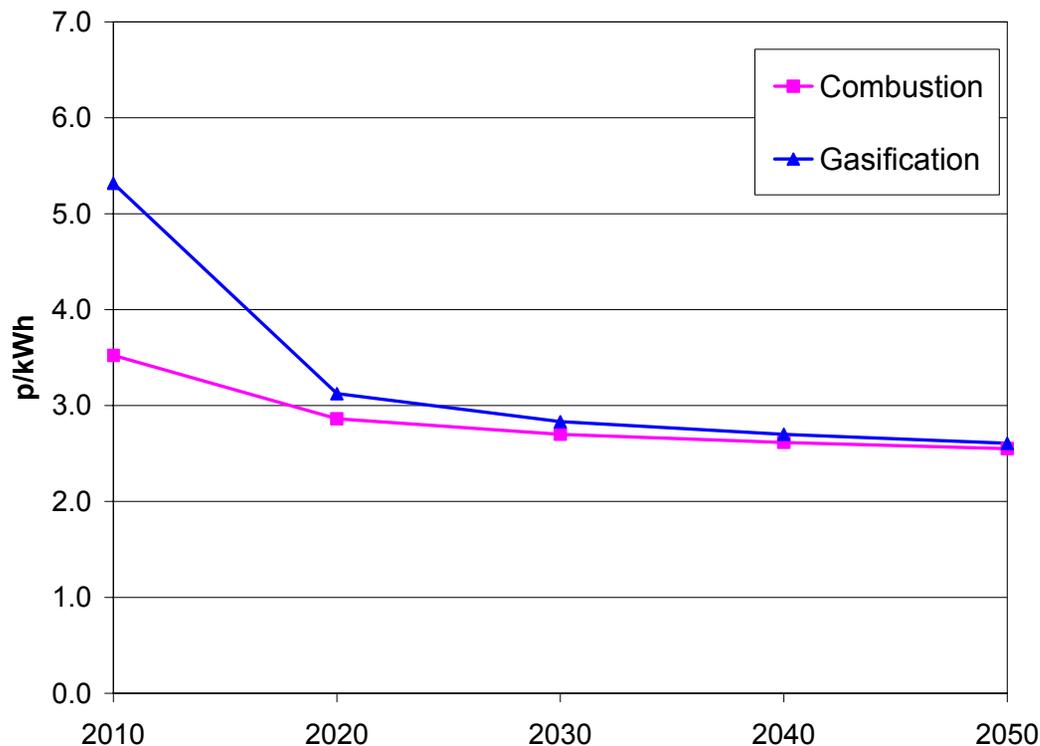
End use	Potential generation (as % of demand)				Energy cost (p/kWh)			Barriers
	2010	2020	Max	Notes	2010	2020	PP	
Combustion - Utility	0.17%	1.26%	6.6%	3 30MW plants by 2010, a further 20 by 2020 High potential to 2050, but gasification likely to be lower cost	3.6-6.8	3.0-5.5	5.0	<ul style="list-style-type: none"> Fuel availability, security and cost stability, with steep increase in fuel supply needed. No fuel infrastructure Plant siting: large plants, increased traffic UK lack of experience with plants at this scale
Gasification - Utility	0.11%	0.66%	8.8%	2 30MW plants by 2010, a further 10 by 2020 Highest potential to 2050, as greater efficiency and therefore lower cost than utility combustion	5.6-9.1	3.0-5.4	5.0	<ul style="list-style-type: none"> Fuel availability, security and cost stability, with steep increase in fuel supply needed. No fuel infrastructure Plant siting: large plants, increased traffic Technology risk as little global experience High cost for 2010 may deter developers Impact of ARBRE failure on confidence
Combustion - CHP -	0.13%	1.95%	5.3%	14 5MW plants by 2010, a further 200 by 2020	3.3-7.6	2.6-6.0	6.4	<ul style="list-style-type: none"> Fuel availability, lack of fuel market, standards and infrastructure Low awareness of biomass CHP as an option High capital cost, especially at low capacities
Gasification-small CHP	0.07%	0.98%	5.5%	70 0.5MW plants by 2010, a further 1000 by 2020	3.5-5.7	2.0-4.1	7.0	<ul style="list-style-type: none"> Fuel availability, lack of fuel market, standards and infrastructure Lack of proven systems High capital cost, especially in the near term
Combustion - Heat	0.10%	1.46%	6.0%	109 1MWth plants by 2010, a further 1560 by 2020	1.0-3.1	0.8-2.5	0.5-2.5	<ul style="list-style-type: none"> Fuel availability, lack of fuel market, standards and infrastructure Pellets required for small scale – lack of suppliers Low awareness of modern biomass heating as an option, including among heating installers High capital costs cf. oil boiler capex

Willow coppice – supporting fuel chains

Primary chains	Supporting chains	Support given
All chains	Co-firing willow	<ul style="list-style-type: none"> •Promotes planting of willow, increasing fuel availability, experience, logistics, cost, and market development which are needed for all other chains. Develops experience of contractual feedstock supply arrangements. •Uses existing plant, avoiding siting problems, could ultimately lead to establishment of dedicated biomass plant at the same site.
Combustion - Utility	Utility combustion of forestry wastes or imported fuel	<ul style="list-style-type: none"> •Provides alternative fuel while willow production ramps up. Adds to fuel security. •Provides experience of large combustion plant construction and operation
Gasification - Utility	Utility gasification of forestry wastes or imported fuel	<ul style="list-style-type: none"> •Provides alternative fuel while willow production ramps up. Adds to fuel security. •Provides experience of large gasification plant construction and operation •Allows demonstration of technology with little fuel supply risk, unlike ARBRE
	Utility combustion of willow	<ul style="list-style-type: none"> •More commercial (outside UK) and currently lower cost technology than gasification, though in the long term likely to be higher cost. Early use would build up the biomass industry, allowing fuel supply chain development with lower technology risk than for gasification.
Combustion - CHP -	CHP combustion of forestry wastes, woodland management and wood processing wastes	<ul style="list-style-type: none"> •Provides alternative fuel while willow production ramps up. Adds to fuel security. •Develops wood fuel market and standards •Provides experience of small combustion plant
Gasification-small CHP	Small CHP gasification of forestry wastes, woodland management and wood processing wastes	<ul style="list-style-type: none"> •Provides alternative fuel while willow production ramps up. Adds to fuel security. •Develops wood fuel market and standards •Allows proof of systems for small gasification technologies
Combustion - Heat	Combustion for heat of forestry wastes and woodland management	<ul style="list-style-type: none"> •Provides alternative fuel while willow production ramps up. Adds to fuel security. •Develops wood fuel market and standards •Stimulates market and support infrastructure for wood heating systems

Willow - long term cost reduction potential

Generation cost projection for utility scale willow units



Assumptions	
Combustion	Gasification
Maximum efficiency is 40%	Maximum efficiency is 56%
Capex falls with 7.5% learning curve after first commercial unit in 2006	Capex falls with 12.5% learning curve after first commercial unit in 2010
Opex is 3% of capex but does not fall after 2020	Opex is 4% of capex but does not fall after 2020
Biomass fuel costs do not fall after 2020	
The installed number of units worldwide is the basis for learning curve benefits. The global number of units grows twice as fast as the UK, starting from the year shown and continuing linearly.	
20 year unit lifetime, 10% discount rate	

Conclusions

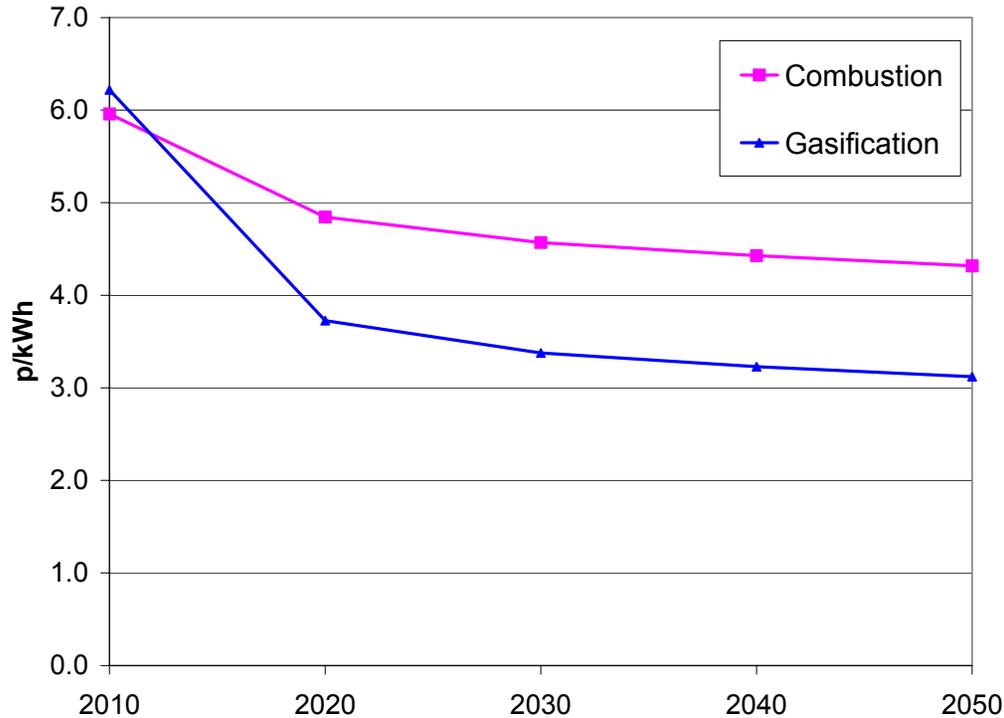
- Both technologies are potentially competitive with CCGT electricity under the RO (1.5+3.0p/kWh)
- For a relatively low cost feedstock such as SRC willow, the efficiency advantage of gasification has a reduced impact on overall generation costs

