



NATIONAL SLAG ASSOCIATION

SINCE 1918

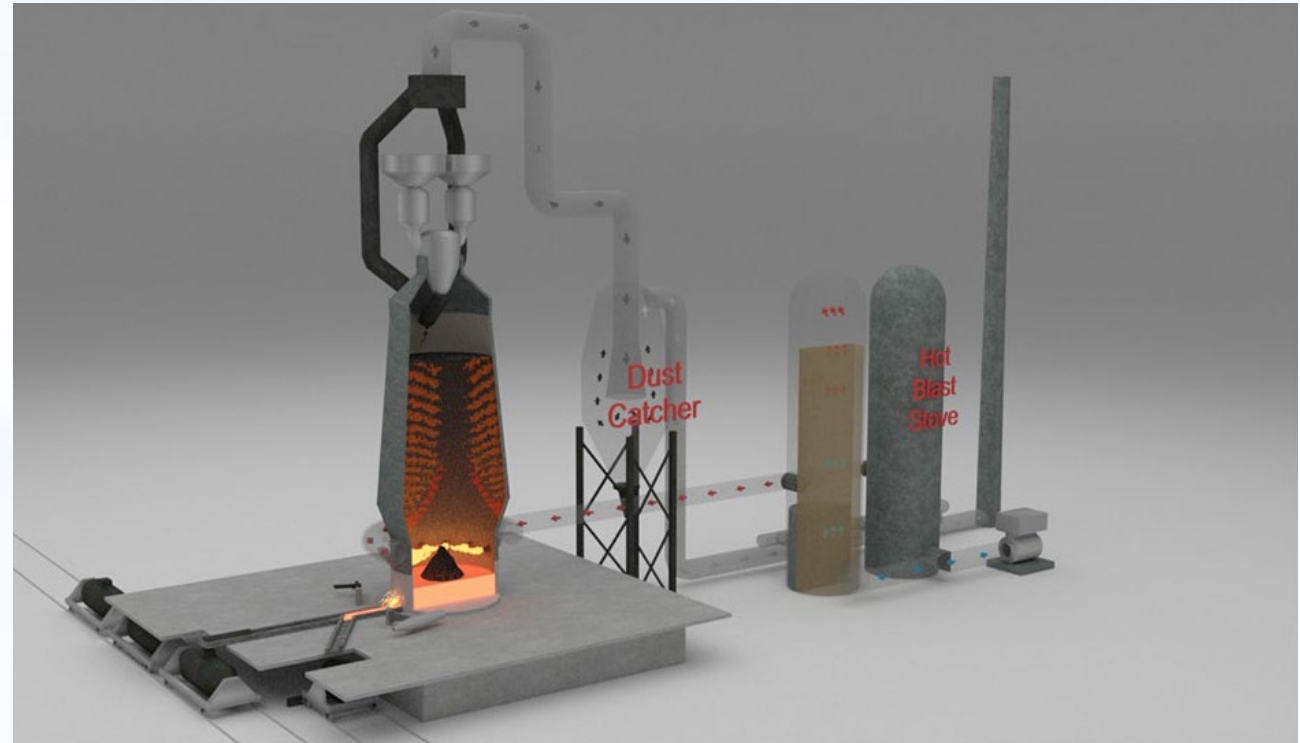
A Review on the Current State of the Iron and Steel Slag Industry

Charles Ochola PhD., P.E., M.ASCE
President, National Slag Association



Blast Furnace Slag Production

- Iron produced from a blast furnace also has as a co-product blast furnace slag.
 - Feed materials include:
 - Iron ore
 - Coal/Coke
 - Lime/Limestone
 - Products Include:
 - Pig iron
 - **Blast furnace slag**



