CalEPA
Meeting #4 of the California Lithium-Ion Car Battery Recycling Advisory Group

ReCell ADVANCED BATTERY RECYCLING

THE ReCell CENTER

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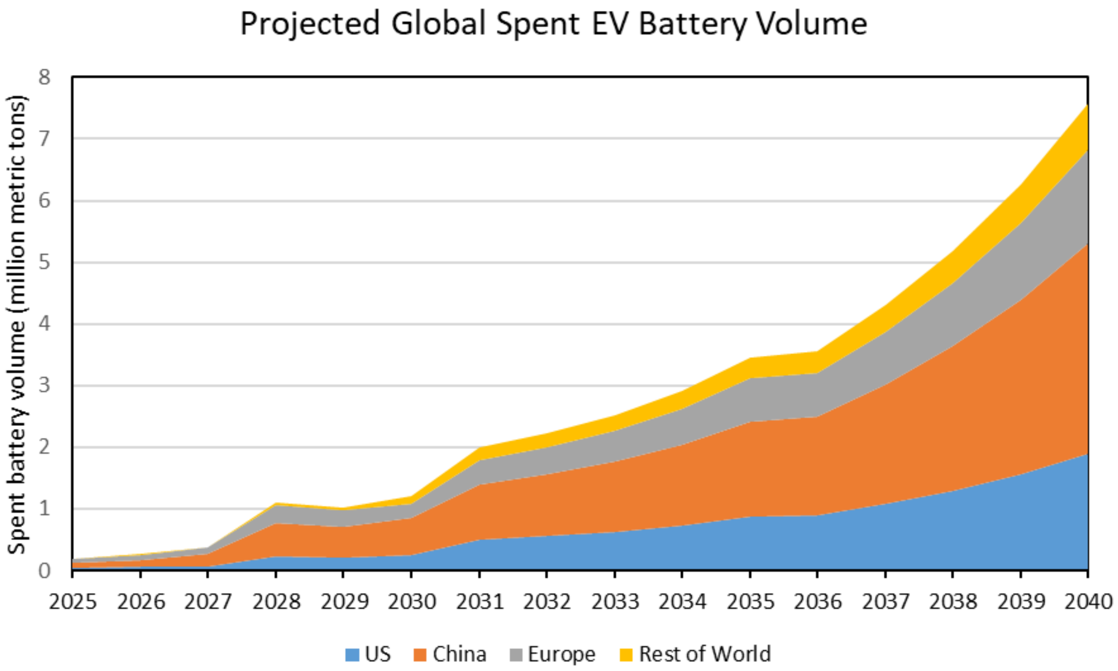
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy
VEHICLE TECHNOLOGIES OFFICE

SETTING THE STAGE

- An increase of lithium-ion batteries coming in electric vehicles (EV)
  - Consumer electronics collection is an issue
  - Stationary applications can be in remote locations
- Cannot meet EV material demand without recycling



(ANL projection based on IEA global PEV projection)

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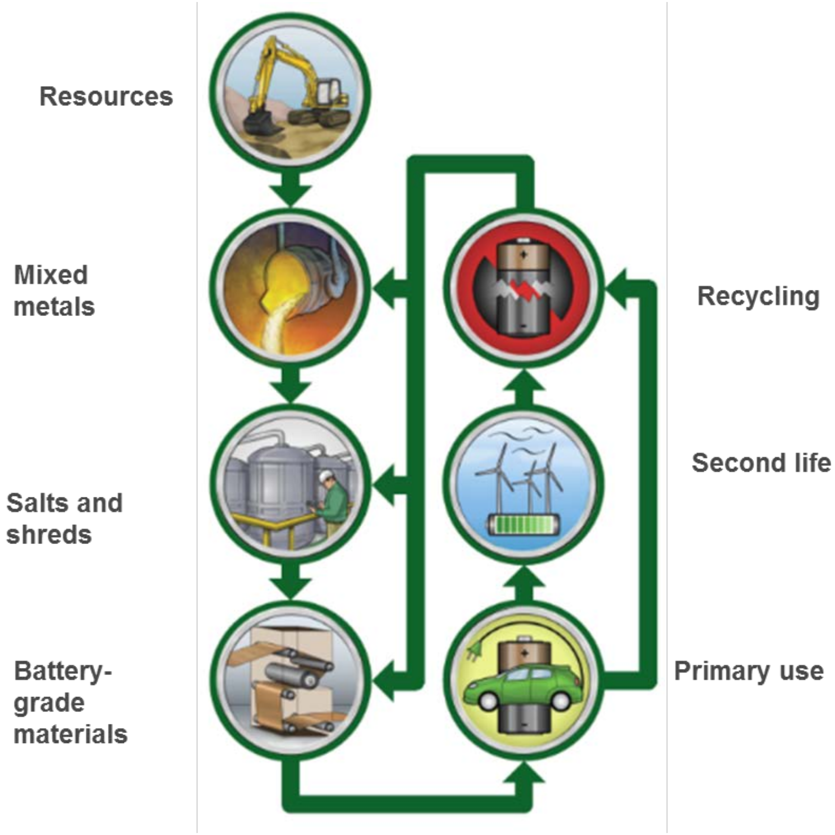
CURRENT PROCESSING