Miscanthus– primary fuel chains

End use	Potential generation (as % of demand)				Energy cost (p/kWh)			Barriers
	2010	2020	Max	Notes	2010	2020	PP	
Miscanthus Combustion - Utility	0.17%	1.26%	8.8%	3 30MW plants by 2010, a further 20 by 2020 High potential to 2050, though gasification likely to have higher efficiency, and lower cost	6.1-8.9	5.1-7.0	5.0	<ul style="list-style-type: none"> •Limited experience of miscanthus growing – hard crop to establish so expensive in short term. Undeveloped fuel chain •Plant siting: large plants, increased traffic
Miscanthus Gasification - Utility	0.06%	0.60%	11.8%	1 30MW plant by 2010, a further 10 by 2020 High potential to 2050, likely to be higher efficiency than utility combustion	6.5-10.8	3.6-6.6	5.0	<ul style="list-style-type: none"> •Technology not developed •Limited experience of miscanthus growing – hard crop to establish so expensive in short term. Undeveloped fuel chain •Plant siting: large plants, increased traffic
Miscanthus Combustion - CHP	0.13%	1.95%	7.1%	14 5MW plants by 2010, a further 200 by 2020	6.6-9.7	5.1-7.5	6.4	<ul style="list-style-type: none"> •Low awareness of biomass CHP as an option •High capital cost, especially at low capacities •Fuel market undeveloped
Miscanthus Combustion - Heat	0.07%	0.80%	0.8%	Resource constrained to 10% of that available as large fuel storage areas needed and handling is difficult No build rate constraint (91 1MWth plants by 2010, a further 883 by 2020)	1.4-2.6	1.2-2.2	0.5-2.5	<ul style="list-style-type: none"> •High capital cost of plant relative to other heating devices

Miscanthus - long term cost reduction potential

Generation cost projection for utility scale miscanthus units



Assumptions	
Combustion	Gasification
Maximum efficiency is 40%	Maximum efficiency is 56%
Capex falls with 7.5% learning curve after first commercial unit in 2006. Inherently more expensive than willow	Capex falls with 12.5% learning curve after first commercial unit in 2010
Opex is 3% of capex but does not fall after 2020	Opex is 4% of capex but does not fall after 2020
Biomass fuel costs do not fall after 2020	
The installed number of units worldwide is the basis for learning curve benefits. The global number of units grows twice as fast as the UK, starting from the year shown and continuing linearly.	
20 year unit lifetime, 10% discount rate	

Conclusions

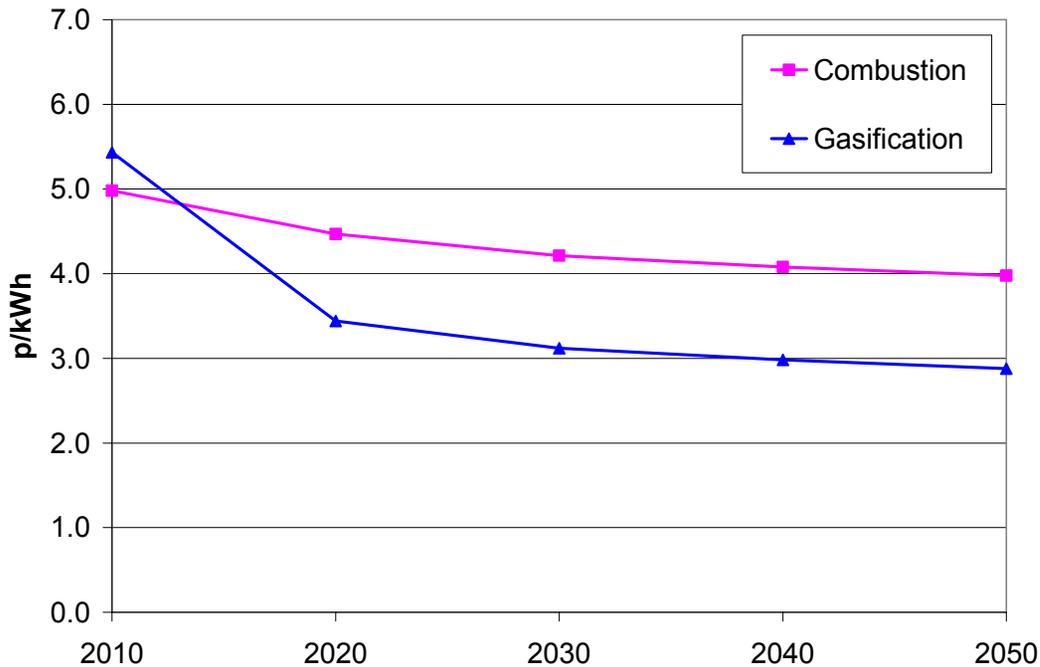
- Only gasification is potentially competitive before the very long term with CCGT electricity under the RO (1.5+3.0p/kWh)
- For a higher cost feedstock such as miscanthus, the efficiency advantage of gasification has a greater impact on overall generation costs

Straw – primary fuel chains

End use	Potential generation (as % of demand)				Energy cost (p/kWh)			Barriers
	2010	2020	Max	Notes	2010	2020	PP	
Straw Combustion - Utility	0.17%	1.26%	2.4%	Three 30MW plants by 2010, a further 20 by 2020 High potential to 2050, though gasification likely to have higher efficiency, and lower cost	5.2-5.8	4.6-5.2	5.0	<ul style="list-style-type: none"> •Potential competition for other straw uses. •Plant siting: large plants, increased traffic
Straw Gasification - Utility	0.06%	0.60%	3.2%	One 30MW plant by 2010, a further 10 by 2020 High potential to 2050, likely to be higher efficiency than utility combustion	5.7-8.3	3.3-5.2	5.0	<ul style="list-style-type: none"> •Technology not developed •Potential competition for other straw uses •Plant siting: large plants, increased traffic
Straw Combustion - CHP	0.13%	1.95%	2.0%	14 5MW plants by 2010, a further 200 by 2020	5.0-5.8	4.6-5.3	6.4	<ul style="list-style-type: none"> •Low awareness of biomass CHP as an option •High capital cost, especially at low capacities
Straw Combustion – Heat	0.10%	0.22%	0.22%	Resource constrained to 10% of that available as large fuel storage areas needed and handling is difficult No build rate constraint (91 1MWth plants by 2010, a further 159 by 2020)	1.1-1.5	1.0-1.4	0.5-2.5	<ul style="list-style-type: none"> •Potential competition for other straw uses. •High capital cost of plant relative to other heating devices

Straw - long term cost reduction potential

Generation cost projection for utility scale straw units



Assumptions	
Combustion	Gasification
Maximum efficiency is 40%	Maximum efficiency is 56%
Capex falls with 7.5% learning curve after first commercial unit in 2006. Inherently more expensive than willow	Capex falls with 12.5% learning curve after first commercial unit in 2010
Opex is 3% of capex but does not fall after 2020	Opex is 4% of capex but does not fall after 2020
Biomass fuel costs do not fall after 2020	
The installed number of units worldwide is the basis for learning curve benefits. The global number of units grows twice as fast as the UK, starting from the year shown and continuing linearly.	
20 year unit lifetime, 10% discount rate	

Conclusions

- Both technologies are potentially competitive with CCGT electricity under the RO (1.5+3.0p/kWh)
- For a higher cost feedstock such as straw, the efficiency advantage of gasification has a greater impact on overall generation costs

Miscanthus and straw – supporting fuel chains

Primary chains	Supporting chains	Support given
Straw Gasification - Utility	Wood gasification – large and small scale	<ul style="list-style-type: none"> •Technology developments in wood gasification will inform developments in straw and miscanthus gasification •May be potential for mixed fuel plants
	Straw Combustion - Utility	<ul style="list-style-type: none"> •Provides experience for reliable long term straw contracts
Miscanthus Combustion - Utility	Straw combustion - utility	<ul style="list-style-type: none"> •Allows miscanthus crop to be planted and ramp up •Assists similar technology to develop •May be potential for mixed fuel plants
Miscanthus Gasification - Utility	Wood gasification – large and small scale	<ul style="list-style-type: none"> •Technology developments in wood gasification will inform developments in straw and miscanthus gasification •May be potential for mixed fuel plants
	Miscanthus Combustion - Utility	<ul style="list-style-type: none"> •Provides a more proven technology for use of miscanthus while fuel supply chain is developed •Currently lower cost than gasification (though this is projected to change after 2010)
Miscanthus Combustion - CHP – and heat	Straw combustion – CHP and straw combustion - heat	<ul style="list-style-type: none"> •Provides experience of small combustion plant for operators and support community •May be potential for mixed fuel plants