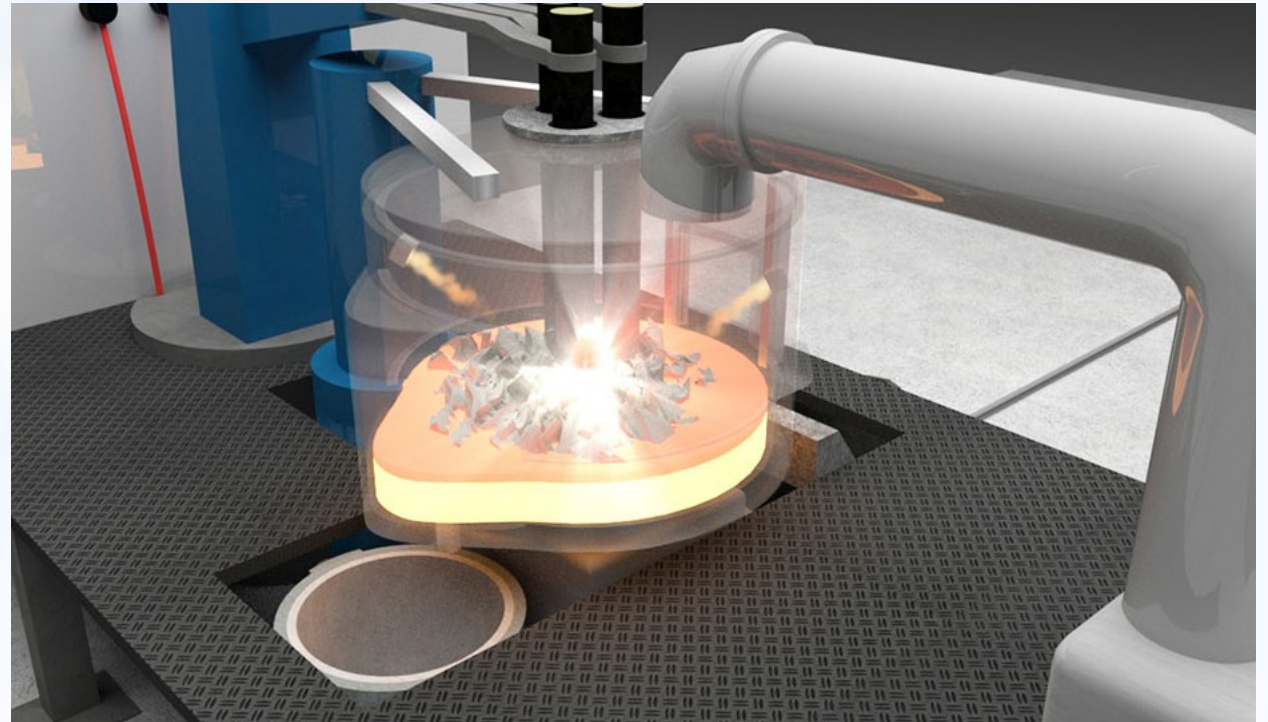
Steel Furnace Slag Production (BOF)

- Steel produced from a basic oxygen furnace (BOF) has as a co-product steel furnace slag.
 - Feed materials include:
 - Recycled scrap
 - Direct Reduced Iron
 - Molten pig iron
 - Lime/Limestone
 - Products Include:
 - Steel
 - **Steel slag**



Steel Furnace Slag Production (EAF)

- Steel produced from an electric arc furnace (EAF) also has as a co-product steel furnace slag.
 - Feed materials include:
 - Recycled scrap
 - Direct Reduced Iron
 - Pig iron
 - Lime/Limestone
 - Products Include:
 - Steel
 - **Steel slag**

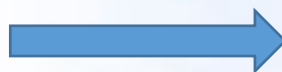




Processing



Transportation



Pot Dumping into
Cooling Pits

Cooled Product Processed in
an Aggregate Plant



Applications

- The history of slag use in road building dates back to the time of the Roman Empire, some 2000 years ago



Applications

- 1589 slag used for canon balls in Germany



Applications

- Today the use of slag as aggregates in bound and unbound mixtures particularly in road construction applications is today well established such that iron and steel slags not only rival similar natural aggregate but in some instance are considered superior materials based on specific properties.



