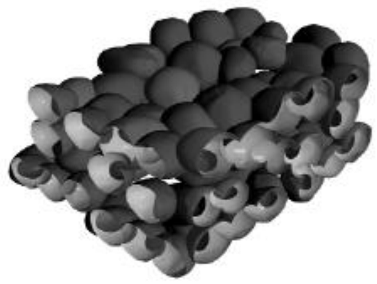
Achieving sustainable energy through cutting-edge carbon

Graphene Mesosponge (GMS), a new carbon material developed by 3DC, will accelerate the evolution of storage batteries.

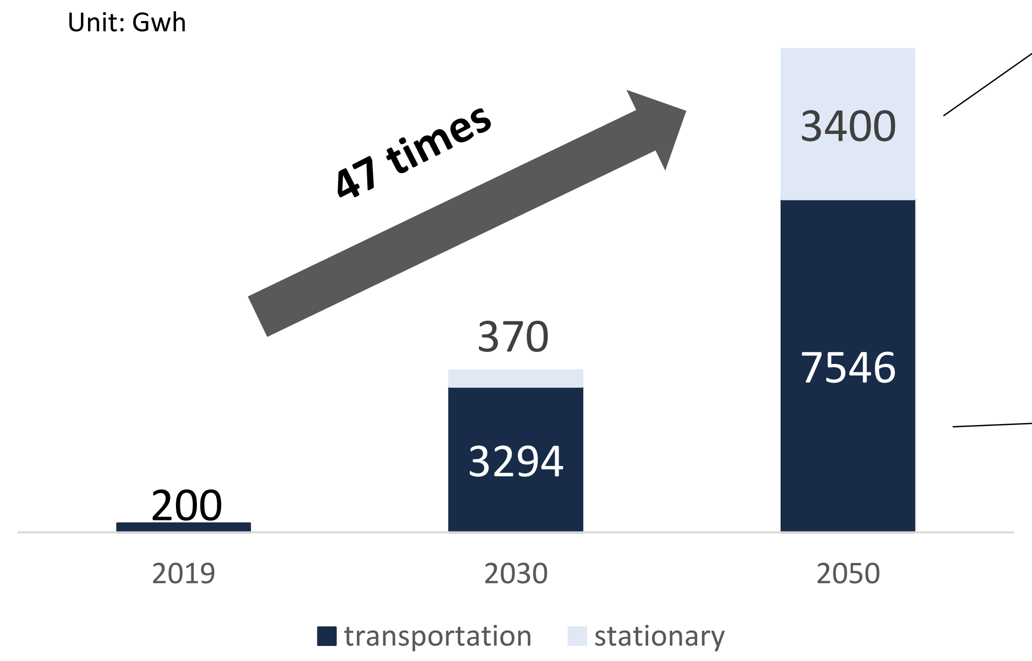
3DC Inc.



Background: Batteries are indispensable for a Decarbonized Society

The battery industry is growing rapidly, driven by the global trend toward decarbonization and the increasing adoption of renewable energy.

Demand for Transportation/Stationary Batteries*.[1]



Stationary Batteries

- Used in conjunction with renewable energy sources to **store and discharge surplus power** or **as an emergency power source in** homes and businesses.
- Renewable energy deployment is accelerating toward decarbonization,with 88% of global electricity generation expected to come from renewables by 2050*.[3]

Transportation Batteries

- Used to power **EVs and PHVs**
- The EV fleet will grow at an average annual rate of nearly 30%, reaching 140 million units by 2030, representing 16% of all vehicles *.[2]

1：IRENA Global Renewables Outlook 2020 (Planned Energy Scenario)
2：Global EV outlook/IEA
3：Net Zero By 2050/IEA

Problem: Increasing environmental damage due to growing demand for batteries

Meeting this demand for batteries requires a large amount of resources, from the manufacturing process to disposal.