- Recycling lithium-ion batteries is possible today
- These processes are mature
- Produce lower value products and are not revenue positive without tipping fees for many chemistries
- The U.S. is trailing other countries in battery recycling



Courtesy Argonne

THE RECELL CENTER

Purpose

- Foster the development of cost-effective, environmentally sound processes to recycle lithium-ion batteries
- Bring together experts from various battery recycling areas and bridge the gaps
- Efficiently address the many challenges that face a successful advanced battery recycling infrastructure

Outcome

- Minimize use of the earth's limited resources, reduce energy consumption and increase our national security
- Provide stability to the battery supply chain
- Drive battery pack costs down to DOE's $80/kWh usable energy goal in about 10 years (currently $185/kWh)

THE RECELL CENTER'S MISSION

Decrease the cost of recycling lithium-ion batteries to ensure future supply of critical materials and decrease energy usage compared to raw material production

Courtesy Argonne

CENTER RIBBON CUTTING

February 2019

ReCell
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recycling today
Chicago Tribune
The New York Times
FOX 25 NEWS
JAPAN TODAY

National

US Seeks Ways To Recycle Lithium Batteries In Cars, Phones

the japan times
Green Car Congress
Taiwan News
South China Morning Post
The Chronicle Journal

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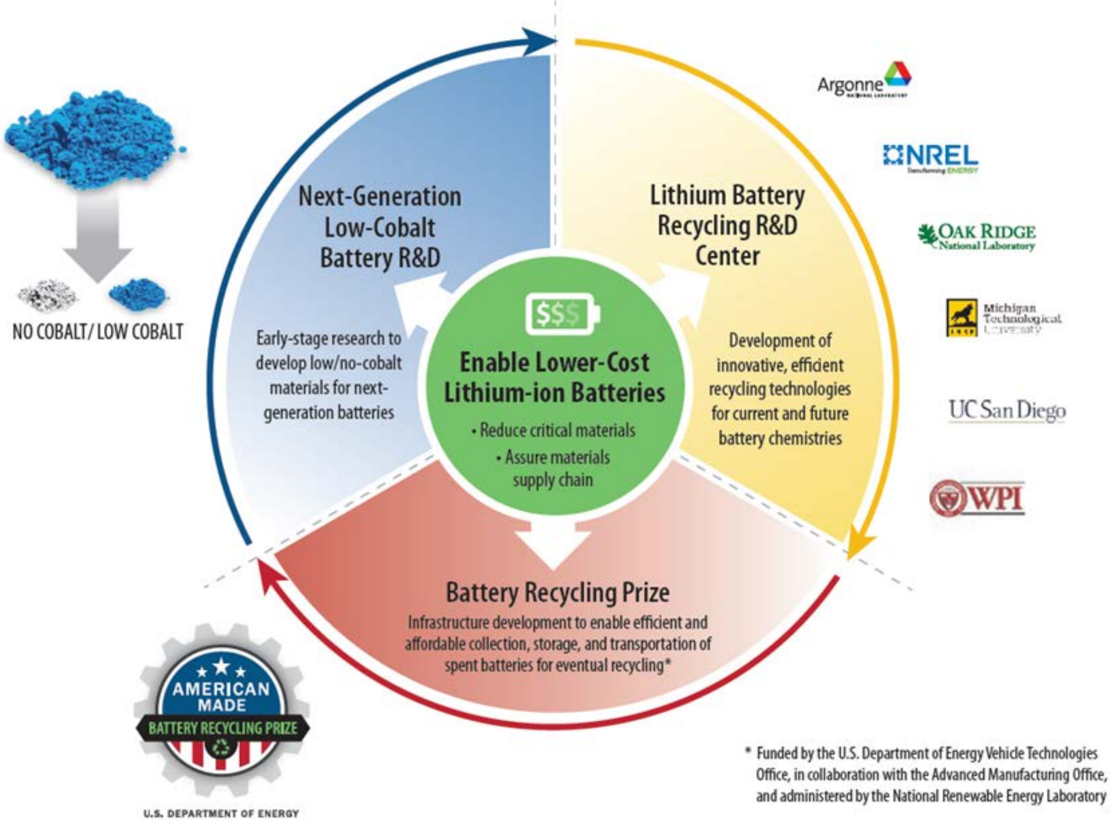
DOE VEHICLE TECHNOLOGIES OFFICE BIGGER PICTURE