Organic solid waste – primary fuel chains

End use	Potential generation (as % of demand)				Energy cost (p/kWh)			Barriers
	2010	2020	Max	Notes	2010	2020	PP	
Large scale gasification	0.13%	1.95%	4.1%	14 5MW plants by 2010, a further 200 by 2020	-1.7 to 9.7	-4.8 to 3.5	5.0	<ul style="list-style-type: none"> •Lack of homogeneous source •Confusion with incineration •Plant siting (especially at large scale) •Policy preference for composting
Small scale gasification	0.01%	0.73%	3.6%	14 0.5MW plants by 2010, unconstrained 2010 -2020 (a further 836)	8.7 to 16.6	1.7-7.8	5.0	<ul style="list-style-type: none"> •Lack of awareness of technology amongst waste authorities •Technologies still in demonstration, none in UK •High capex
Combustion	0.57%	2.19%	3.3%	20 15MW plants by 2010, a further 60 by 2020	-5.7 to 2.7	-8.1 to -0.2	5.0	<ul style="list-style-type: none"> •Plant siting •Concerns over emissions of heavy metals, dioxins, furans •Low public acceptability •Long planning times and high planning refusal rate •Policy preference for composting
Large scale mixed anaerobic digestion with wet wastes	0.27%	1.35%	3.1%	70 2MW plants by 2010, a further 300 by 2020	-12.4 to -2.9	-13.3 to -5.2	5.0	<ul style="list-style-type: none"> •Policy reference for composting •Need to dispose of residue at end of process •Technologies still in demonstration •Now requires high temperature step due to animal by products legislation •May involve feedstock transport to locations with wet waste(e.g. slurries) availability (i.e. out of urban areas)
Small scale anaerobic digestion of OSW only	0.24%	0.68%	3.1%	265 0.5MW plants by 2010, a further 500 by 2020	-10.1 to 2.9	-11.5 to -0.4	5.0	<ul style="list-style-type: none"> •Preference for composting •Need to dispose of residue at end of process •Technologies still in demonstration for OSW in UK •Now requires high temperature step due to animal by products legislation •Plant siting – may be in urban areas

Organic solid waste – supporting fuel chains

Primary chains	Supporting chains	Support given
OSW Small scale gasification	Solid food waste gasification	<ul style="list-style-type: none"> •Easier resource to work with as more homogeneous and available on-site. Could help to prove similar technology which may provide scale-up and cost reduction benefits to OSW gasification
OSW Small scale anaerobic digestion	Solid food waste anaerobic digestion	<ul style="list-style-type: none"> •Easier resource to work with as more homogeneous and available on-site. Could help to prove similar technology which may provide scale-up and cost reduction benefits to OSW gasification
OSW large scale mixed anaerobic digestion	Sludge from waste water anaerobic digestion, farm slurries anaerobic digestion, liquid food industry wastes anaerobic digestion	<ul style="list-style-type: none"> •This is inherently a mixed input process, accepting wet wastes, and therefore policies (including industrial effluent policy, agricultural waste policy) to support AD of these wastes will aid development of this technology

Sewage sludge – primary fuel chains

End use	Potential generation (as % of demand)				Energy cost (p/kWh)			Barriers
	2010	2020	Max	Notes	2010	2020	PP	
Gasification CHP	0.00%	0.53%	0.53%	2 1MW plants by 2010, a further 306 by 2020- exploits the whole available resource	13.7	9.1	5.5	<ul style="list-style-type: none"> •Technology not proven •Uncertain costs, high capex expected •Lack of interest on part of water industry in a novel energy solution to waste issue
Anaerobic digestion - CHP	0.37%	0.35%	0.5%	411 0.5MW plants built by 2010 to exploit the whole resource. No more needed as resource does not increase	32.6-36.7	19.7-22.1	5.5	<ul style="list-style-type: none"> •Although process is well known it is not currently optimised for energy recovery •Requires change of mindset on part of waste water industry
Combustion CHP	?	?	?	Commonly used process, however energy balance not clear or constant – varying levels of natural gas input	?	?	5.5	<ul style="list-style-type: none"> •Planning concerns relating to incineration •High minimum scale for energy recovery •Process requires constant moisture content of feedstock

- Note: electricity costs assume zero feedstock costs. Therefore before the avoided costs of alternative sludge disposal are considered, electricity costs from gasification in 2020 are around 9 p/kWh. As the costs of alternative methods in 2020 are likely to be high (at least 50% more than the cost of gasification) the overall electricity 'cost' is likely to be negative.

Sewage sludge – supporting fuel chains

Primary chains	Supporting chains	Support given
Gasification CHP	OSW gasification, solid food waste gasification	•Small scale waste gasifier development may provide experience and cost reduction benefits to sewage sludge gasification

Appendices

1. Scale definitions and price points
2. Primary and supporting chains
3. Other considerations
4. Mechanisms to overcome barriers

Willow – potential competitive advantage

Chain/step	UK strengths	International positioning	Sector requirements
Fuel provision	<ul style="list-style-type: none"> •Plant breeding capabilities (Murray Carter and previously at Long Ashton) •Forestry research, including SRC crop management and yield research, and field trials (through the Forestry Commission's <i>Forest Research</i> group) •Other related research at Central Science Laboratory, Silsoe Research Institute and Rothamsted Research •Some expertise in SRC establishment and management e.g. Coppice Resources Ltd 	<ul style="list-style-type: none"> •Swedish, German, Australian and Danish equipment manufacturers have developed specialist planting/harvesting equipment •Swedish willow plant breeding and forestry harvesting systems are world market leaders •Scandinavia and Austria widely experienced in wood fuel processing (e.g. pelletisation) •Scandinavia, Austria and Switzerland have established wood fuel marketing systems 	<ul style="list-style-type: none"> •Longer term development is needed for better yielding crop varieties and site-to-clone matching •Further development is needed on establishment and harvest mechanisation
Combustion - Utility	<ul style="list-style-type: none"> •Technology: several global large scale power equipment companies (eg Alstom, Babcock) with relevant technologies. Good supporting research. 	<ul style="list-style-type: none"> •US, Sweden, Finland and Austria lead in biomass power generation using steam turbines, based largely on the paper and forestry sectors 	<ul style="list-style-type: none"> •Incremental improvements required to existing technologies e.g. grates, boilers, turbines, fuel feeders
Gasification - Utility	<ul style="list-style-type: none"> •Wellman is developing gasifiers •EGT is developing a range of gas turbines that will burn the gas from biomass gasifiers •Strong supporting research sector in e.g. gas turbines 	<ul style="list-style-type: none"> •The majority of gasification technologies are being developed in the US and in Nordic countries. Battelle and IGT in the US, TPS in Sweden, Volund in Denmark, Lurgi in Germany 	<ul style="list-style-type: none"> •Development of components suited to biomass e.g. gas clean-up, gas turbines •Demonstration of large scale systems
Combustion - CHP	<ul style="list-style-type: none"> •A few established equipment companies (e.g. Talbotts) •Small scale power generation equipment (e.g. Talbotts for hot air turbine, Sustainable Engine Systems for Stirling engine) 	<ul style="list-style-type: none"> •Sweden, Finland and Denmark lead in biomass CHP using steam turbines, mainly based on steam turbine systems 	<ul style="list-style-type: none"> •Incremental improvements required to existing technologies e.g. grates, boilers, turbines, fuel feeders •Development of small scale power generation equipment

Willow – potential competitive advantage (continued)

Chain/step	UK strengths	International positioning	Sector requirements
Gasification - Small CHP	<ul style="list-style-type: none"> •Small sector of gasifier and turbine developers (e.g. Rural Generation, B9 Biomass, Biomass Engineering, Bowman Turbines) •Supporting research in e.g. process engineering, gasification, turbines 	<ul style="list-style-type: none"> •Netherlands, Switzerland, Belgium, US, New Zealand, Austria, Australia, France, Denmark and India have companies which are pursuing small scale wood gasification •At small scale there are some successful manufacturers but more failures 	<ul style="list-style-type: none"> •Breakthrough in small wood gasification would allow large market to be accessed – main problems at present are sensitivity to feedstock quality and tar. •Development of components suited to biomass e.g. gas cleaning, engines, micro-turbines, fuel cells
Combustion - Heat	<ul style="list-style-type: none"> •A few established equipment companies (e.g. Talbotts) 	<ul style="list-style-type: none"> •Small and medium systems: Austria, Denmark, Sweden •Large scale: Sweden, Finland, Denmark 	<ul style="list-style-type: none"> •Incremental improvements to improve efficiency and emissions through e.g. control systems •Standardised designs

Willow – other factors

Growing

- Willow can be grown on some types of contaminated land (such as landfills) to provide bioremediation
- Willow planting needs to carefully consider effect on groundwater quantity and quality
- Crops are currently grown on a 3 year cycle. There are attempts to push this to 2 years, with improved productivity and cash flow for growers
- ARBRE has made much of the growing community nervous about energy crops
- Long-term contracts required as SRC has a 15 lifetime of about years and removal costs are high

Transport

- Transport of wood fuel may be perceived as a problem if large plants served from a wide area

Conversion

- Regulated pollutant emissions not significant where modern conversion technologies are used

Competition

- Willow has limited other uses and so is less likely to disturb other markets and could contribute significantly to security of fuel supply. However, it must compete with other potential land uses. It could, in theory, be used for liquid biofuels, but this is unlikely in the short-medium term
- Is co-firing a support or a hindrance? Dedicated willow conversion plants may not be able to get sufficient fuel if co-firing goes on too long

