Landfill Aftercare Scoping Study

DEPARTMENT FOR THE ENVIRONMENT FOOD AND RURAL AFFAIRS

Gregory Environmental Consulting

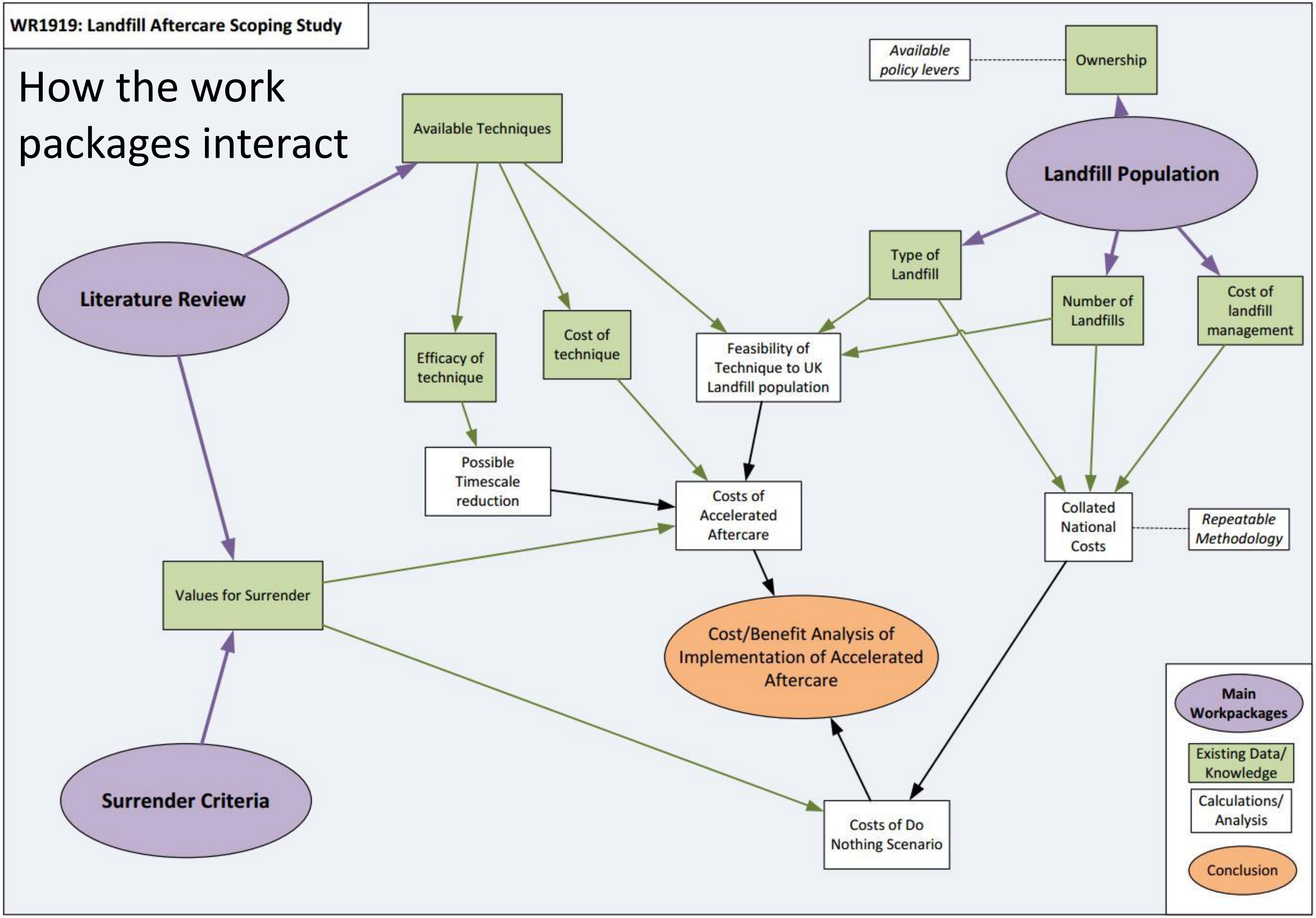
HONACE

Phoenix Engineering

Report Aim and Objectives

- A scoping study to investigate the environmental and financial issues associated with the aftercare of landfills in England and the feasibility of reducing the length of the aftercare period
  - To remove the uncertainties surrounding aftercare planning
  - To potentially shorten the aftercare period
  - To have a beneficial effect of limiting the cost of aftercare for operators
  - To reduce the risks to the environment from landfill leachate and LFG emissions
- Technical Objectives
  - Determine the availability of data on UK landfills
  - Assess the risks (environmental, financial and reputational) of the current landfill aftercare position
  - Provide evidence on accelerated aftercare in a UK context
  - Evaluate the current and alternative approaches to determining surrender in the context of completion criteria standards and models

How the work packages interact



The Project Team

Bob Gregory (GECL)	Steve Shaw (Honace)	Anne Jones (Defra)	Howard Robinson (Phoenix)	David Brown (Honace)

Project Interviews and Consultations

Consulted Industry Groups

- Landfill Regulation Group: Closed Landfill Sub-Group and Leachate Sub-Group
- Landfill Gas Implementation Group
- Renewable Energy Association: Landfill Gas Sector Group

Specific Organisations and Representatives Interviewed

- Private Operators: Biffa, Cemex, FCC, SUEZ, Veolia, Viridor, Yorwaste
- Local Authorities: Birmingham, Derbyshire, Norfolk, Sheffield, Worcestershire
- International Experts in Austria, Denmark, Netherlands, USA

Information from interviews and consultations fed into Cost Models and Surrender Criteria evaluations