Courtesy Vehicle Technologies Office of DOE

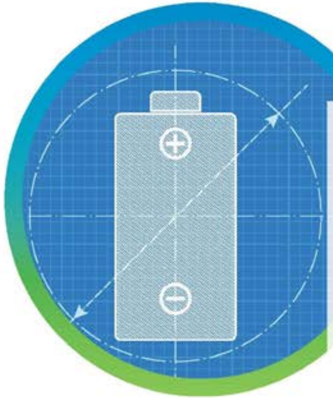
RECELL HAS FOUR FOCUS AREAS

DIRECT CATHODE RECYCLING

- Cathode Separation
- Binder Removal
- Relithiation
- Compositional Change

OTHER MATERIAL RECOVERY

- Electrolyte
- Graphite
- Electrode/Foil



DESIGN FOR RECYCLING

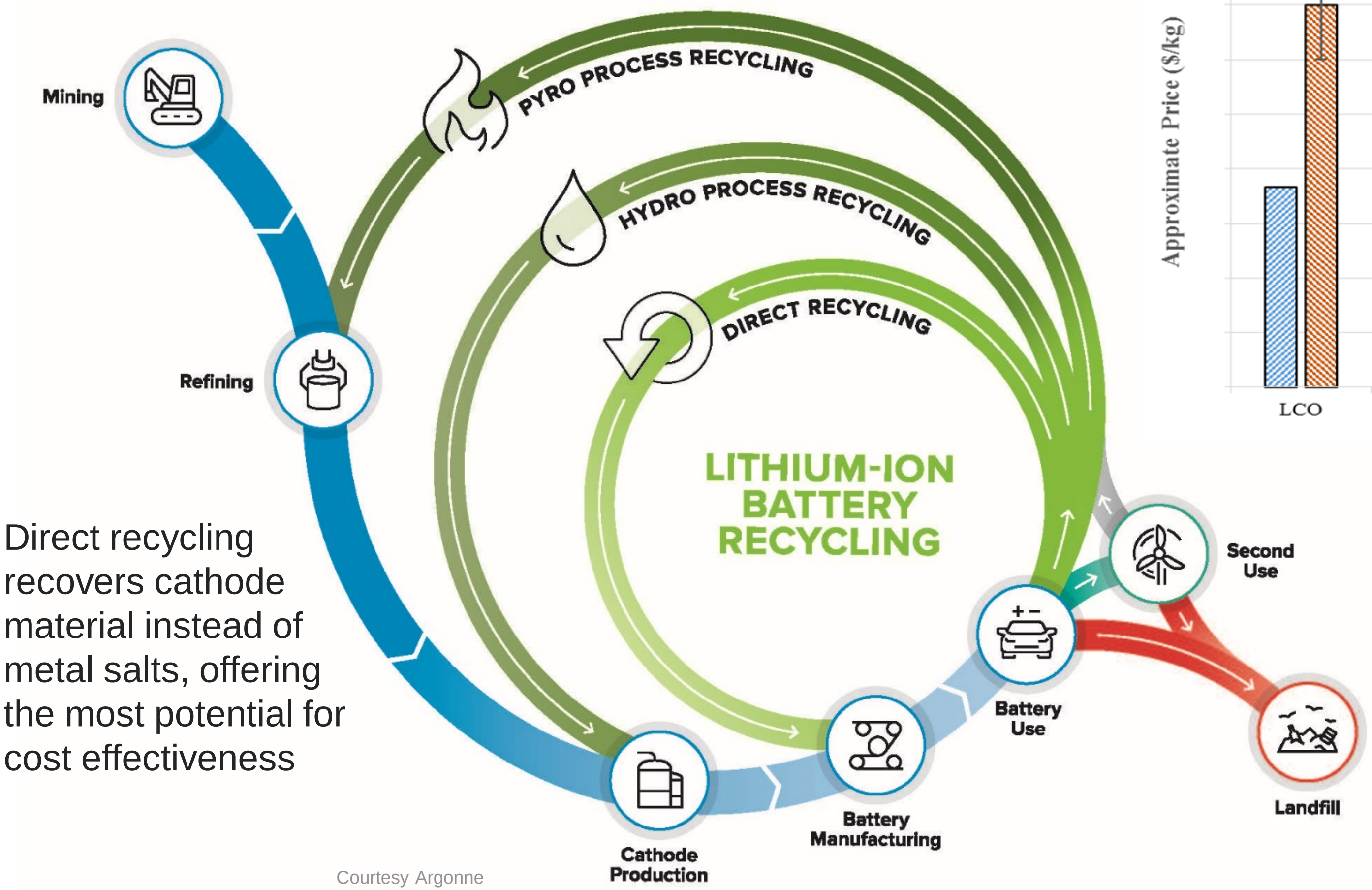
- Cell Design
- Cell Rejuvenation

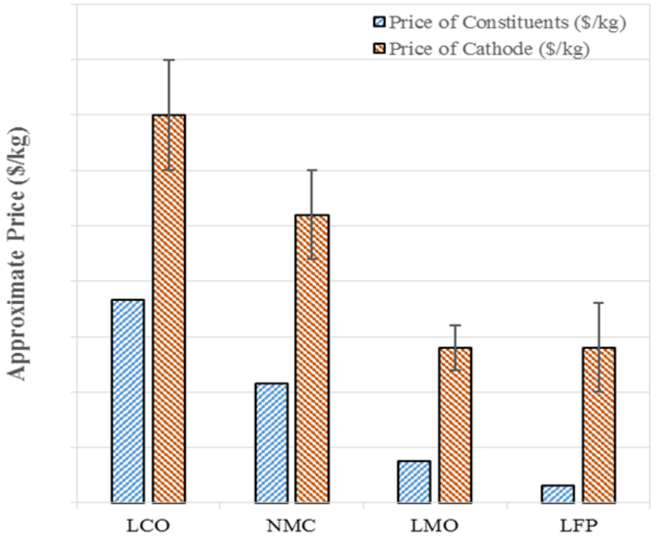
MODELING AND ANALYSIS

- Materials Analysis
- Thermal Analysis
- Supply Chain Analysis
- TEA/LCA Modeling