Straw and miscanthus - potential competitive advantage

Chain/step	UK strengths	International positioning	Sector requirements
Fuel provision	<ul style="list-style-type: none"> Miscanthus plant breeding capabilities and some experience with growing and rhizome supply (e.g. ADAS and Bio-renewables Ltd) Agronomic research and carbon cycles at Rothamsted Research 	<ul style="list-style-type: none"> Some miscanthus breeding capabilities in other EU countries e.g. Germany German, Danish, Dutch and Australian equipment manufacturers have developed specialist planting/harvesting equipment for energy grasses 	<ul style="list-style-type: none"> Longer term development is needed for better yielding miscanthus crop varieties Further development is needed on establishment and harvesting techniques and equipment
Combustion - Utility	<ul style="list-style-type: none"> Technology: several global large scale power equipment companies (eg Alstom, Babcock) with relevant technologies. Good supporting research in combustion Project experience at large scale with Ely straw plant – based on Danish technology 	<ul style="list-style-type: none"> Danish companies are world leaders in straw boilers and have ~15 year programme behind them Finnish companies are market leaders for multifuel fluidised bed boilers 	<ul style="list-style-type: none"> Improvements needed, in particular for advanced combustion technologies, to operate on straw and energy grasses Need for better understanding of ash properties and uses
Gasification - Utility	<ul style="list-style-type: none"> Wellman developing gasifiers EGT are developing a range of gas turbines that will burn the LCV gas from biomass gasifiers Strong supporting research sector in e.g. gas turbines 	<ul style="list-style-type: none"> Some commercial development of gasifiers operation on agri-wastes (e.g. PRME in US). A number of other gasifier manufacturers have carried out some tests e.g. Swedish and Danish manufacturers 	<ul style="list-style-type: none"> Development of components suited to straw and energy grasses Demonstration of large scale systems
Combustion – CHP and heat	<ul style="list-style-type: none"> A few established equipment companies (e.g. Farm 2000 Ltd) 	<ul style="list-style-type: none"> Many small combustion equipment providers worldwide 	<ul style="list-style-type: none"> Incremental improvements required to existing technologies e.g. grates, boilers, turbines, fuel feeders Development of small scale power generation equipment

Straw and miscanthus – other factors

Growing

- Further research is required to improve UK miscanthus establishment rates, which are currently very low. This is probably a minimum requirement before any volume deployment of this crop. Other energy grasses may complement miscanthus (e.g. switchgrass or reed canary grass)
- Straw and dry grasses (hay) have several other higher value uses and so obtaining security of supply will be difficult except in regions where there is a large surplus. For straw this is the case for several regions of the UK.

Transport

- The low density of the fuel makes it unattractive to transport over long distances (e.g. Ely draws straw from a maximum of 50 miles radius). Transport of fuel may be perceived as a problem if large plants are served from a wide area.
- Straw can be pelletised, though this also requires an energy input so there is a trade-off with transport distance. In practice, pellets are of most use in small scale heat systems.

Conversion

- Some technical issues remain with the co-firing of straw and energy grasses, and the inability to use ash from combustion of straw and energy grasses in concrete is an obstacle to co-firing.
- Regulated emissions are not significant where modern conversion technologies are used.

Competition

- Straw and grasses could be used for liquid biofuels, but this is less likely than the use of wheat (which provides a straw residue). Liquid biofuels could, therefore, be complementary with straw plants.

Organic solid waste - potential competitive advantage

Chain/step	UK strengths	International positioning	Sector requirements
Fuel handling	<ul style="list-style-type: none"> •Several waste management companies interested in waste separation technologies including mechanical biological treatment (MBT) than can be combined with energy technologies 	<ul style="list-style-type: none"> •Strong UK drivers e.g. in landfill reduction will lead to interest from most waste management players •The UK has lower levels of source separation than other EU countries 	<ul style="list-style-type: none"> •Continued development and demonstration of separation methods and technologies with outputs suitable for integration with specific energy from waste technologies
Large scale gasification	<ul style="list-style-type: none"> •One technology company (JND Thermal Process) •One UK developer demonstrating US core technology (Brightstar Environmental) in Australia •Thermoselect has UK representation 	<ul style="list-style-type: none"> •Leading companies are in Japan (Mitsui, Nippon Steel) and Switzerland (Thermoselect) •Brightstar Environmental is considered a potentially leading company, which could rival Thermoselect in the EU market if successfully proven 	<ul style="list-style-type: none"> •Reliable longer term operation of multiple plants from the same technology developer
Small scale gasification	<ul style="list-style-type: none"> •Small number of technology companies (e.g. JND Thermal Process, Compact Power, IET) with some strong technology •Supporting research in e.g. process engineering 	<ul style="list-style-type: none"> •Compact Power are considered to be one of the leading small gasifier developers •Other leading developers are in Norway (Organic Power ASA) and Germany (PKA) 	<ul style="list-style-type: none"> •Cost reduction, especially in efficient, small scale electricity generation technology
Combustion	<ul style="list-style-type: none"> •Experience with mass-burn combustion plants with several active players, but little technology development •One UK demonstration of fluidised bed technology (Kvaerner, already used for sewage sludge) 	<ul style="list-style-type: none"> •Main players in EU e.g. CNIM, Von Roll, Lurgi, Martin, Kvaerner, Alstom (Foster-Wheeler), Austrian Energy (Babcock Borsig) •Several of these players are also involved in large scale gasification 	<ul style="list-style-type: none"> •Further testing of fluidised bed systems •Development of use with refuse derived fuel (RDF) •Development of integrated drying technologies for higher moisture content wastes

Organic solid waste - potential competitive advantage (continued)

Chain/step	UK strengths	International positioning	Sector requirements
Large scale mixed anaerobic digestion with wet wastes	<ul style="list-style-type: none"> •Experience with several electricity generating plants, including support under NFFO •Engineering capabilities in small scale plant, but little UK technology at large scale 	<ul style="list-style-type: none"> •EU has strong technological lead •Historically, most large digesters have been built by domestic companies. Some exports from EU countries to Canada and Japan 	<ul style="list-style-type: none"> •Further demonstration of larger, mixed input plants in the UK •Use of novel technologies to maximise yields, and improved gas conversion •Development and testing of biofertiliser product to enable market establishment
Small scale dry anaerobic digestion of OSW only	<ul style="list-style-type: none"> •Small number of technology companies (e.g. Greenfinch, Organic Power Ltd, Enviro-control) •Engineering capabilities in small plant but tends to be focussed towards wetter wastes 	<ul style="list-style-type: none"> •Leading technology in Germany, Belgium and Switzerland where strong waste policies •China and India have very large numbers of small scale digesters for eg cooking gas, though not technically advanced. 	<ul style="list-style-type: none"> •Demonstration of OSW and food waste only plants •Use of novel technologies to maximise yields, and improved gas conversion •Development and testing of biofertiliser product to enable market establishment

Organic solid waste – other factors

Waste collection and separation

- There are currently low levels of source separation of MSW in the UK
- Separation can also be achieved through Materials Recovery Facilities (MRFs) and a range of Mechanical Biological Treatment (MBT) processes combining separation and treatment
- Production of refuse derived fuel (RDF) – a pelletised fuel with increased energy content could allow easier transport and thermal conversion

Conversion

- Perceived health risk from heavy metals, dioxins and furans from MSW combustion plants
- For combustion of MSW or RDF to qualify for the RO, at least 98% of the feedstock must be biomass, a level which is difficult to guarantee for fuel separated from mixed wastes
- Past incineration emission problems have, in general, led to a lengthy planning process for new incineration plants. New thermal processes may suffer from association with incineration, however are expected to have shorter planning times. AD plants are generally easier to site.
- Anaerobic digestion (and also composting) produce a biofertiliser by-product which may have a market value, whilst thermal processes produce an ash or other solid residue

Alternatives

- Composting is currently the preferred option for treatment of biodegradable MSW, and contributes to local authority recycling targets, unlike the waste to energy technologies considered, including AD.
- Methane emissions from landfill sites may be reduced through alternative waste disposal processes

Sewage sludge – potential competitive advantage

Chain/step	UK strengths	International positioning	Sector requirements
Gasification and pyrolysis	<ul style="list-style-type: none"> •Small number of technology companies (Compact Power, GEM, Waste to Energy, Waste Gas Technology, CPL Biomass) •Research in process engineering 	<ul style="list-style-type: none"> •Main players are Lurgi (Germany) and ESI Enersludge (Australia) 	<ul style="list-style-type: none"> •Processes with integrated sludge drying •Successful UK demonstration at multiple sites •Demonstrable cost reduction
Anaerobic digestion - CHP	<ul style="list-style-type: none"> •Some water companies interested in new AD technology e.g. Thames, Wessex, Anglian •Technology in ultrasound systems for improved AD (Sonico –Atkins/ Purac (Anglian Water AWG) joint venture) •Strong consultancy capabilities 	<ul style="list-style-type: none"> •Majority of technology providers are multinational e.g. ACWa, Vivendi, VA Tech Wabag and originate outside the UK 	<ul style="list-style-type: none"> •Improved volatilisation technology e.g. through ultrasonic pre-treatment •Improved digester design and control systems •Replacement of older digesters and non-optimised gas conversion equipment
Combustion	<ul style="list-style-type: none"> •Some technology development activity in small plant •Larger plant dominated by larger non-UK combustion players 	<ul style="list-style-type: none"> •As for MSW, large EU players dominate 	<ul style="list-style-type: none"> •Reduced energy use in sludge drying for efficient combustion with low natural gas inputs

Sewage sludge – other factors

Current methods

- There are increasing drivers for reduction of sludge volumes in the UK, with increasing costs of disposal to land, landfill and incineration.
- The water industry is experienced with use of AD for this purpose – operating the plants themselves, but conservative about energy generation, and new technologies in general
- Current AD technology used is generally not state of the art – leading to low methane generation and low methane recovery, with significant methane emissions. Electricity and generation is also often of low efficiency in non-optimised equipment
- Incineration may involve non-renewable energy inputs to pre-dry the sludge or to aid combustion

Transport

- We have considered energy from sludge at the wastewater treatment works. If sludge were transported from satellite plants to a central site, it may be necessary to pre-dry the sludge to reduce transport volumes, and transport would have associated energy use and emissions