Landfill Population

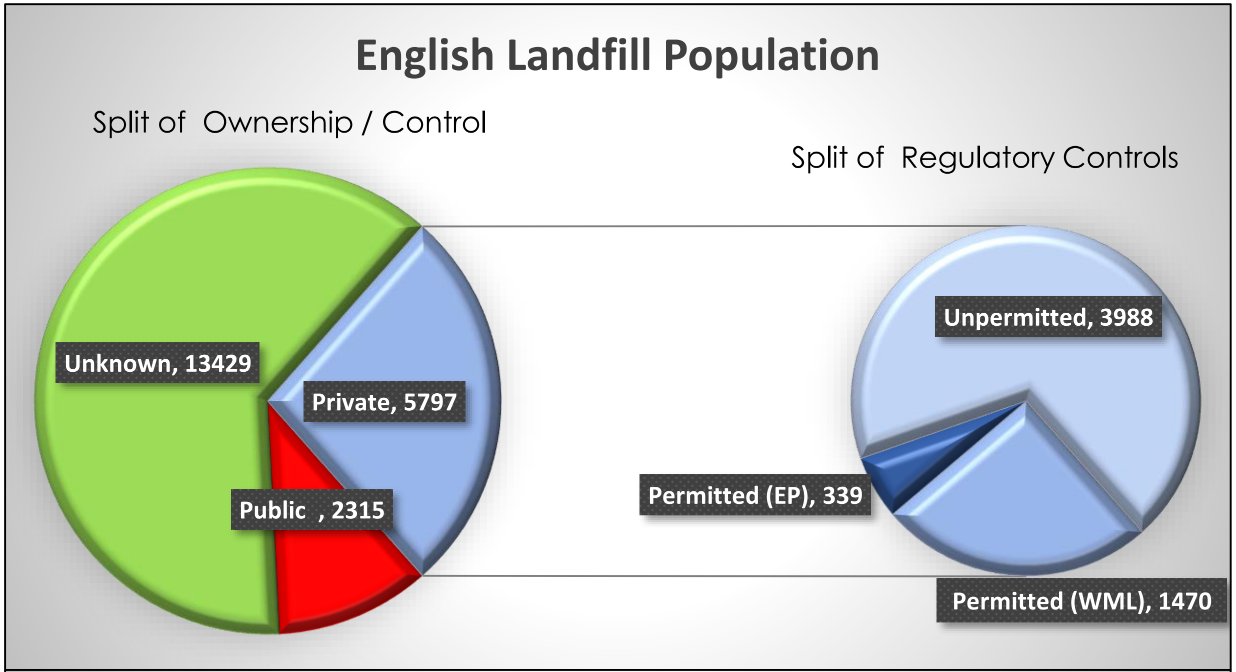
Over 21,000 landfills in UK

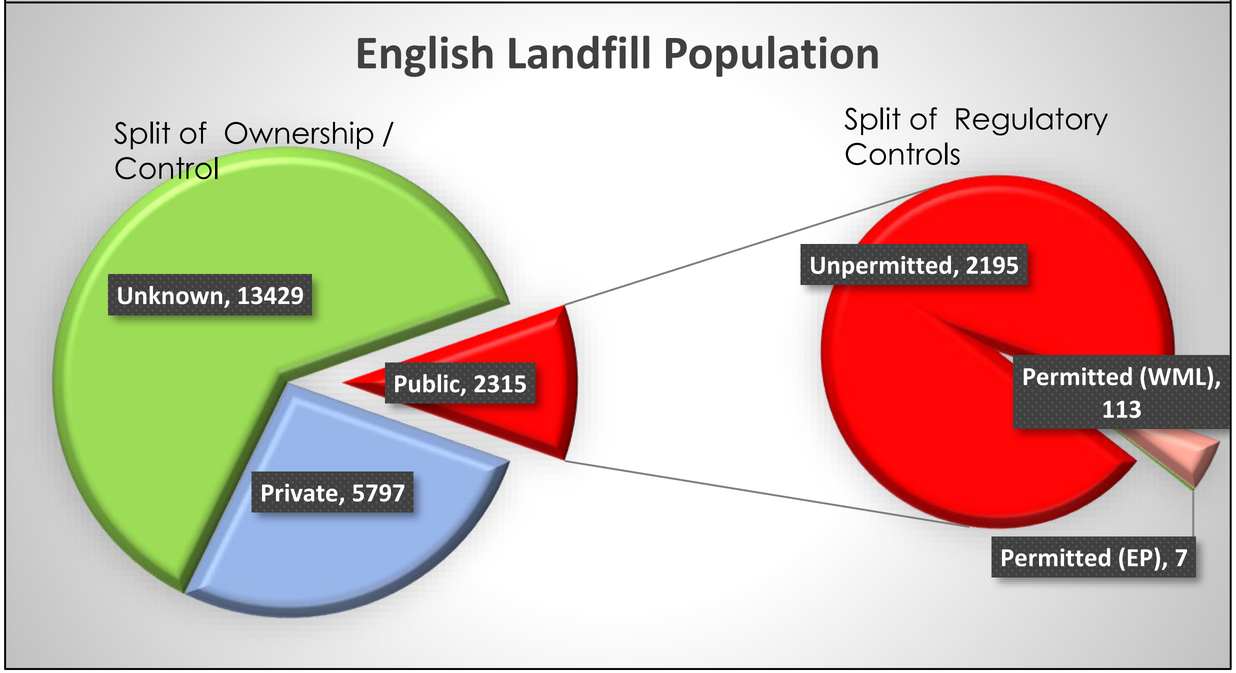
Only 1,900 permitted under EPR (inc. former WML sites)