Courtesy Argonne

DIRECT RECYCLING





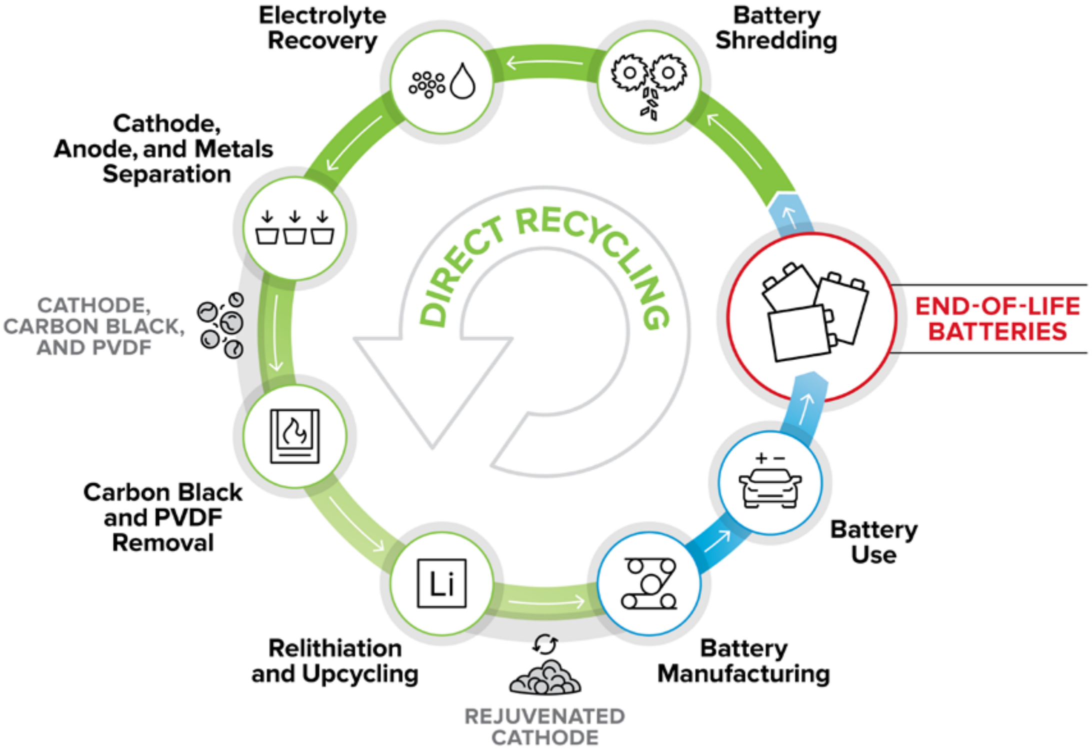
Direct recycling recovers cathode material instead of metal salts, offering the most potential for cost effectiveness

Courtesy Argonne

DIRECT RECYCLING

Typical Direct Recycling Process Flow

- Multiple processes investigated to mitigate risk
- Continual review of new project ideas
- End projects that are not showing promise in cost and performance
- These unit operations can benefit other recycling processes



