SUSTAIN

Future Steel Manufacturing Research Hub

SUSTAIN Engagement Event

4th December 2019

Grand Challenge Workshop Session Output

UKRI Engineering and Physical Sciences Research Council
Swansea University Prifysgol Abertawe
The University Of Sheffield.
WMG THE UNIVERSITY OF WARWICK

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All event presentations are available for download on the SUSTAIN website:

https://www.sustainsteel.ac.uk/2019-inaugural-engagement-event-1

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Grand Challenge Workshop Session Output:

GCRA1 Carbon Neutral Iron and Steelmaking - Materials Resources and Energy

Poster Board Capture and Scope for Call




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Grand Challenge Workshop Session Output

GCRA1 Carbon Neutral Iron and Steelmaking – Materials Resources and Energy

"Wastes":

Carbon Substitutes

- Fuel by-product from steelmaking gasses TRL <3
- Redesign of tyres to improve recyclability in ironmaking
- 'Carbon looping ' use waste as carbon source captures CO_2 processes into plastic etc.
- Tyre recycling as new raw material – carbon + high quality steel source
- Tyres from steel off-gas and/or precipitated carbon (kish) (TRL1?)
- Burn waste instead of carbon (Wales 20% non -recyclable target / could be for coke too
- EV batteries as feedstock to steel plant
- Non plastic electrical cable insulation

Dusts

- Reduce/negate effect of tramp elements
- Reuse of waste/by-products
- Steelworks as industrial refinery (reprocessing all elements in periodic table with commercial value)
- Removal of residuals in recycled materials (either use slag or zone melting/refining)
- Reverse waste definition ->element mining
- Element refining to overcome diminishing value of waste
- Reuse of carbon and dust precipitates (TRL 4-5)

Water

- 100% reuse
- Separation and extraction tech
- Policy and design of waste streams

Metals

- Vertically integrated scrap processing and steel plants
- Alloy element recovery ->metal solvents
- De-coat post consumer scrap, recover coatings, increase value
- Advanced metal /material recovery for battery technology
- Re-mining soil and waste
- Upstream segregation of scrap- segregate into precious components and wasteful impurities
- Slag metal prospecting
- Co-hosting waste processing for value of metal and fuel content
- Foaming slag for fireproof insulation (TRL 5-6)
- Nano markers imbedded into steel products – in steel forever
- Who wants the material – redesign of supply chain
    - Melting
    - Purification
    - Recycling
- Tracking steel through production and lifetime
- Competition for coproducts
- All digital - record traceability
- Remanufacture and reuse of product component parts
    - Rent and lease known grade steel
    - Develop thermomechanical treatment to send to other applications

Other

- More waste sharing and symbiosis between industries
- Slag practices in steelmaking for extraction of valuable elements

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GCRA1 Carbon Neutral Iron and Steelmaking –

Materials Resources and Energy

Disruptive Technologies

- Electrolytic
- Electrolytic production of iron follow on from ULCOS
- Alternative, non-carbon chemical reduction of iron ore
- Electric Steelmaking, Electrolysis Hydrometallurgy
- Novel ironmaking technology ? (Pyro/vapour/ molten salt metallurgy)

Virtual

- Intelligent sensors/sensing AI
- Qualification of process or production uncertainty (by simulation – virtual uncertainty modelling)
- 5G communications
- Digital twin
- Internet of Things – to share information between processes

Biomass & Alternative to C

- Biomass based steelmaking (or into BF)
- Small scale domestic H_2 generation from PV
- Use of (non-food) biomass/wastes
- Use gas from stoves
- Use char from ironmaking
- Plastics as carbon source / energy in blast furnace or supplementary energy in EAF

Pre-reduction transition

- Flash reduction microwave pre-production
- Pre reduction in pellet or sinter making; plasma pre-reduction.