94% of permitted sites under private management

6,000 unpermitted sites under known ownership

13,000 sites under unknown ownership/management





Landfill Population

Most permitted landfills are former WML sites

Half are Non-Hazardous

41% are Inert

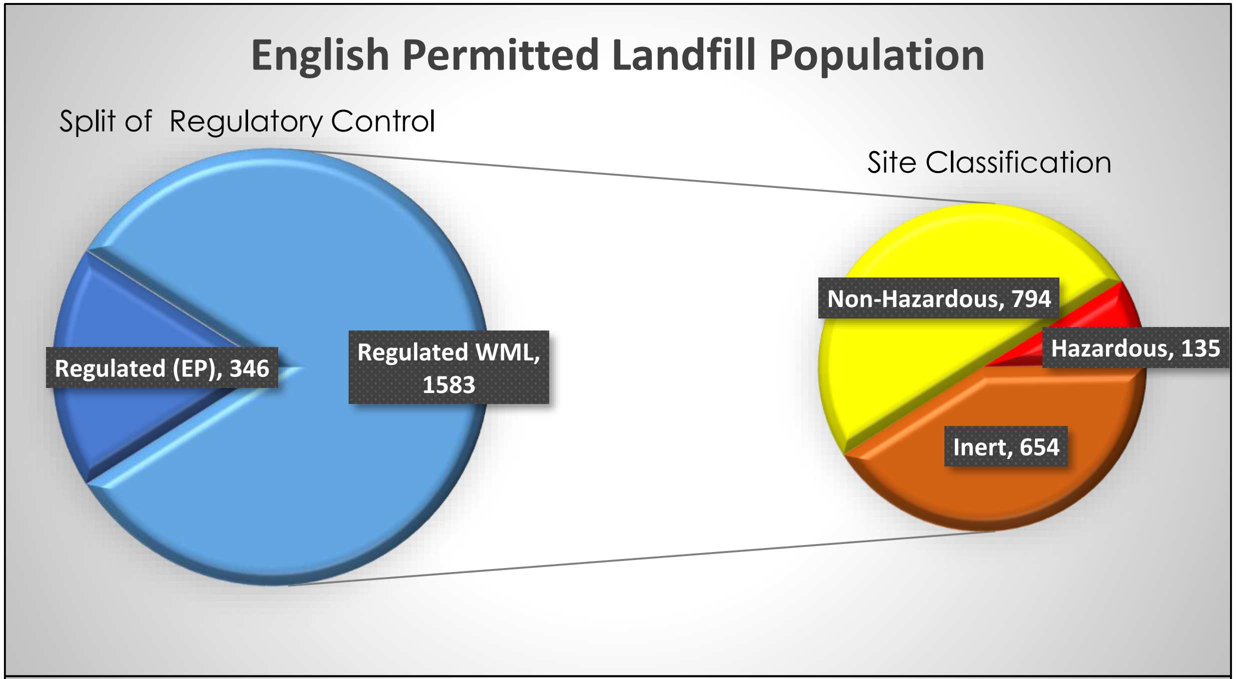
Only 9% are Hazardous

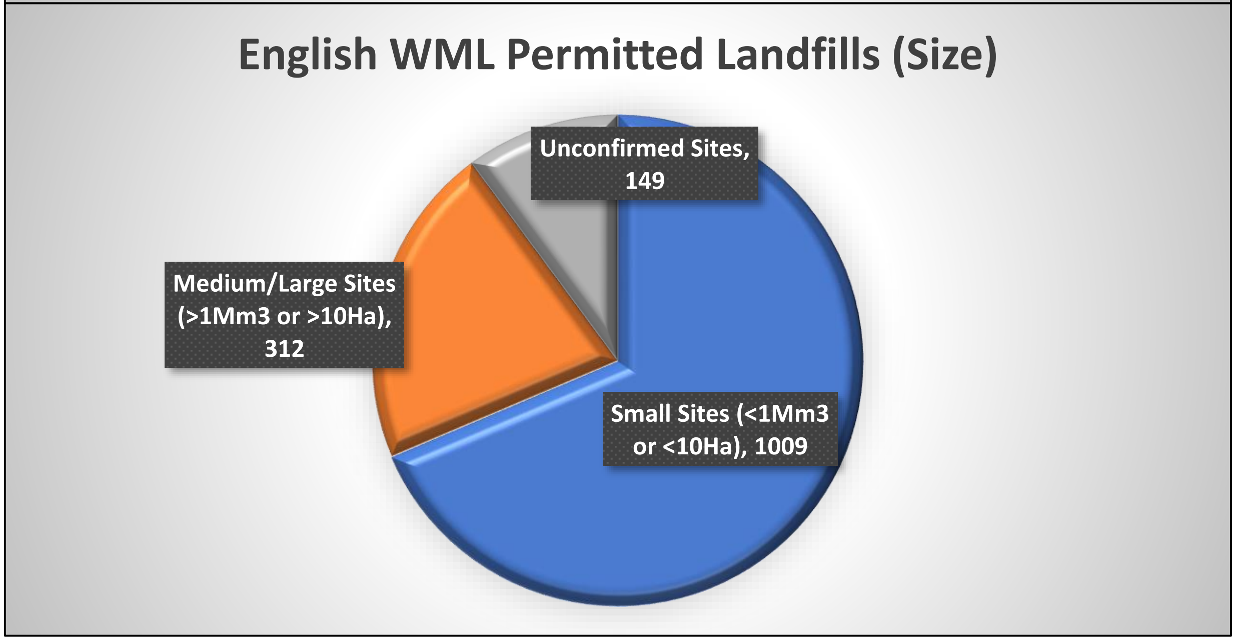
Approximately one third are Containment

One third are Dilute and Attenuate (this is a much higher fraction unpermitted)