Courtesy Argonne

MANUFACTURING SCRAP RECYCLING

Manufacturing scrap is an entry point with where we will validate a partial list of unit operations being developed within ReCell

Cathode Powder → Laminate → Cell Assembly → Cell Formation → Cell Testing

Demonstration from this point

Unit Operations

Shredding
Delamination
Binder Removal
Relithiation

Courtesy Argonne

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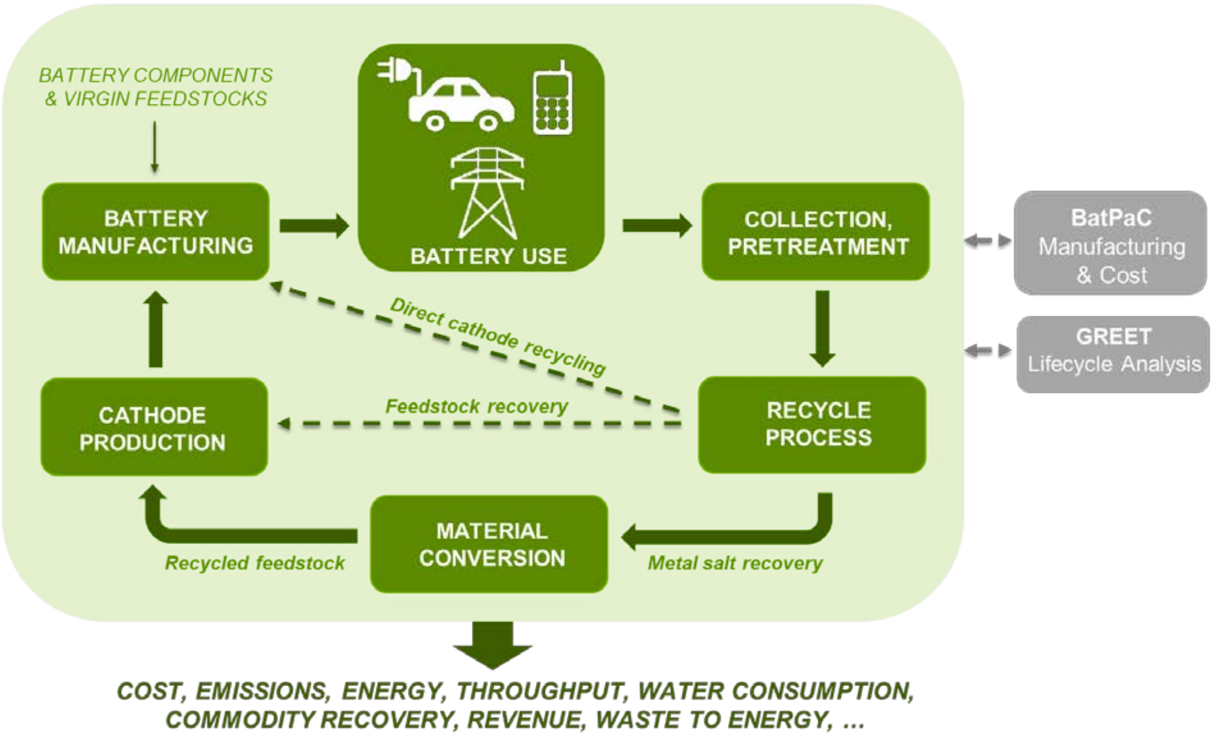
EVERBATT MODEL FLOW