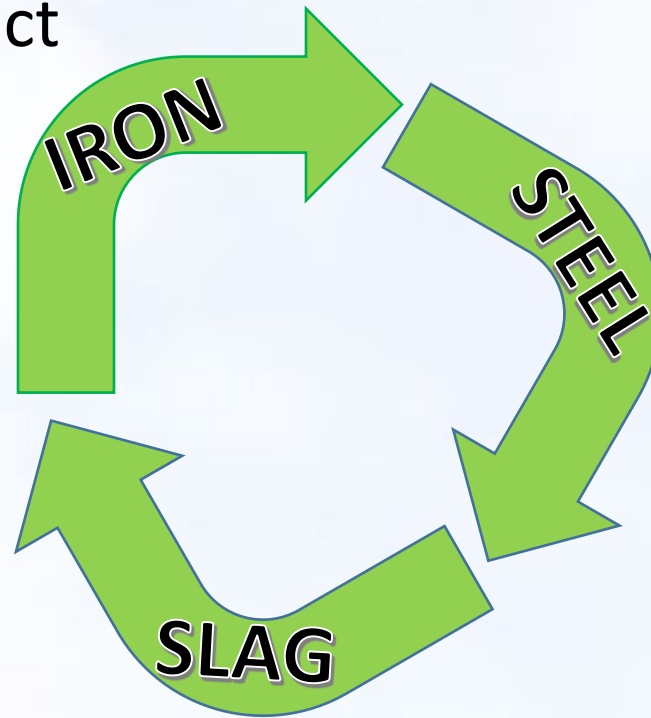
Applications

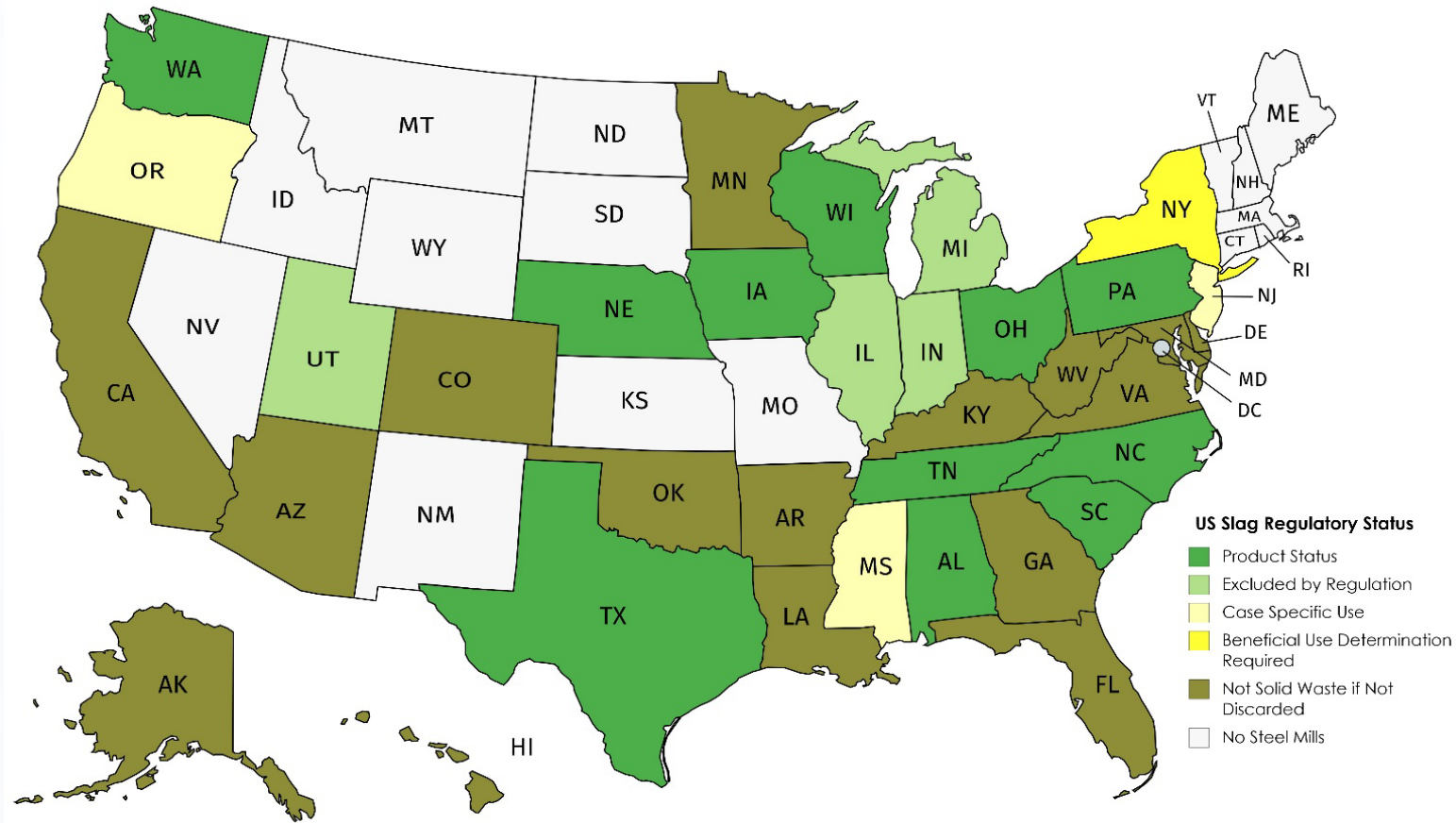
- Other uses include the production of cement, concrete, rock wool, fertilizers/soil amendments etc. and it appears that the only limitation is imagination.