One third mixed or unconfirmed

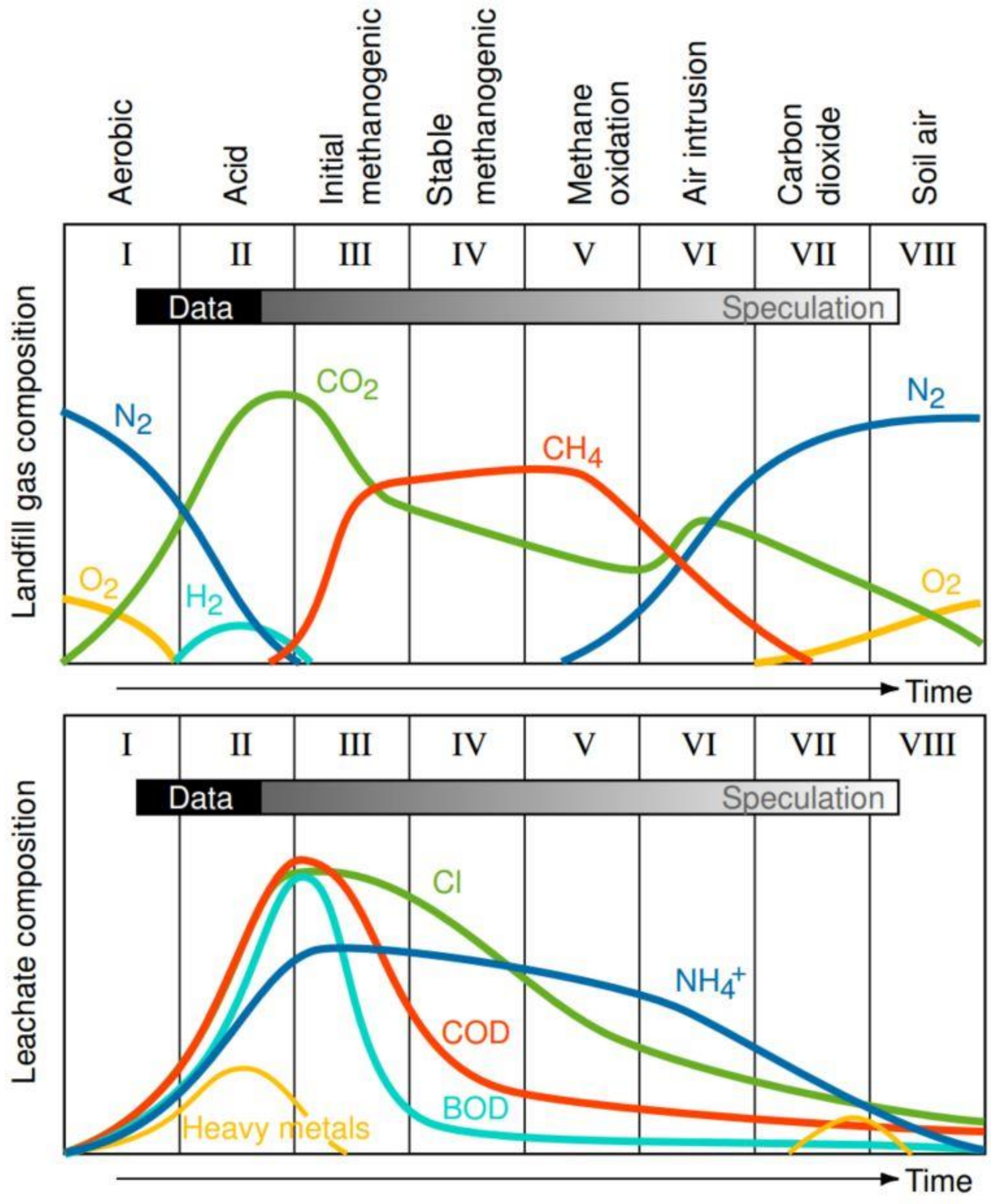
Two-thirds are <1Mm^3 or <10Ha in size





The stages of a landfill

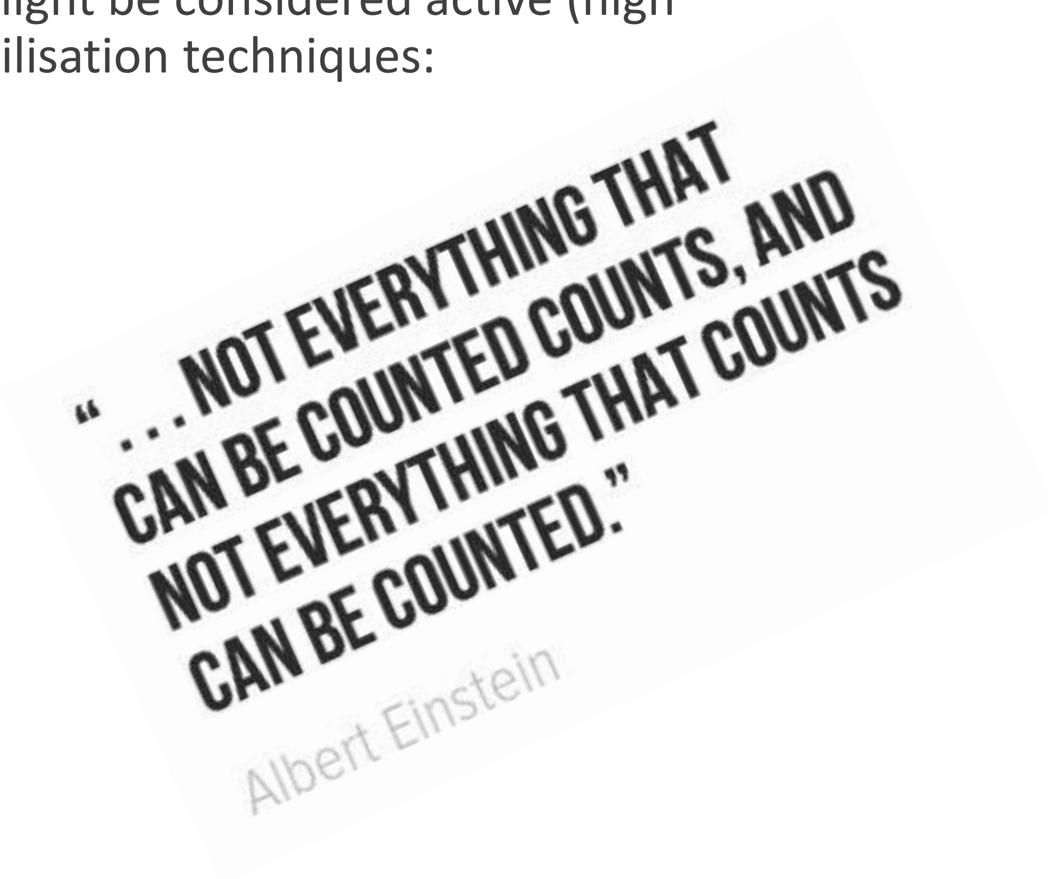
Stages I-III	approx. 1 year
Stage IV	as long as the landfill is operating
Stage V	Immediate post-closure to start of use of ACUMEN techniques
Stage VI	ACUMEN techniques to end of 60 year FP period
Stages VII-VIII (landfill gas)	next 40 years
Stages VII-VIII (leachate)	next 500+ years



Accelerated Stabilisation

There are a number of what might be considered active (high intervention) accelerated stabilisation techniques:

- ❑Water addition
- ❑Leachate recirculation
- ❑In-situ aeration of waste
- ❑Ex-situ aeration of waste
- ❑Landfill mining
- ❑Enhanced landfill mining



Accelerated Stabilisation: Water Addition/Leachate Recirculation

- Water addition and leachate recirculation methods are designed to accelerate waste degradation and tend to be undertaken in the operational phase
- Leachate recirculation does not accelerate leachate stabilisation
- These techniques are only recommended in the early operational phase as a method for accelerating waste degradation, although their use currently extends beyond that

Accelerated Stabilisation: Landfill Aeration

The aeration concepts employed across Europe split into the following approaches:

- High pressure aeration and enhanced off-gas extraction. This approach uses shock pressure aeration up to 6bar prior to landfill mining (the Bio-Puster ® technique)
- Active aeration and off-gas extraction (the AEROflott ®, AIRFLOW ® and Smell-Well ® techniques)
- Active aeration without off-gas extraction. Continuous or intermittent aeration by vertical wells or air injection into the unsaturated zone beneath the waste
- Passive aeration. Ambient air drawn into open gas wells driven by a negative pressure induced within the landfill body (The DEPO+ ® technique)
- Energy self-sufficient long-term aeration. This approach uses wind-driven aspirators mounted directly on existing gas wells

Accelerated Stabilisation: Landfill Aeration

Quantitative data from documented full-scale case studies are limited, but:

- ❑Landfill aeration appears to have some potential to accelerate stabilisation of the cellulose-rich food waste components of landfilled waste on relatively small, shallow, landfill sites
- ❑The technique has not been tested on larger landfills
- ❑There is a cost implication requiring treatment for at least ten years
- ❑Even when aeration is employed for stabilisation of the methane-generating fraction of the waste, the environmental impacts of ammoniacal-N and heavy metal release following the aeration of landfills does not appear to have been studied in detail
- ❑Trials carried out to date have shown that the leachate is nowhere near a condition which could be considered to be close to surrender criteria