New technologies

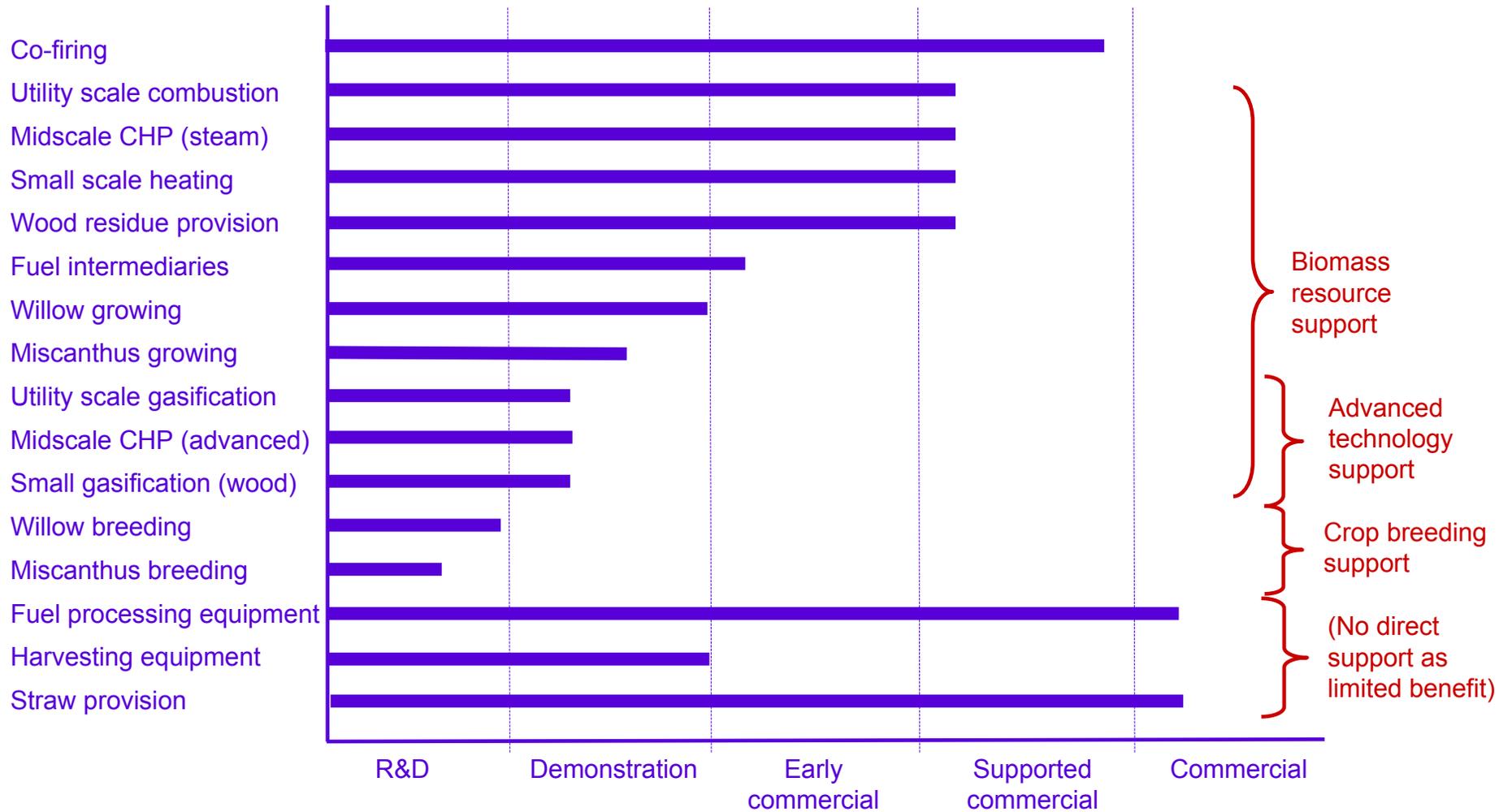
- Gasification and pyrolysis technologies are unlikely to be operated by the water companies themselves
- Several new technologies may incorporate sludge drying using heat produced

Appendices

1. Scale definitions and price points
2. Primary and supporting chains
3. Other considerations
4. Mechanisms to overcome barriers

Activities within energy crops and straw should be supported by three main types of initiative

Development stage of activities grouped by appropriate support initiative



Biomass resource support measures should focus on developing fuel markets using proven technologies

Goals	<ul style="list-style-type: none">• Attract establishment of energy crops• Encourage exploitation of forestry residues for energy purposes• Develop fuel intermediaries• Increase biomass project and operating experience with proven technologies
Mechanisms	<ul style="list-style-type: none">• Support paid to supplier of UK-sourced energy crops to a biomass energy project. Only valid if sold to a project under a purchase contract. This incentive is set at a level to make the whole chain economically viable, and would be distributed through the chain by the market• Equipment grants available for forestry residue collection equipment. Payable to investor against proof of woodfuel supply contract.• Additional support for growers in the form of exit cost insurance in case of market disappearance• RDAs/regional bodies well-placed to identify potential projects and invite project developers and growers to act
Issues	<ul style="list-style-type: none">• Initial focus needed on smaller scale applications• Co-firing excluded as already 'economic'• Domestic scale heat projects may require additional capital incentives to overcome high personal discount rates• Does not apply to straw as would distort other markets

Advanced technology support measures should counteract the perceived risk inherent in unproven technologies

Goals	<ul style="list-style-type: none">• Support introduction and proving of key advanced biomass technologies
Mechanisms	<ul style="list-style-type: none">• Capital support for installation of advanced technologies from an approved list• Apply capital support for large plant to the point where they achieve acceptable profit margins• Include additional support for smaller plant (even those that break even on paper) to allow for increased risk of earlier stage smaller technologies, and to stimulate a flexible market
Issues	<ul style="list-style-type: none">• Focus on regions where fuel supply development matches requirements• Each advanced technology has a different support requirement• Soft loan may be a more attractive mechanism?• Grants may also be suitable for small scale heating

Crop breeding support measures should increase yields for UK growers and provide export benefits

Goals

- Support R&D of energy crops to improve yields and improve export capability

Mechanisms

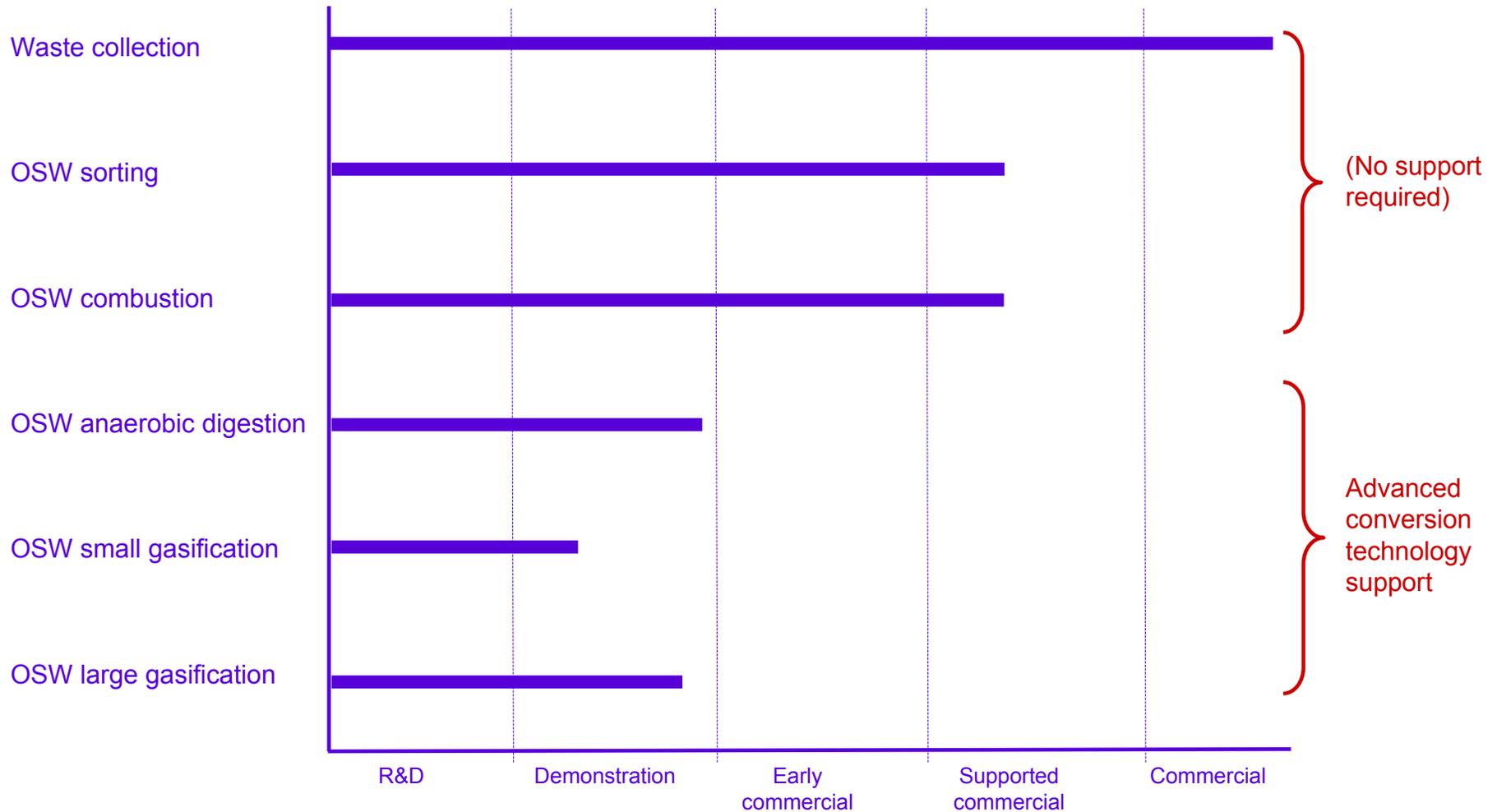
- Increase research grants at key facilities