EverBatt breaks down and evaluates each stage of the battery's lifecycle providing the opportunity to compare each stage's impact to the overall impact.



Courtesy Argonne

PARAMETERS

Default inputs are used as a starting point

General

Labor cost

Material cost

Utility costs

Equipment

Plant Life

Battery Production

Throughput

Chemistry

Format

Location

Collection

Distance

Classification

Mode

Recycle

Process

Throughput

Chemistry

Location

Cathode Manufacture

Throughput

Chemistry

Location

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INPUTS

Inputs are entered by number in tan cells and through drop down menus in blue cells

Collection & Transportation (click to link)		
From end use to collection	20	Miles
From collection to recycler	1000	Miles
From manufacturer to recycler	500	Miles
From recycler to cathode producer	500	Miles
From cathode producer to manufacturer	500	Miles
Include shipping manufacturing scrap material to recycler	No	
Include shipping rejected cells to recycler	No	

Go

DEFAULT PARAMETERS

Parameters are overwritten by typing in a new number in the tan “User-defined” cells

1.3 Truck payload (ton)			
	Selected	Default	User-defined
Heavy heavy-duty truck	25	25	
Medium heavy-duty truck	8	8	

1.4 Transportation cost ($/ton-mile)

	Nonhazardous materials			Hazardous materials		
	Selected	Default	User-defined	Selected	Default	User-defined
Rail	$ 0.05	$ 0.05		$ 0.97	$ 0.97	
Heavy heavy-duty truck	$ 0.14	$ 0.14		$ 6.28	$ 6.28	
Medium heavy-duty truck	$ 0.15	$ 0.15		$ 9.40	$ 9.40	
Ocean tanker	$ 0.02	$ 0.02		$ 0.50	$ 0.50	
Barge	$ 0.02	$ 0.02		$ 0.50	$ 0.50	

OUTPUT

Model output is consistent between lifecycle stages

Recycle				
	Pyro	Hydro	Direct	Custom
Cost per kg cell recycled	$	$	$	
Energy use in MJ per kg cell recycled				
Total Energy	15.959	20.987	6.494	
Water use in gallon	5.3	0.5	1.5	
Total Emissions in g per kg cell recycled				
VOC	0.342	0.333	0.098	
CO	1.688	1.439	0.421	
NOx	5.478	2.700	0.789	
PM10	0.248	0.228	0.107	
PM2.5	0.208	0.207	0.076	
SOx	17.297	22.332	0.765	

* Example data is from hypothetical processes and will vary depending on process specifics

Other outputs include:
Energy from fossil fuels, coal, natural gas and petroleum
Total emissions from BC, OC, CH_4, N_2O, CO_2, CO_2 (w/C in VOC &CO), and GHGs

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FACILITIES

Center accomplishments – cont'd

- ReCell Laboratory Space
- Equipment
  - Screener
  - Magnet
  - Froth column
  - Calciners
  - Powders hood
  - Sink/float separation
  - Aspirator
  - CSTR

Courtesy Argonne

Courtesy Argonne

RECELL INDUSTRY COLLABORATION MEETING

November 2019

134 people
from 76 organizations

Provided an opportunity for ReCell and industry stakeholders to exchange challenges and ideas.

The meeting included stakeholders from every corner of the vehicle battery value chain

Courtesy Argonne

COLLABORATION AND ACKNOWLEDGEMENTS

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