Accelerated Stabilisation: Landfill Mining

- Ex-situ methods which remove, treat and dispose of landfill waste is one option that would potentially reach ‘surrender criteria’ in a much shorter period, and is usually referred to as landfill mining (LFM)
- The drivers for LFM include the following
  - reducing the area of land that a landfill occupies
  - dealing with local pollution concerns
  - creating additional landfill airspace
  - recovering locally required materials such as landfill cover and restoration soils
  - recovering resources for recycling value or energy recovery

Accelerated Stabilisation: Landfill Mining

- Our findings indicate that LFM projects could provide an alternative means of reducing the long-term aftercare commitment and therefore cost whilst reducing pollution potential to the local environment
- Economic viability will be dependent upon specific circumstances
  - LFM is not suitable to all UK landfill population but could be targeted to sites such as coastal sites or as part of large engineering projects
  - Enhanced landfill mining (ELM), is most suitable for sites infilled from 1970s to 1990s, before waste pre-treatment diverted material from landfill and materials and energy recovery are a prime motivation
  - ELM may still be economically marginal, even when aftercare provision savings, commodity/energy revenue, land value uplift and other savings and revenues are considered
  - There may be some value in combining aeration with landfill mining approaches, to stabilise waste ex-situ following excavation and prior to re-landfilling the material
- The opportunities for landfill mining in the UK may still be some 10-15 years away, when resource value, land value and processing costs align unless support mechanisms can be developed to allow suitable sites to be developed

Costs of Aftercare

- Landfill Permit holders are required to provide Financial Provision for 60 years post closure, in accordance with EA guidance
- Models were developed for different site types based on the analysis of the landfill population and the site classifications
- Data on the sizes of sites was only available for WML sites
  - 69% were <1Mm^3 and <10ha these have been classified as 'Small' sites
  - The remaining 21% were classified as "Medium"
  - There was 10% of sites of unknown size
- Costs were developed for Small and Medium sites based on them being operated either on a dilute and attenuate or containment principle for a 60-year period

Costs of Aftercare

- In the first 30 years post closure, model gas management costs are offset against landfill gas utilisation. These costs will not occur until years 31-60 post closure
  - This assumption is dependent upon utilisation of landfill gas being economic and post RO there is indication from industry that this will not be the case
  - The models including a range of low to high cost estimates and low to high frequencies
- The ranges were used to generate a low, high and central cost scenario for each site types
  - Statistically It is likely that there will be very few, or no sites, at the extreme ranges where all categories are high frequency and high cost or low cost and low frequency
  - Some sites are likely to be at the extreme ranges for some cost lines but not all
- In developing the models, it became clear that long term leachate management costs are the most significant cost element and the method of treatment a key factor

Landfill Gas Utilisation Income

- The range of income from RO qualifying landfill gas generation is estimated at £88 – £111/MWh
- The typical range of income *following expiration of ROCs in 2027 and reduction of TRIAD income for embedded generation* is estimated at £52 - £60/MWh
- The cost of generation from landfill gas is estimated to be £43 – 91/MWh
- Feedback from landfill gas Industry groups indicates that they see there being a significant risk of generation schemes becoming terminated early, following the cessation of RO support from April 2027 onwards
- Potentially the risk is greater where third party operator may decide to terminate their commercial agreement
  - Under this scenario landfill gas would be flared by the landfill operator to maintain environmental control under their permit obligations

Other Income Sources

- Operators are increasingly seeking other sources of income to offset long term aftercare costs and utilise existing assets
- Industry feedback has indicated a desire to maximise and secure the use of spare electrical export capacity for alternative forms of generation, where landfill gas generation rates are declining
- There is a particular interest in using the landfill surface for ground mount solar PV generation as a potential use of land unsuitable for other built developments
- There are a small number of landfills that have developed ground based solar PV, albeit under prior higher tariffs
- Industry feedback suggests new solar PV developments on landfill are constrained by the higher costs and lower returns
- Other land uses such as crop growing or Short Rotation Coppicing (SRC) for biomass fuels are reported and can deliver a source of small but nevertheless long term income for some sites

Surrender Criteria

- Landfill surrender criteria differ throughout the EU despite the Landfill Directive
- A key finding of this research is that landfilled wastes are significantly different across the EU, even though we are subject to the same waste diversion criteria in the Landfill Directive
  - sometimes because of stricter in-Country regulation
  - sometimes because of the risks from landfilling different waste types
- There are several existing alternatives for the long-term management of landfills

Surrender Criteria: fixed time or perpetual care

Termination of aftercare after a definite time period

- Landfill management by the operator is terminated after a specific time period (e.g. 30 years or any other time specified by the regulator)
- The advantage is that the aftercare period is predictable and the owner knows what is required for what period of time
- Society remains responsible for problems that could arise after the operator is no longer responsible for aftercare

Perpetual care

- Perpetual care is at the other extreme and is recognised as having many similarities to Dutch surrender criteria
- The landfill operator is required to monitor and maintain the landfill forever
- This removes uncertainty about the duration of aftercare for owners and authorities
- It offers maximum protection of human health and the environment
- There is no appetite for this approach in the UK from the operators

Surrender Criteria: chemical criteria or complete stabilisation

Specific chemical criteria

- The landfill is maintained until specific criteria for the leachate, solids and gas are reached
- Criteria for landfill gas might relate to a decrease of gas production rate or a minimum fraction of the expected total gas production has taken place at the site
- Criteria for leachate from MSW landfills might include a BOD5/COD ratio of less than 0.1
- Waste Management Paper 26A (1994) defined this approach, which in the UK has subsequently evolved into the current waste stabilisation approach

Complete waste stabilisation

- The landfill is managed until the waste's chemical, biological and physical characteristics (without containment) do not pose a threat to human health and the environment
- Physical stability can be assessed more easily by settlement profiling than can chemical stability
- The evaluation of biochemical stability will be difficult due to ammonia, trace organics and persistent chemicals in leachate