Applications

- Additionally the recognition of slag as a sustainable alternative to natural materials makes it an ecologically sound and economically intelligent use of this product





Slag Regulatory Status



STATE	SLAG STATUS	DATE STATUS ADOPTED
Alabama (AL)	Product	April 2, 2010
Nebraska (NE)	Product	2013
Iowa (IA)	Product	2014
North Carolina	Product	2015
South Carolina (SC)	Product	2015
Tennessee(TN)	Product	2015
Texas	Product	2015
Washington (WA)	Product	2016
Ohio (OH)	Product	2017
Pennsylvania (PA)	Product	2018
Wisconsin (WI)	Product	2018
New York (NY)	Product Use dependent on EPD	In progress 2022
New Jersey (NJ)	Product Use dependent on EPD	In progress 2022

How was this (product status) achieved:

Recap

- In 1998, the Steel Slag Coalition (SSC), a group of 63 companies that produce steel, process slag, or both, undertook a comprehensive study to evaluate the chemical composition of three types of steel slag and the potential human health and ecological risks associated with possible exposure to such slag.
- Risk assessments developed as part of this research project demonstrated that these **“slags pose no meaningful threat to human health or the environment when used in a variety of residential, agricultural, industrial, and construction applications.”**
- The Human Health Risk Assessment has been one of the most effective tools in our arsenal with regards to allowing the utilization of slag and its recognition as a product.

How was this (product status) achieved:

Recap

- In 2008 and 2009 regulatory developments and increased scrutiny particularly on the airborne fractions of slag with greater relevance for human exposure prompted the industry to initiate a characterization project on these fine slag particle size fractions.
- The results from this slag characterization study were used to develop updated risk assessments for the three types of steel slag. These updated risk assessments were completed in 2011 and utilized the most current risk assessment guidance, including new exposure models and chemical toxicity information. The conclusions from this most analysis were consistent with previous risk assessments, **“commercial and industrial uses of steel slags do not pose a health risk.”**

Challenges

- Just because slag has been declared a product does not change existing perceptions
- Numerous articles exist that consider iron and steel slag as an industrial waste product and even a health hazard
- Regulators are pushing back and placing obstacles impeding the use of iron and steel slag (Indiana, Iowa, and Colorado are states that come to mind)

Challenges - Indiana

- The state of Indiana has requested that Industry provide an explanation for how leachate occurs during the utilization of blast furnace slag in road construction applications.



Challenges - Indiana

- INDOT is specifically requesting that Industry devise a test to predict when leachate is most likely to occur and how to mitigate its occurrence since current methods do not appear to be effective.
- The burden has been placed on Industry since INDOT's efforts to provide an explanation for unwanted leachate occurrence were strongly criticized.
- Reports prepared by Purdue University were flawed and riddled with inaccuracies.