CCUS

- CCU/S steel plants
- HISarna with CCUS
- Top gas recycling / O_2 injection into Blast furnace
- New equipment for low CO_2 steelmaking will be financed by supplier in return for share in financial returns (assumes some financial incentive will exist)
- Carbon recycling materials
- Carbon looping (short loop) BF CO_2 into BF feedstock
- Develop a concept zero C steel plant with zero waste
- Ensure +/-100% CO_2 emissions in our own flue gas (also BF)
- Storage needs research

Made to purpose

- How to deal with a wider variety of production techniques with a wide difference in cost
- Generating one unique set of process data
- Incentives to design for reduced use, but increased value
- Melt process purification – maintaining highest utility
- Customised production line
- Powder metallurgy / additive manufacturing
- Powder metallurgy and NNAM (near nett additive manufacture)
- Hot isostatic pressing of steel powder
- Near net shape casting
- Combining additive manufacture with primary production
- More flexible casting processes to facilitate near net shape casting for a range of products
- Is there a (high volume) market for AM steels?

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Materials Resources and Energy

Energy / Gas

Thermal Management

- Direct hot charging
- Electrical heating of slabs and blooms to rolling temperature (or at least some preheat before conventional reheating)
- Energy efficiency in transient operation of metal heating processes
- How much use do we make of our (warm) water?
- Reduce cost of reheating in process by retaining heat
- Aligned processing to minimise heat losses
- Smart energy micro grids
- Local clusters to reduce waste heat transfer costs
- Energy exchange between industry and consumers
- Steel plants become part of local energy hubs, e.g direct heating and power
- Maintaining production when there are more renewables used for power generation
- If electricity was free + low C how would we make steel
- Optimum material processing temperatures currently in use?
- Pyrolysis of natural gas into H_2 + solid C use this to feed HISarna
- If traditional BF still exist ~_> segregation / upgrading BF gas to usable H_2 + CO_2 streams
- SEWGS – sorption enhanced water gas shift for lower energy CO_2 + H_2 production from BF gas.
- Standard processes for use and capture – needs a business model/or substantial change in taxation
- No-one is looking at the path to transition – SUSTAIN remit?

Heating Methods / Transfer

- Induction heating of steel (from green electricity)
- Heat recovery using solid state thermal collectors
- Tailored heating strategy for hot rolling
- Heat storage using solar store tech
- Selective microwave heating to reduce energy requirement for ironmaking
- Induction/electric heating of reheat furnace

Heat Conversion

- High efficiency PV (>50%)
- Recycle lubricant as fuel
- Why not make dry ice out of CO_2 – ship as refrigerant
- Low level heat recovery (Organic Rankine cycle / IR photovoltaic)
- What happens if you inject H_2 into a BF to replace some of the carbon:
    - Metallurgy
    - Off gases
    - Carbon reduction

Low Demand Process

- Smaller scale processes (mini-mill) for local production – easy access to energy sources)
- Battery technology to enable EAF furnaces -> mini VAR furnaces powered by renewable electricity to offer bespoke steel based upon application
- H_2 as a fuel
- Zero coal steel
- H_2 fuelled metal heating processes
- H_2 use in reheat furnaces
- Renewable H_2 fed DRI as part of broader H_2 economy
- Distributed H_2 generation, plants from domestic suppliers of electricity

New technologies for bulk H_2 -> reduction of ore.

Hot/molten DRI (H_2 based)-> utilise BOS (instead/ as well as EAF)

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GCRA1 Carbon Neutral Iron and Steelmaking –

Materials Resources and Energy

Materials & Other

Material Management

- Quality assured steel scrap largely free from contaminates this will disrupt scrap supply chain by 1. Reusing existing data on products
- Disassembly sorting pre-treatment and segregation of products using robotics /sensor
- Using robotic systems to recognise marked materials – what sensors and markers?