Surrender Criteria: accelerated stabilisation with target values

Target Value Approach

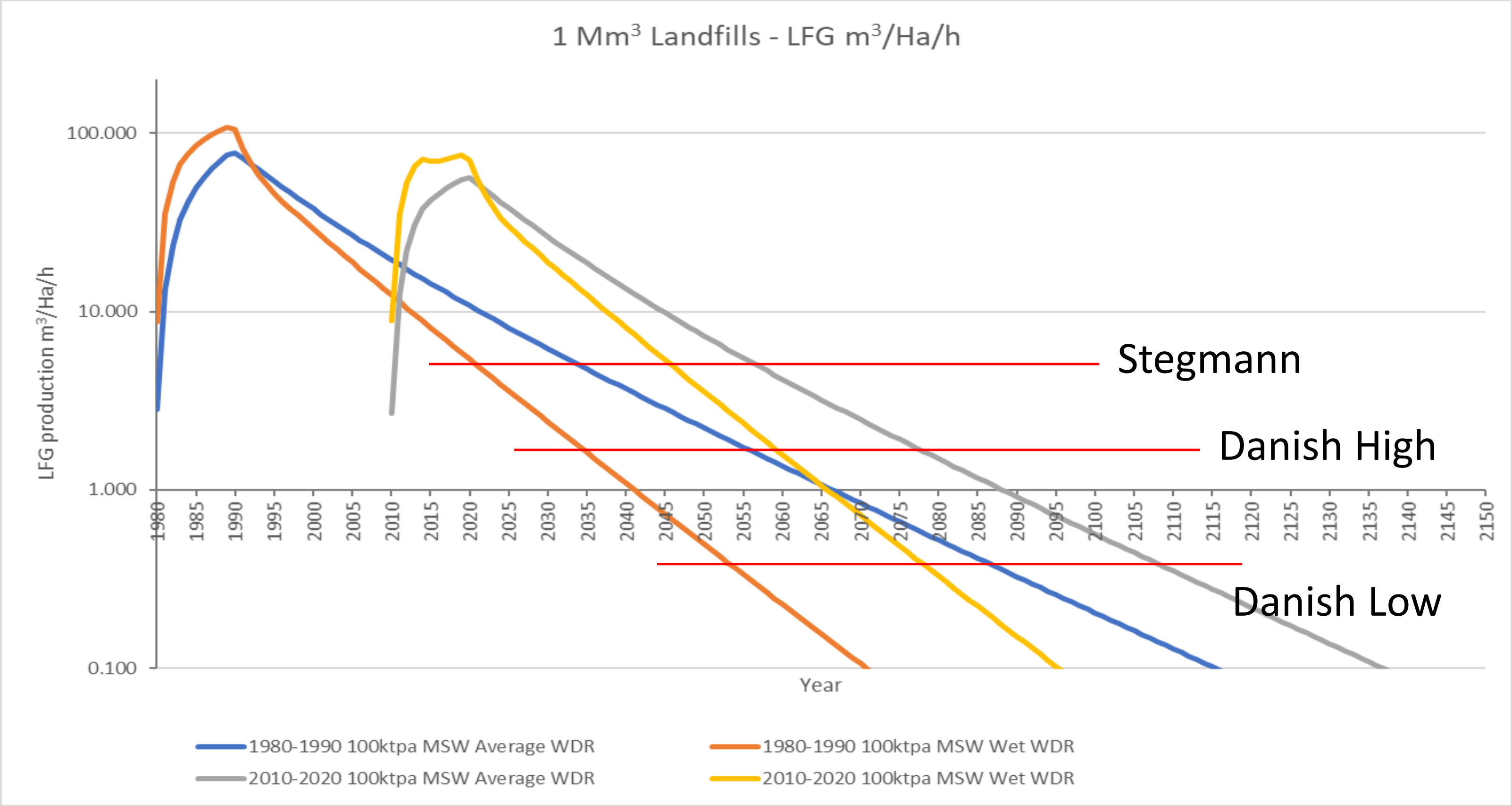
- This approach is based on chosen targets that could be applied without further evaluation
- This approach is often coupled with in-situ aeration and bio-flushing technologies that aim to enhance biodegradation and accelerate stabilisation over shorter timescales
- These technologies are often applied because of gas management issues and local landfill receptors
- These techniques focus on the carbon burden and although conversion of ammoniacal-N takes place in the laboratory, this is not obvious in field trials
- These techniques also do not consider natural attenuation processes taking place in the subsurface below the landfill

Surrender Criteria: The Duration of LFG and Leachate Generation

- For landfill gas generation and emission, the Stegmann (2006) value of 5 m^3 CH_4/Ha/hour, equivalent to 7.7 g CH_4/m^2/day, is one proposed criteria for the completion value for landfill gas generation
  - It is also one of the six Ritzkowski and Stegmann (2013) proposed stability criteria for completion of aeration and end of post-closure care
- The Danish values from Kjeldsen and Schultz (2015) of 0.6 – 1.8 g/m^2/day are aligned with natural emissions phenomenon at 0.4 – 1.2 m^3 CH_4/Ha/hour, and are less than 25% of the Stegmann value
- We used GasSim to forecast the surface emission rate for a small 1Mm^3 landfill of 10Ha area and 10m depth, and a medium 6Mm^3 landfill, of 30Ha area and 20m deep
- We modelled two different fill periods, and two waste degradation rates
- Site surface areas were used to determine the emission rate, assuming worst case with no lateral emission, no gas collection, and no methane oxidation
- These values are therefore more representative of surface emission rates after landfill gas flaring has stopped