Challenges - Iowa


- In 2019 a public concern was raised over the use of slag on unpaved roads
- Shotgun approach
 - Nuisance dust
 - Vehicle damage
 - Livestock exposure
 - Exposure to adults
 - Exposure to children (pica)
- Faulty science used by public group to support outright ban of slag used on roads
- Temporary moratorium on use of slag until further study completed

Challenges - Colorado

Background

- Superfund Site
- EPA Remediating (Lead & Arsenic were Chemicals of Concern)
- EPA Tested EAF Slag Beneficially Used Onsite
- EPA Questioned Replacing Slag on Superfund Site

Challenges - Colorado

- In 2020 EPA collected 21 in-situ samples for analyses
 - EPA conducted screening-level risk assessment for ingestible and bulk fractions on Contaminants of Potential Concern (COPC) that exceed residential soil Regional Screening Levels (RSL)
 - Using ultra-conservative defaults in the screening level risk assessment, EPA determined As, Cr(VI), and Mn were considered COPC with Mn being the primary driver
 - EPA questioned whether was slag an appropriate material for xeriscaping and driveways?
 - EPA concluded that they cannot rule out the possibility of unacceptable risk
- 

Challenges – Colorado

- Region 8 stated that HHRA may underestimate some COC
- Slag erosion due to compressive forces not considered in HHRA
- Respirable manganese in eroded slag may be higher than original respirable slag
- Trivalent chromium may oxidize to hexavalent chromium in the environment
- Emission factors used may not be representative of Pueblo, CO.
- Bioaccessibility used for manganese is only approved for lead and arsenic

Challenges - ASTSWMO

- In April 2021 at a Meeting of the Association of State and Territorial Solid Waste Management Officials (ASTSWMO) there was a discussion on the Colorado EAF slag investigation
- The group met with EPA HQ and raised concerns that EAF slag can exceed soil screening levels for manganese and hexavalent chromium
- The group has been in discussion with 19 states where EAF slag is marketed for landscaping and ground cover material



Challenges - NASEM

- Towards the end of 2021 there was an announcement that the USEPA had contracted the National Academy of Science Engineering and Math (NASEM) to evaluate human health risks from unencapsulated uses of EAF slag.
- A panel of “experts” has been assembled to assess the following:
 - Chemical & physical properties of slag
 - Beneficial uses of slag, emphasis on residential
 - Effects of weathering and wear on exposure to toxic components
 - Bioavailability of toxic components
 - Potential exposure levels and adverse health risks

Challenges – NASEM (Activities)

- Meeting # 1 Closed Session held on 2/3/2022 discussed the following:
 - National Academies study process
 - Committee's statement of task
 - Provisional members' background and potential conflicts of interest
 - Committee composition and comments from the public
 - Next steps in the project


Challenges – NASEM (Activities)

- Meeting # 2 Closed Session portion held on 2/7/2022 discussed the following:
 - Discussion of a provisional member's background and sources of conflicts of interest
 - Committee composition
 - Upcoming presentation from EPA representatives
- Meeting # 2 Open Session was a webinar presented by the USEPA delineating why there was a need for NASEM involvement

Challenges – NASEM (Activities)

- Meeting # 3 Closed Session held on 3/17/2022 discussed the following:
 - Items in the committee's statement of task
 - Approach to carrying out the task
 - Topics covered during the information-gathering session held on February 7
 - Written comments submitted for the committee's consideration
 - Future inform Project timelines

Challenges – NASEM (Activities)

- Meeting # 4 Open Session held on 6/29/2022 included:
 - Presentations on how EAF steel slag products are manufactured and utilized and about EAF slag risk assessments from representatives of the National Slag Association, Steel Manufacturers Association, and American Iron and Steel Institute.
 - Presentation on the Leaching Environmental Assessment Framework (LEAF) and how it is being used to evaluate EAF slag, through research by EPA's Office of Research and Development working with Vanderbilt University.
 - Meeting # 4 Closed Session included:
 - Review of prior presentations
 - Project Status
- 

Challenges – NASEM (Activities)

- Meeting # 5 Closed Session held on 7/12/2022 discussed the following:
 - Information-gathering session held on June 29.
 - Next steps for the project.

Challenges – NASEM (Activities)

- Meeting # 6 Open Session held on 9/12/2022 discussed the following:
 - PBPK Modeling.
 - Deb Proctor will talk more on this on Wednesday Morning.