Coatings

- Alternatives to zinc and tin coating that don't affect recyclability
- Removing zinc and tin coatings from recycled steel
- Identifying zinc coated steels to recycle separately and capture and recover Zn – targeted high Zn melts

New Processes

- Purification, separation technologies
- Designing a process that can use low grade feed-stocks
- Surface engineering (simple) recyclable steels can be used in more applications
- Remove Cu from liquid steel

Functional Steels

- Production of high Si electrical steels

Training / Skills

- Training (success will only be as good as its knowledge share e.g. outreach and implementation) – linked to marketing and communication
- Generate outputs which can be used as tools in industry

Socioeconomic

- Ethical steel value chain
- Linked to economics (reporting milestones re Gov funding for SUSTAIN) Optimum business solution
- Optimum sustainable solution
- Sustainable construction model materials /m£ - cost vs emissions/ LCA software for environmental impact of building
- Engagement positive messages
- Educating next generation of steel engineers and scientists to be zero C by default
- Loss of expertise and personnel
- Policy, economics and training – need dissemination
- Influence politicians on carbon emissions

Government Policy

- Renew the ETS credit scheme (Emissions trading scheme).
- Reverse current policy on grade diversification due to recycling difficulty – more standardisation to promote easy recycling
- Legal framework to enable waste reclassification as raw material

Business / Technical

How to move from a high carbon process to low carbon process as economically as possible.

Cost model based upon value in use to recompense need for smarter steel at lower volumes:

- Policy report
- Interactive Model
- Including factors to facilitate leasing model

GCRA1 Carbon Neutral Iron and Steelmaking: Scope for Proof of Concept Funding Call

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GCRA 1

Disruptive Technology

- Alternative Chemical Iron Reduction (non C based / CO_2 emission
- Electrolytic refining
- Hydrometallurgy
- Novel Alloy Separation
- Nano Markers for Product Tracking

Energy

- Thermal Management
- Heat Conversion and Recovery
- Reduced Energy Demand
- Hydrogen Use & Generation
- Alternative Carbon (including waste) & Non-Carbon Combustion

Materials

- Scrap Supply Chain Distribution
- Removal and Recycling of Coatings and Alloying Elements
- Automated Material Identification (input/Output)
- Co-Hosting Specialist Materials Processing Plants on Site
- Novel Reuse of Slags, Scales, Dusts and Other By-Products
- Processing Dusts, Oils and Scale for Re-Use

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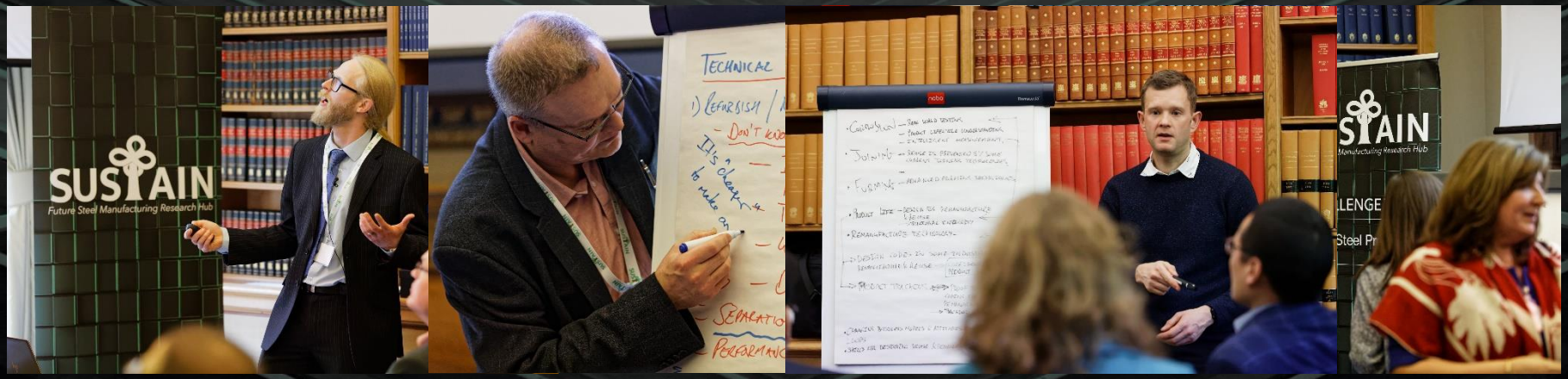
Grand Challenge Workshop Session Output:

GCRA2 Smart Steel Processing -
a.) Retaining the Embedded Value of Steel
b.) Steel as a Service
Flip Chart and Scope for Call



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Grand Challenge Workshop Session Output:

GCRA2 Smart Steel Processing –

Decoupling the Material Value Carbon Nexus: Retaining the Embedded Value of Steel

Technical challenges to enabling the circular economy loops:

- Unpredictability of waste products
- Raw materials – QA
- Societal change
- Higher quality products; not designed to fail
- in-line/ rapid feedback are we measuring the properties of the materials as we are making them (challenge)
- Industrial expertise (challenge)
- Corrosion – testing, life cycle prediction and monitoring. how do you measure how corroded something is in service? Solution would be in-situ corrosion monitoring
- Joining – (barrier) reuse is prevented by some current joining technologies (remanufacture – reuse of welded material and then how do we reform it)
- Forming – advanced forming technologies: barrier – linked to the joining approach - high yield forming and reforming material – how do you remanufacture.
- Product life – design for remanufacture or reuse - what would the structural integrity assessment be? Approach: the use of data, modelling, collecting data to make models.
- Remanufacturing technology
- Design codes in safety critical applications prevent remanufacturing use – what's the confidence in material product life (barrier)? (nuclear power stations are now operating beyond their life span because they know more about the materials involved)
- Product tracking – proof that once it's coming for reuse or remanufacture – how do we know?
- Changing business models and attitudes to allow the tighter loops
- Skills required for reuse and remanufacture
- Tagging / Tracking
- Refurbish and remanufacture we ned to know the integrity of the new product (virgin product as its made first time)
- Trust in the product through its life
- Warranty – standards, are they meeting standards?
- If it doesn't meet standards its going to have to downgrade (separation of material in complex structures, e.g. construction)
- Provenance – what's the performance in use and what's the history of the material?
- AS IS - Can we reuse anything now? Could we characterise that existing material?
- Barriers in terms of what's available to us – untracked material, how do you achieve that?
- Throwing culture assembly vs maintenance
- If you replace rather than repair you get less downtime
- Creating more links – accountability
- Responsibility for leased product (insurance etc.)
- Managing profitability when producing / selling less material should the steel companies be the gate keeper of materials? Should the material processor control the asset life?
- Considering end of life at manufacturing stage

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Grand Challenge Workshop Session Output:

GCRA2 Smart Steel Processing –

Decoupling the Material Value Carbon Nexus: Retaining the Embedded Value of Steel

Overcoming the Challenges:

- Changing consumer attitude (societal)
- More modelling and sensors for in line fast measurement (continuous measurement)
- Scrap (raw materials) – segregation of scrap (disassembly), can we valorise slag and other ‘wastes’ / by-products

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Grand Challenge Workshop Session Output:
GCRA2 Smart Steel Processing –
Steel as a Service

Steel as a Service

- Worried about balancing sheets and what can be counted as assets – economic
- Moving from linear to circular **(Opportunity, barriers what are the economics)**
- Retaining value – looking at reusing of parts and how can it retain value as its used (safety and structural implications) - barrier is safety of use.
- Moving away from single point of sale
    - Problem – transfer of responsibility
    - Opportunity - overcoming the barrier- transfer of responsibility to supply chain
- Where can they make more money – what's the value in use? Steel company can lease material into a market and monitor the material when the end user has it whereas now they don't have that guarantee through the links – short circuiting and whole life cycle
- Profit opportunities (how do you make the money), barrier is how do you monitor the material in use)
- Steel designed to last – entire life cycle is planned out before its manufactured
- Shift success from volume to value
- Success is linked to volume currently but we want it to be moving towards value (servicing, maintenance e.g. Rolls Royce lease all their engines)
- Buying from whole complex supply chain or disrupt the supply chain – which one is going to deliver success?
- Designing product for disassembly – end users or metallurgy?
- Opportunity barrier is the technicality and policy
- Critical applications – is it safe to use when have experienced problems previously
- Do steel companies need to move down the supply chain? Steel needs to be involved further down the line – helping manage material usage with customers
- Opportunity to move down the supply chain, barrier is do you get buy in or disrupt complex supply chain)