Issues

- Existing or new facilities?
- Balance between miscanthus, SRC and other breeds

Activities within OSW should focus on support for advanced technologies

Development stage of activities grouped by appropriate support initiative



OSW advanced conversion technology support measures should act to compensate the additional cost of energy recovery via novel technologies

Goals

- Prove advanced energy conversion technologies through demonstrations

Mechanisms

- Capital support for projects (likely to be operated by waste management companies). Include technologies that achieve good margins 'on paper' as capital cost is still a barrier to uptake
- Technologies drawn from approved list
- Start with low risk feedstock supply such as food waste

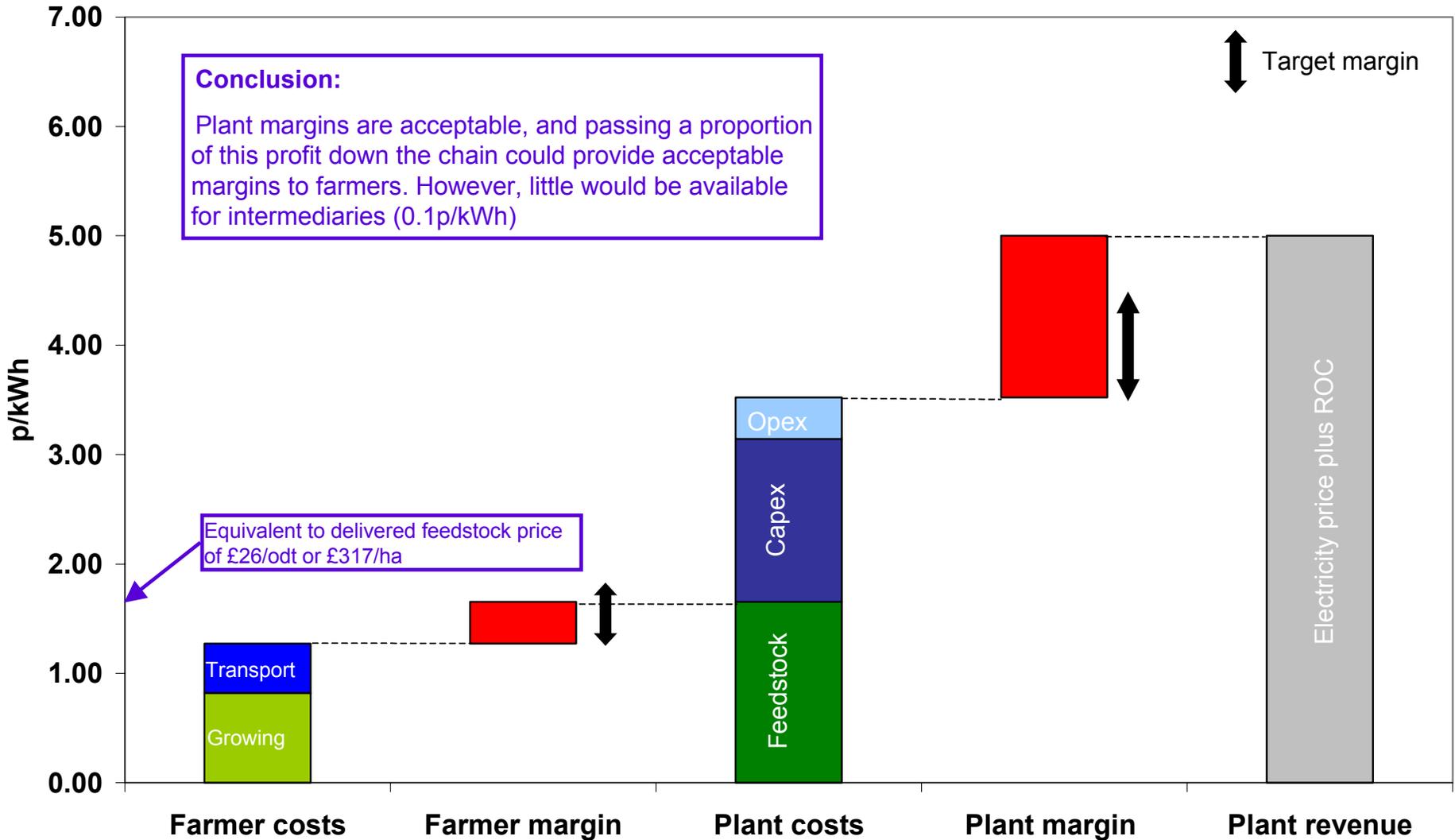
Issues

- Unfair competition with incineration?

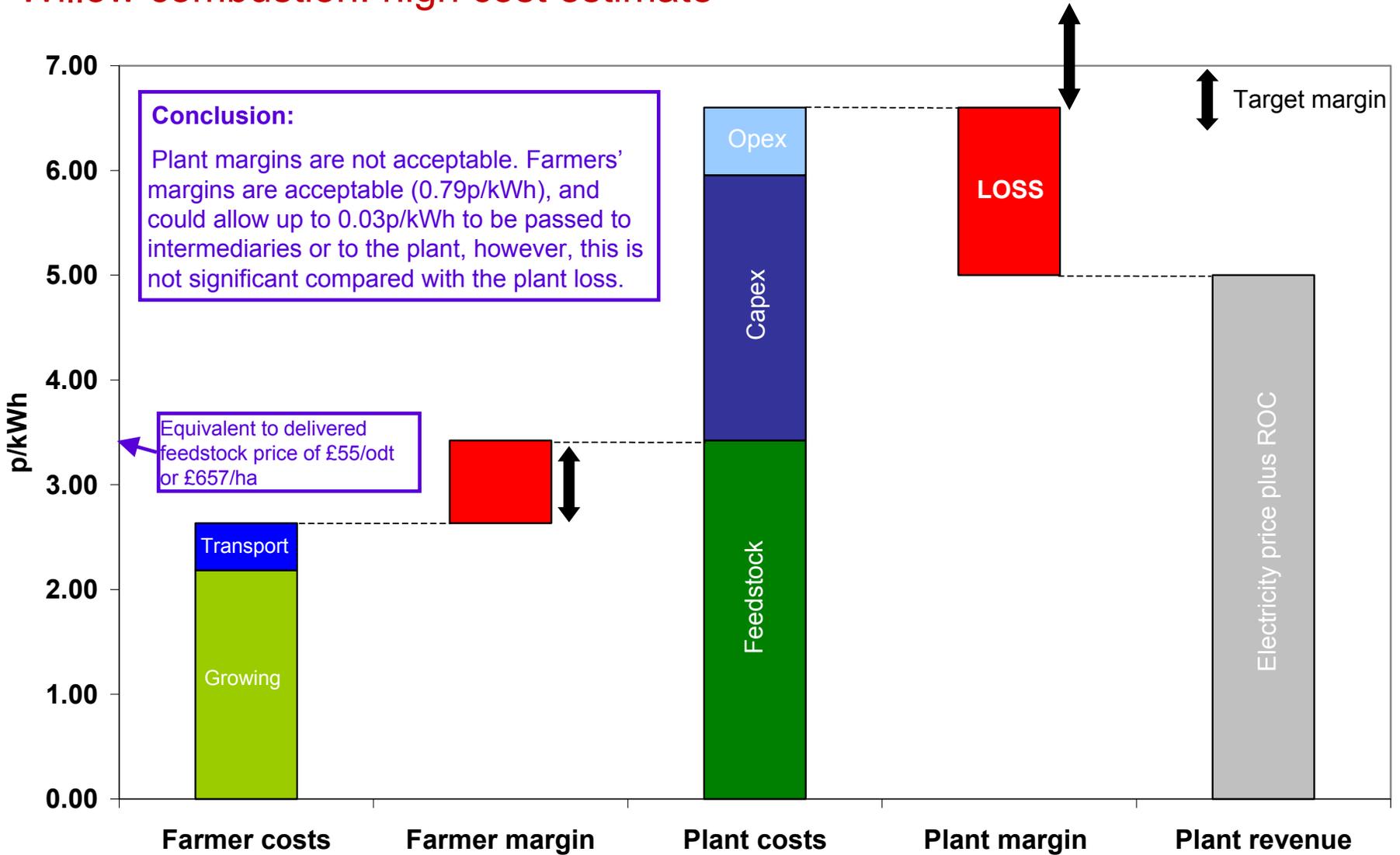
Value chain assessments for energy crop utility scale chains

- The following slides give a value chain assessment for utility scale combustion and gasification of miscanthus and willow in 2010
- For each of the four chains, the low and high estimate breakdowns are given – using low and high feedstock cost, capex and opex
- No subsidies are included in the graphs
- The model included a 30% profit margin to the farmer, shown on the graph
- The black arrows show likely acceptable profit margins to the farmer and plant
 - The farmer's acceptable margin is based on a possible margin of £350/ha for an alternative crop (such as winter wheat), reduced by £204/ha set aside payment to £146/ha. This is then converted into p/kWh using the plant efficiency
 - The plant acceptable margin of 1p/kWh is based on a level cited in a DEFRA paper on energy crops as suggested by ADAS for a reasonable target level of profitability for the industry
- In each case, if a fuel intermediary were present, they would cover the transport costs, and reduce the farmers' margin