Industry Activities

- Prior to any of the challenges posed by the USEPA and other external agencies, the slag industry in 2018 recognized the need to update the 2011 Risk Assessment to conform with changes to EPA guidelines.
- The plan was to incorporate the latest risk assessment tools and parameters , including a careful analysis of slag mineralogy
- The initial scope proposed included a comprehensive chemical characterization of all the iron and steel slag products marketed, geochemical modeling, physiologically based pharmacokinetic (PBPK) modeling for manganese, and mineralogical analysis to enable updates to the human health and ecological risk assessments.

Industry Activities – Initial Scope of Work

TASK	DURATION
1. Comprehensive chemical characterization of all slag types	8 months
2. Develop and Run Leach testing Procedures	6 Months
3. <i>SPLP Leach Tests (30 Samples)</i>	<i>Test Duration is Dependent on Number of Samples.</i>
4. <i>Inhalation Lung Bioaccessibility Tests for Mn (New)</i>	
5. <i>Oral Bioaccessibility Tests (15 samples) (New)</i>	
6. <i>Geochemical Leaching Tests (15 samples) (New)</i>	
7. <i>XRD/XRF Analysis(New)</i>	
8. Update of Human Health Risk Assessment	2 Months
9. PBPK Modeling of Manganese (<i>New</i>)	4 Months
10. Update of Ecological Risk Assessment	7 Months
11. Peer Reviewed Journal Publications	TBD
12. Brief Communication of Risk Assessment	TBD
13. <i>Develop and Run Reactive Transport Models (New)</i>	TBD

Industry Activities – Course Adjustment

- The challenges that have been posed by the USEPA and specifically region 8 has necessitated a focus on addressing the issues that are being raised.
- The concerns raised by ASTSWMO on EAF slag utilization at the beginning of 2021 and subsequent Involvement of NASEM highlighted the urgency to update the risk assessment as soon as possible.
- Given the emphasis on EAF slag, all resources in 2022 were directed towards updating the risk assessment for this product. BF slag risk analysis is on hold for the moment, but we believe many of the findings from the EAF study will translate to the BF study.

Industry Activities – Changes Scope of Work

TASK	STATUS
1. Comprehensive chemical characterization of <u>all slag types</u>	Complete
2. Develop and Run Leach testing Procedures <u>all slag types</u>	Complete
3. <i>SPLP Leach Tests (30 Samples) <u>all slag types</u></i>	<i>Complete</i>
4. Inhalation Lung Bioaccessibility Tests for Mn (New) Assume 100%	
5. Oral Bioaccessibility Tests (15 samples) (New) <u>EAF slag</u>	Complete
6. Geochemical Leaching Tests (15 samples) (New)	
7. XRD/XRF Analysis(New) <u>all slag types</u>	Complete
8. Update of Human Health Risk Assessment <u>EAF slag</u>	In Process
9. PBPK Modeling of Manganese (New) <u>EAF slag</u>	In Process
10. Update of Ecological Risk Assessment	On Hold
Added – Chemical Forensic Analysis for Hexa-Valent Chromium <u>EAF slag</u>	Complete
Added – Bioavailability Testing on Animals (Rats) <u>EAF slag</u>	Complete
11. Peer Reviewed Journal Publications <u>EAF slag</u>	In Process
12. Brief Communication of Risk Assessment <u>EAF slag</u>	In Process
13. Develop and Run Reactive Transport Models (New)	

Strategies for addressing the various challenges

- Aggressively promoting iron and steel slag as products
- Increasing the number of publications that highlight these products
- Internally educating those we work with that slag is a product
- Enhancing quality control of our products to avoid negative perceptions
- Utilizing these products as recommended (There are some applications and locations where they can not function adequately without adverse effects)
- Think outside the box and recommend novel applications for these products (This requires proper investigation/research)
- Obtain an Environmental Product Declaration (EPD)

Promoting a Product

- Manure is defined as organic matter, mostly derived from animal feces that can be spread on land to increase its fertility. Question would it be easy to sell this as a product??