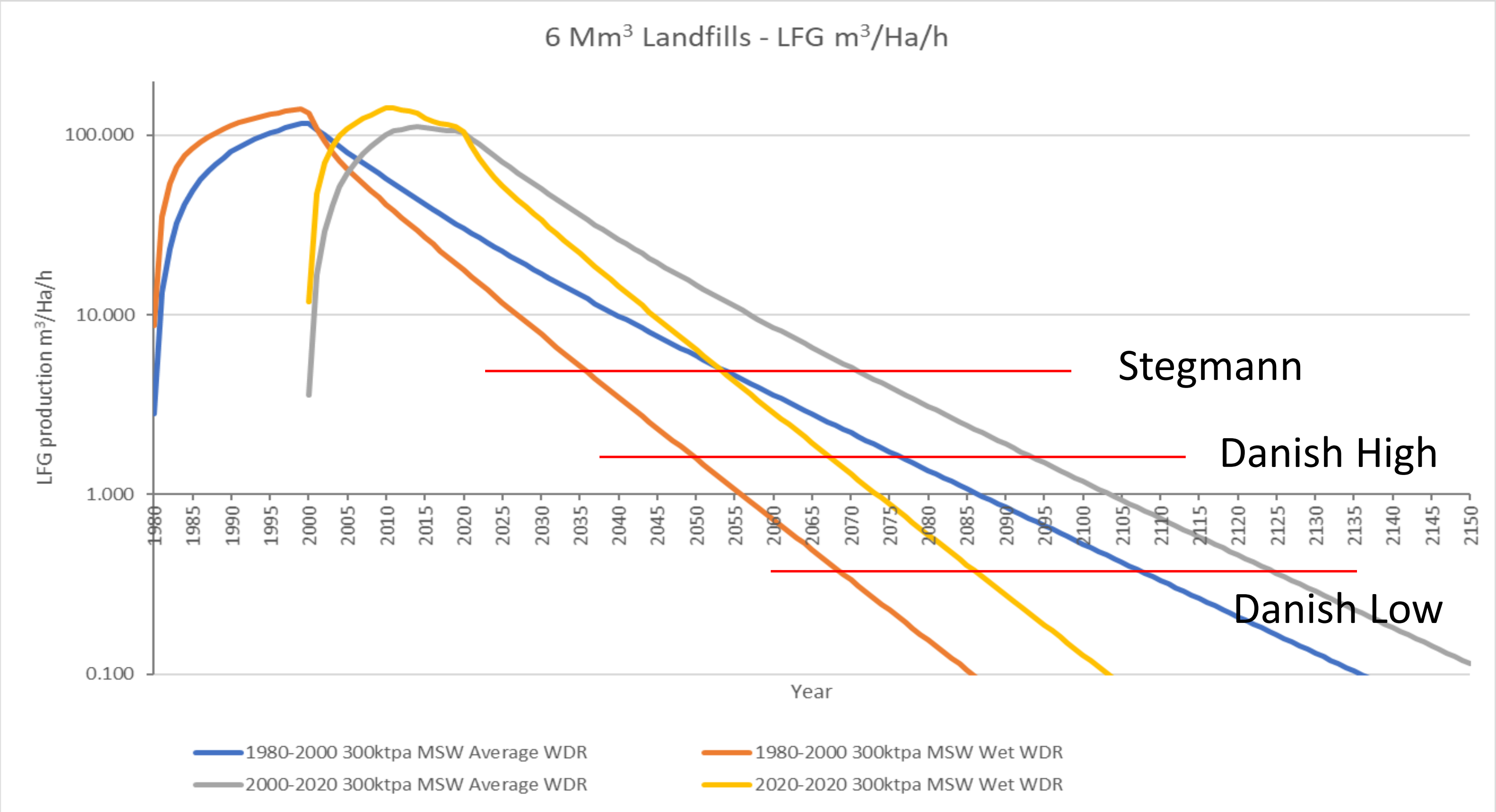
Surrender Criteria: The Duration of LFG and Leachate Generation

1 Mm^3 Landfill Scenarios



Surrender Criteria: The Duration of LFG and Leachate Generation

6 Mm^3 Landfill Scenarios



Surrender Criteria: The Duration of LFG and Leachate Generation

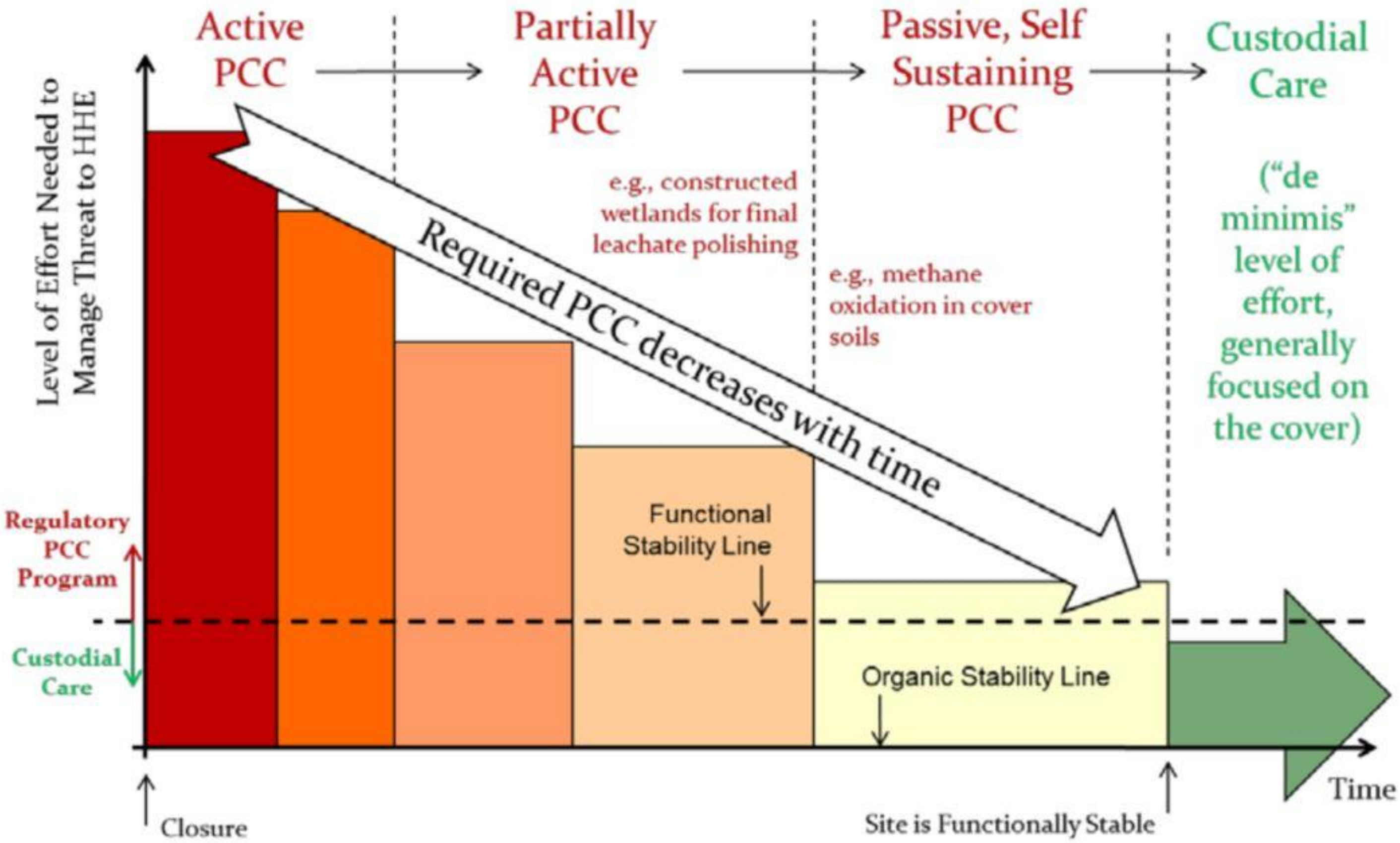
- All the sites modelled could achieve the German methane emissions value within the 60-year timeframe for financial provision
- The Danish criteria prove harder to achieve within a 60-year timeframe, and only sites modelled "wet" achieve this for the higher Danish value
- The sites which could benefit most from in-situ aeration projects are those which have been engineered under LfD engineering principles and have a greater duration of time to achieve completion criteria
- Leachate timescales are still in the hundreds to thousands of years timeframe. The evidence from accelerated stabilisation projects to date do not demonstrate active reduction of the ammoniacal-N or heavy metal burden
- It is clear that there is not a straightforward technical approach to managing the leachate burden