	Steel as a Service	
	Opportunities	Barriers
1.	Linear to circular	Economics
2.	Retaining value over lifecycle	Safety of use
3.	Move away from single point of sale	Transfer of responsibility to supply chain
4.	Profit opportunities	Monitoring the material in use
5.	Steel designed to last	Shift success from volume to value
6.	Steel companies to move down the supply chain	Buy-in or disrupt complex supply chain
7.	Design for disassembly	Technical and policy

GCRA2 Smart Steel Processing:
Scope for Proof of Concept Funding Call

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Societal Change and Education

- Skills training and changing opinions on Steel industry
- Education around material re-use and remanufacture
- Linear to circular education on benefits
- Expertise on recycled and repurposed material
- Informing the public around the need for materials such as steel, and the steps being taken to improve the manufacturing and EOL processes
- A greater push to fixing products rather than buying new – explaining the benefits

Alter Business Models

- Transfer of material responsibility to supply chain
- New skills training for re-use and remanufacture
- Sell value rather than volume
- With lower sales, offer service contracts and leasing options to maintain profitability
- Steel companies move down supply chain
- How could this be built in to balance sheets?

GCRA 2

Life Cycle Analysis

- Design for disassembly at EOL
- Consider entire lifecycle during design phase
- Consider change in application rather than wait until failure
- Safety critical applications – confidence levels in material properties and how to build 'trust' in recycled material
- How to 'grade' recycled material
- Joining methods
  Forming methods
  Design codes and guidelines
  Recyclability mark required by legislation

Product Tracking

- Need knowledge of product composition, lifetime traceability and QA
- Monitoring of product in service, such as corrosion development etc.
- Use sensors, data and modelling to predict lifetimes and potential issues in service
- How to successfully tag and track material's use
- How is an un-tagged material dealt with?

SUSTAIN Next Steps

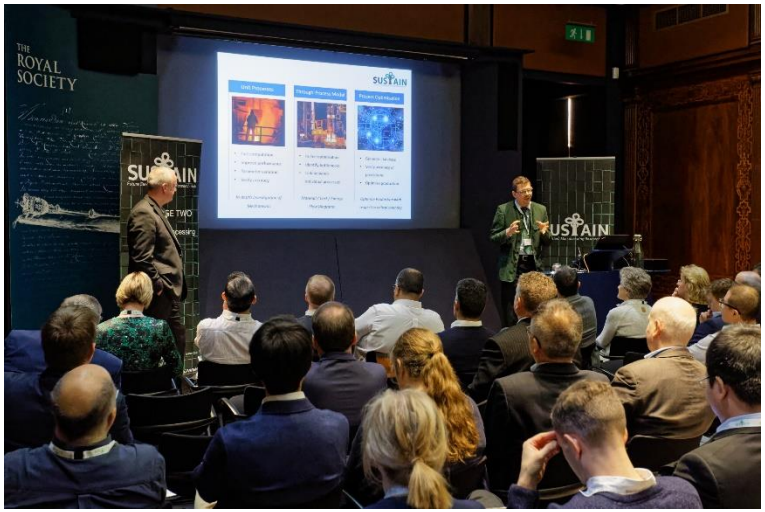
Future Steel Manufacturing Research Hub

1. SAND PIT: date TBC

A follow-up session will be arranged in the near future to facilitate the formation of inter-institutional and inter-disciplinary project teams and development of outline proposals.

2. PROPOSAL CALL: Summer 2020

A call for will be published on EPSRC / Swansea / SUSTAIN websites inviting proposals from new partners within the scope defined during the Engagement Event & Sandpit Session.



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Thank you to everyone who contributed to the engagement event and the ideas present in this document.

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