- Fertilizer is defined as a chemical or natural substance added to soil or land to increase its fertility



Benefits of an EPD

- In today's market, manufacturers can **no longer** make unsubstantiated "green" claims. Increasingly, specifiers and purchasers expect **credibility** and **transparency**.
- The Product Category Rules (PCRs), Product Life Cycle Assessment (LCAs) and verifications by an outside expert required with an EPD provide the **trust and transparency** being sought by procurement professionals.
- Bottom line is that **credibility and transparency** are crucial for our brand reputation, especially now customers are becoming increasingly savvy to unsubstantiated 'green' claims. By creating environmental product declarations (EPD) for our products, we can comply with the accepted industry standards and communicate objectively about our environmental performance.

EPD Related Legislation

Year introduced	Source	Bill
2017	California Legislature	<u>Buy Clean California Act</u>
2019	Minnesota Legislature	<u>HF 2203/ 2204</u>
2020	New York State Senate	<u>S542</u> (Original)
2021	California Legislature	<u>AB-1365</u> , <u>SB-778</u>
2021	Colorado State Assembly	<u>HB 21-1303</u>
2021	Oregon State Legislature	<u>HB 2688</u>
2021	New Jersey Assembly	<u>AB 5223</u>
2021	Washington State Legislature	<u>HB 1103</u>
2021	House of Representatives, 117th Congress	H.R.1512 <u>CLEAN Future Act</u> – Subtitle C – Federal Buy Clean Program

Inflation Reduction Act Signed into law in August 2022 provides \$250 million for Environmental Product Declarations Assistance to support the development and standardization of EPDs for construction materials and \$100 million for Low-Embodied Carbon Labeling for Construction Materials to identify and label low-carbon materials and products for federally funded transportation and building projects.

Conclusion

PROJECT	REASON FOR PROJECT
Risk Assessment (RA)	Needed to update 2011 RA based on regulatory changes (<i>Completion date Sept 2022</i>)
<i>Chromium Study</i>	Required based on slag analysis for Risk Assessment a significant quantity of the samples analyzed are showing hexavalent chromium concentrations that have not been seen in prior risk assessments why? Is this an artifact of the analysis?
<i>Supplemental Risk Assessment Work</i>	Needed to get in front of toxicologist and National Academy of Science Engineering and Math (NASEM) panelists, obtain EPA review and agreement on PBPK modeling
<i>Quality Assurance Project Plan for PBPK</i>	EPA has requested a plan for the study and the model developers need to update the NHP/human transporter model to include age and sex specific physiology
<i>Hardness Study</i>	EPA Region 8 wants proof of slag durability. We consistently say slag is durable but there is insufficient published material to back this claim. Testing will include La Abrasion, Micro Deval, and Mohs Hardness.
Environmental Product Declaration (EPD)	Required to promote slag as a sustainable product (<i>Completion date December 2022</i>)
Blast Furnace Slag Leachate Study	Required by INDOT to understand the causes of BF slag leachate. Since we successfully managed to stop the publication of erroneous studies by Purdue University, IDEM has requested that industry show and present why/how unwanted leachate occurs, and if possible, how to mitigate it. (<i>Completion date not yet established</i>)

Conclusion

- The NAS study on the unencapsulated uses of EAF slag in “Residential Scenarios” has altered the proposed HHRA presented in 2019.
- Currently the focus is on EAF slag even though characterization has been done on other slag products
- Funding requirements have ballooned due to the inclusion of animal studies, hardness testing, modification of the PBPK QAPP, and the forensic analysis of the presence of hexavalent chromium in some samples. We are approaching our budget caps for expert resources and we are only just getting started.
- We need to continuously engage the NAS to ensure there is no scope creep especially given that the EPA has hinted at giving them some latitude on where they should place their focus

Conclusion

- **USEPA has allocated \$921,046,00** to funding the NASEM study
- The National Slag Association (NSA) is working closely with the Steel Manufacturers Association (SMA) and the American Iron and Steel Institute (AISI) to continually engage the National Academy of Sciences and USEPA.
- There is a need for collaborative R&D to find additional markets and uses for slag products and this will require monetary resources.
- The NSA has engaged the Association for Iron and Steel Technology (AISTech) towards this endeavor.
- Its time to get more proactive and not remain reactive, its not going to get easier.