Surrender Criteria: performance based EPCC approach

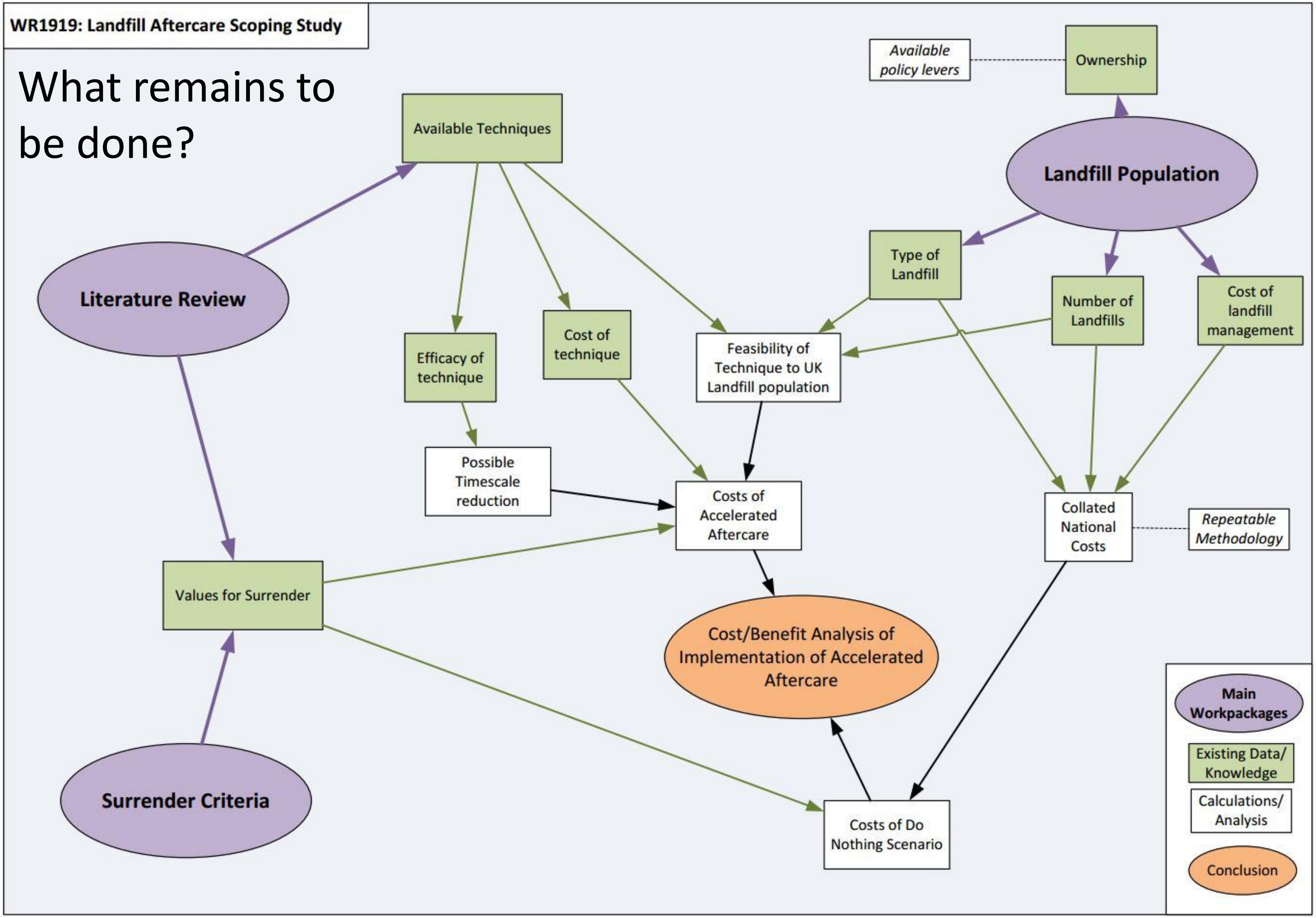
Performance-based criteria

- ❑A US initiative using an "Evaluation of Post Closure Care" approach
- ❑Adapt post-closure management at the site based on landfill performance criteria
- ❑The focus of this approach (used on licensed operational landfills in the US, not closed unregulated landfills) is to support development of site-specific management strategies to control the duration and cost of post closure care while providing long-term protection of human health and the environment
- ❑The desired state at the end of aftercare is not defined, but aftercare intensity is reduced as warranted by site-specific land use requirements
- ❑There is broad support for a form of this US "Evaluation of Post Closure Care" approach across industry consultees

How Post Closure Care (PCC) changes with time



What remains to be done?



Summary – Current Situation

- The vast majority of sites are not permitted and have no formal requirement for Financial Provision. They are typically managed on a <u>needs</u> basis by private and public sector, due to corporate responsibility and reputational standing
- Containment sites generally have the most significant long term financial burden, mostly as a result of leachate management requirements
- Current surrender criteria unclear hence uncertainty on long term costs
- Landfill gas passive control could be achieved within 60 Years (German, and Danish emission criteria on "wet" landfills) but leachate unlikely to be achieved
- Aeration works for carbon emissions but there is no need to accelerate stabilisation unless this gives improvements for ammoniacal-N as well as carbon
- Techniques for accelerated stabilisation are rarely implemented in the UK due to surrender end point uncertainty, viability, regulatory burden and cost
- There is potentially a higher risk of landfill abandonment (RO removal, incomplete void, increasing regulatory burden and costs)

Summary – Possible Options

- ❑ Each landfill is unique in both the nature of its development, its environmental setting and its operation and management
- ❑ 90% of English landfill population is unpermitted and arguably has provided few significant environmental issues. Already managed under Part IIA of EPA 90
- ❑ Adoption of Surrender Criteria for permitted sites following a proportionate risk based approach seems favoured, to minimise regulatory burden
- ❑ This could be a variant of the US Evaluation of Post-Closure Care protocol, where age and design of site, historic environmental performance, and risk for future land use are considered
- ❑ A compliance point away from the landfill, down hydraulic gradient, is another important component of EPCC and other European surrender criteria
- ❑ Potential for landfilling mining and aeration as accelerated stabilisation techniques requires more research
- ❑ Clear guidance and support for alternative income opportunities (e.g. solar PV/ SRC) required to offset long term costs

Thank you for your attention

From the
Landfill Aftercare Scoping Study team

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