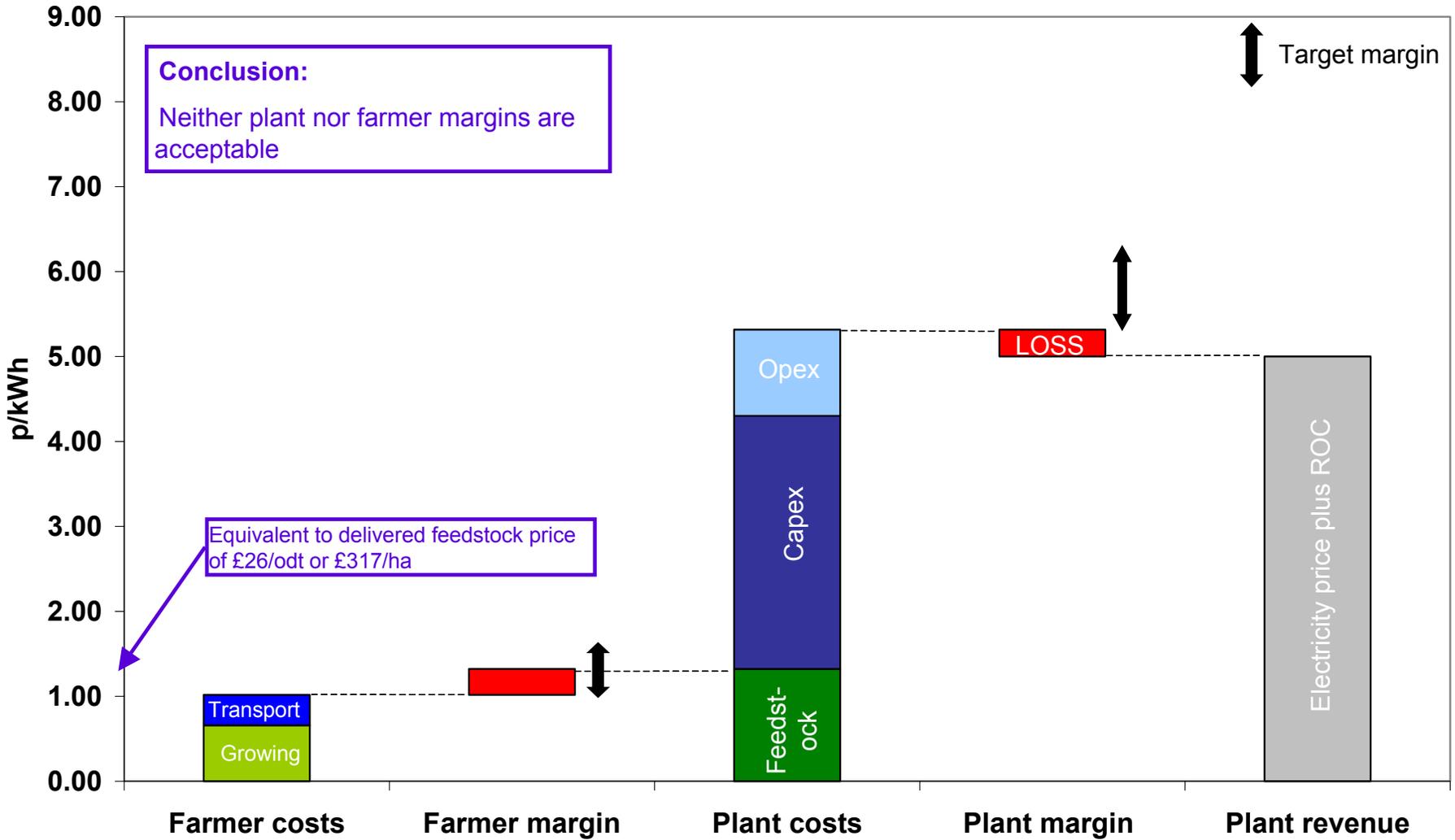
Willow combustion: low cost estimate



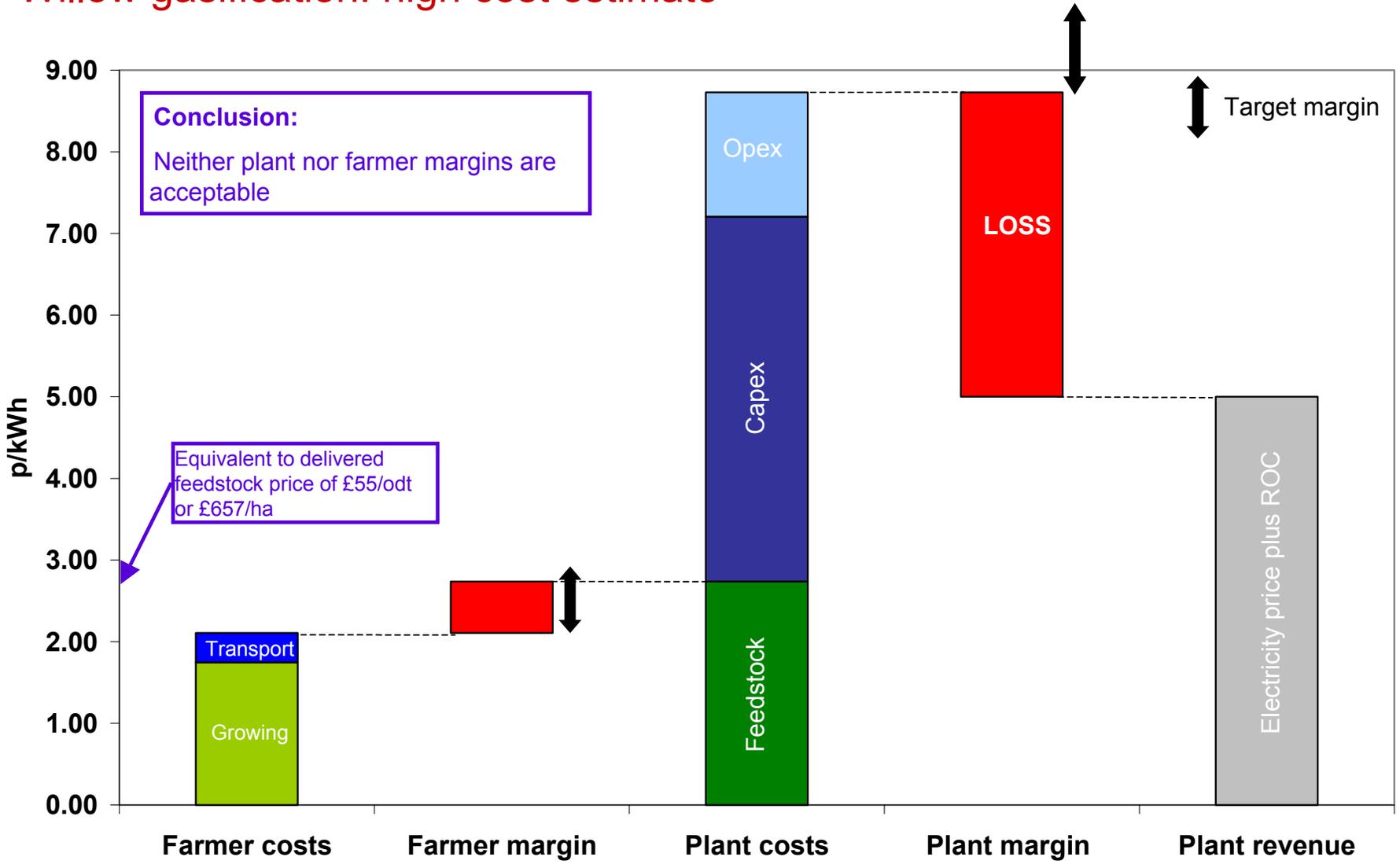
Willow combustion: high cost estimate



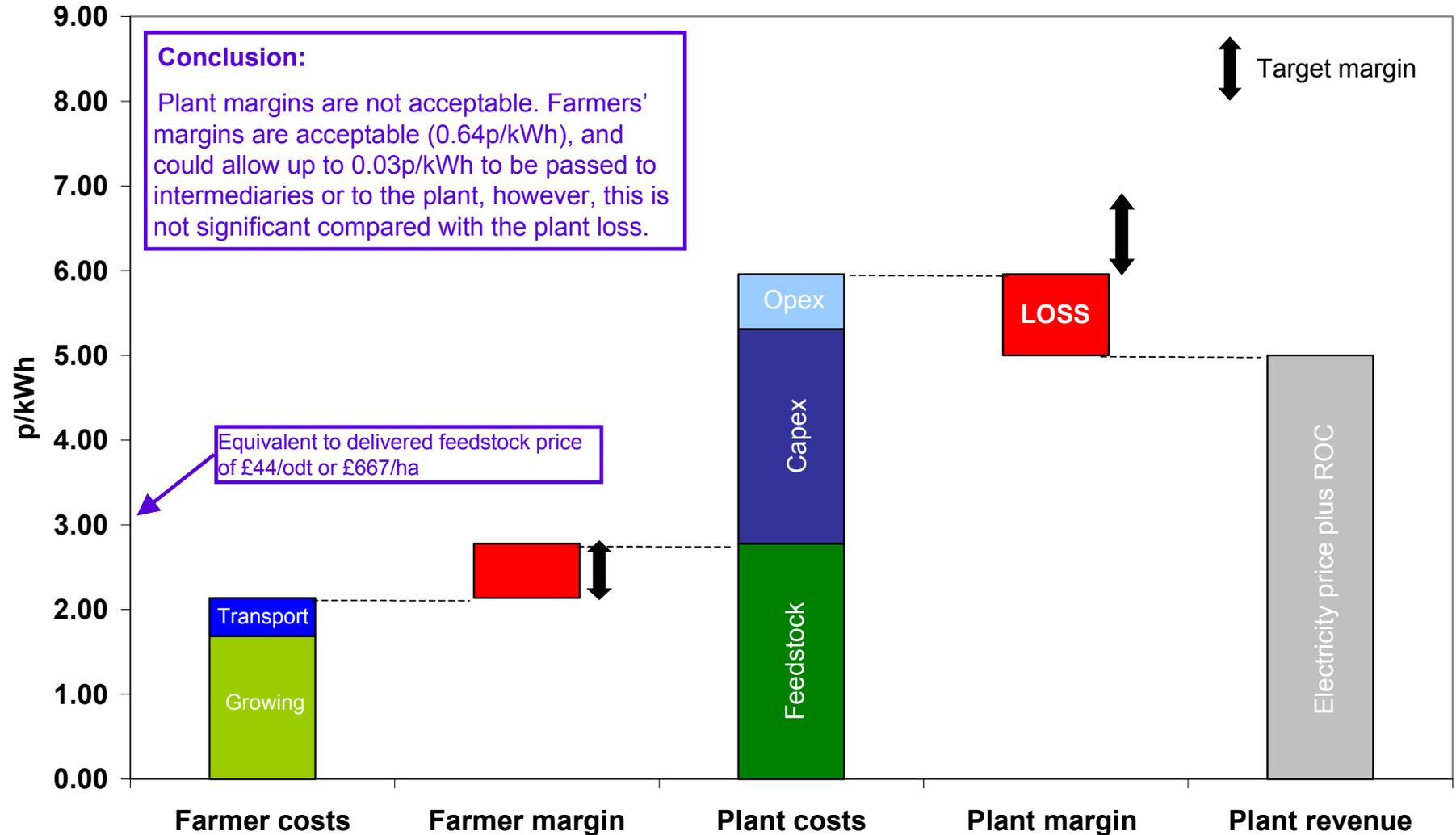
Willow gasification: low cost estimate



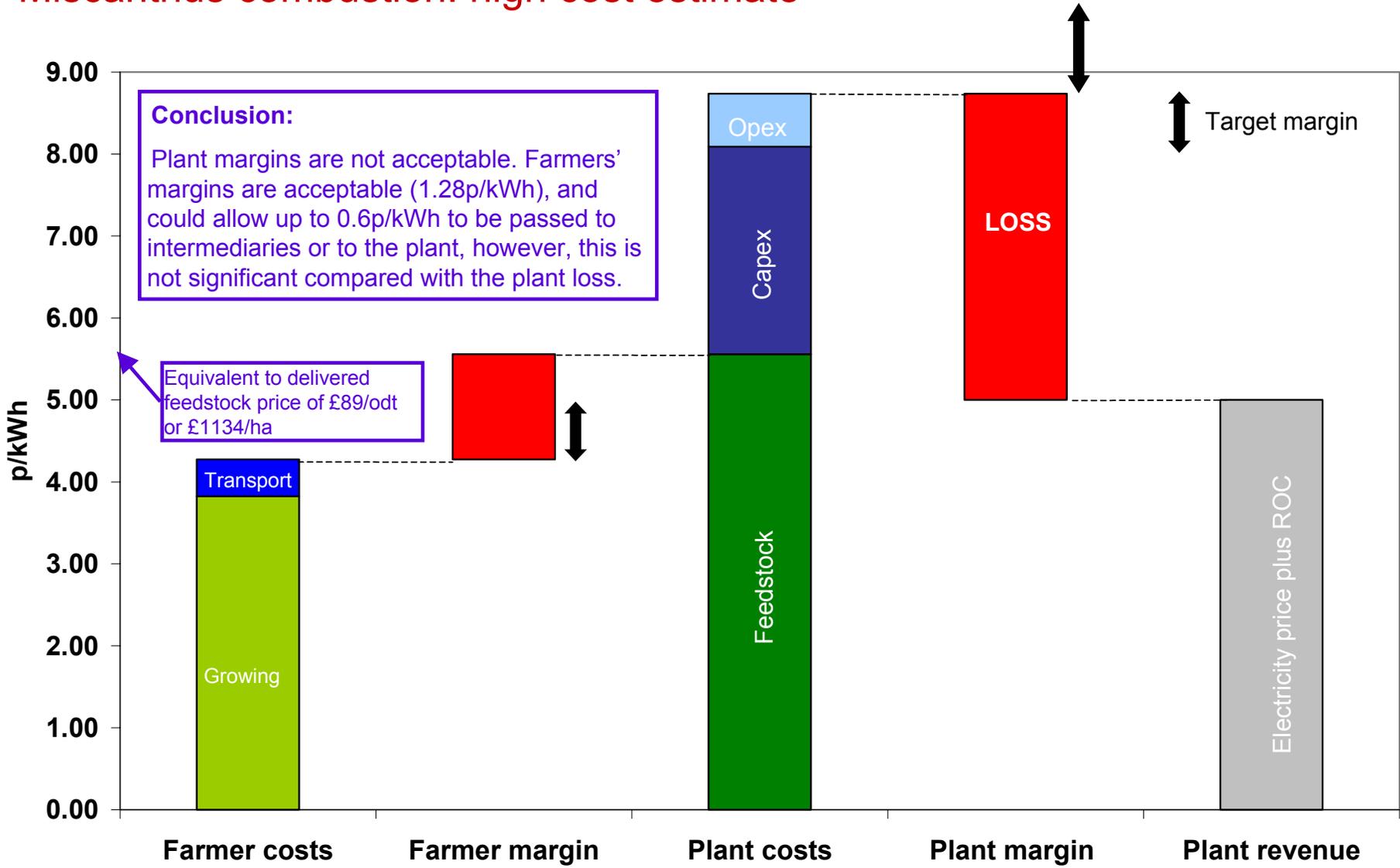
Willow gasification: high cost estimate



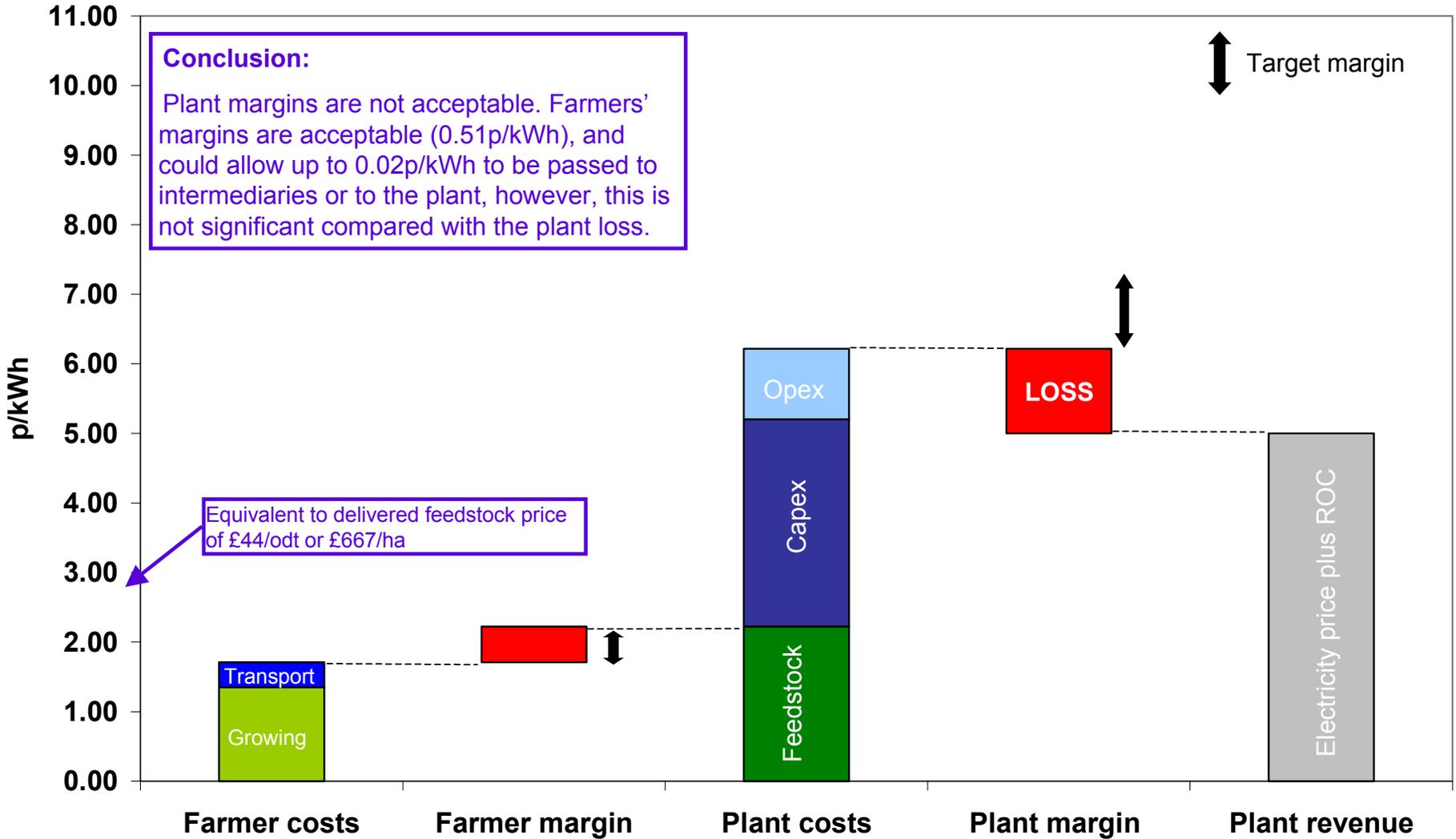
Miscanthus combustion: low cost estimate



Miscanthus combustion: high cost estimate



Miscanthus gasification: low cost estimate



Miscanthus gasification: high cost estimate