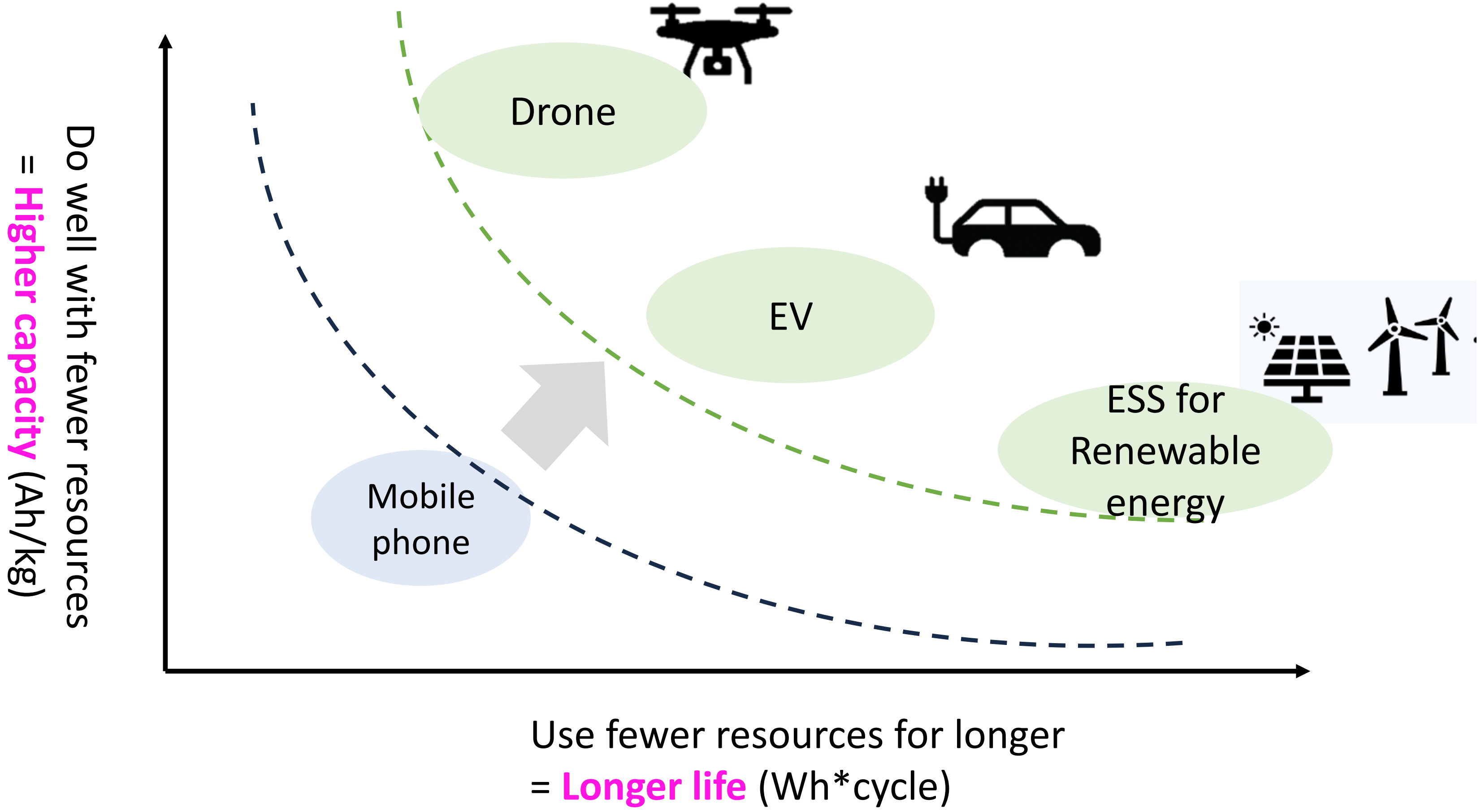
Battery Value Chain and Environmental Damage

Raw material mining	Manufacture	Use	Disposal/Recycling
Massive consumption of minor metals	CO_2 emissions in the manufacturing process	CO_2 emissions/resource consumption associated with maintenance such as replacement of batteries due to degradation	CO_2 emissions from disposal and recycling of storage batteries
a: 58.5 kg	b: 6 t/CO_2	c: a + b x (Service life of on-board applications/average battery life) times	d: 6.6 t/CO_2
Minor metals required to produce lithium-ion batteries (LiB) for one EV	CO_2 emissions in the manufacturing process of LiB for an EV	CO_2 emissions through the LiB lifecycle	CO_2 emissions through the LiB recycle process (for an EV)

Global EV outlook/IEA

Issue: Development of batteries that minimize environmental impact

There is an urgent need to develop **battery technologies for 1) longer service life** to utilize limited resources 2) **high capacity.**



Solution: Innovations of carbon materials to increase battery capacity and lifetime

The use of GMS (graphene mesosponge), developed by 3DC, as **a conductive aid in storage batteries** suppresses chemical and mechanical degradation, **greatly improving durability** and enabling **more power** to be **stored.**

1

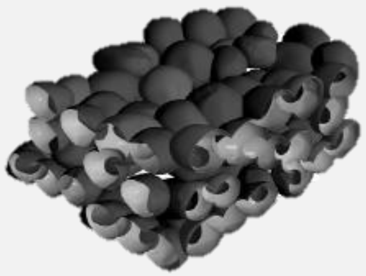
Flexibility

Absorbs electrode expansion and compression, allowing **more current** to be **stored** and **preventing** mechanical **degradation**

3

Customizability

The ability to freely control hardness, pore size, and particle size enables optimum physical properties to be achieved for each application.



GMS (Graphene Mesos sponge)

2

Structure with few edge sites

The area that reacts with the electrolyte is drastically reduced and degradation is suppressed.

4

Hydrogen Production

Hydrogen, a byproduct of the methane to GMS process, is an energy source as carbon-free hydrogen.

Solution: Innovations of carbon materials to increase battery capacity and lifetime

Batteries with GMS will not only reduce the environmental impact of battery production, but will also accelerate the **decarbonization of the entire value chain**

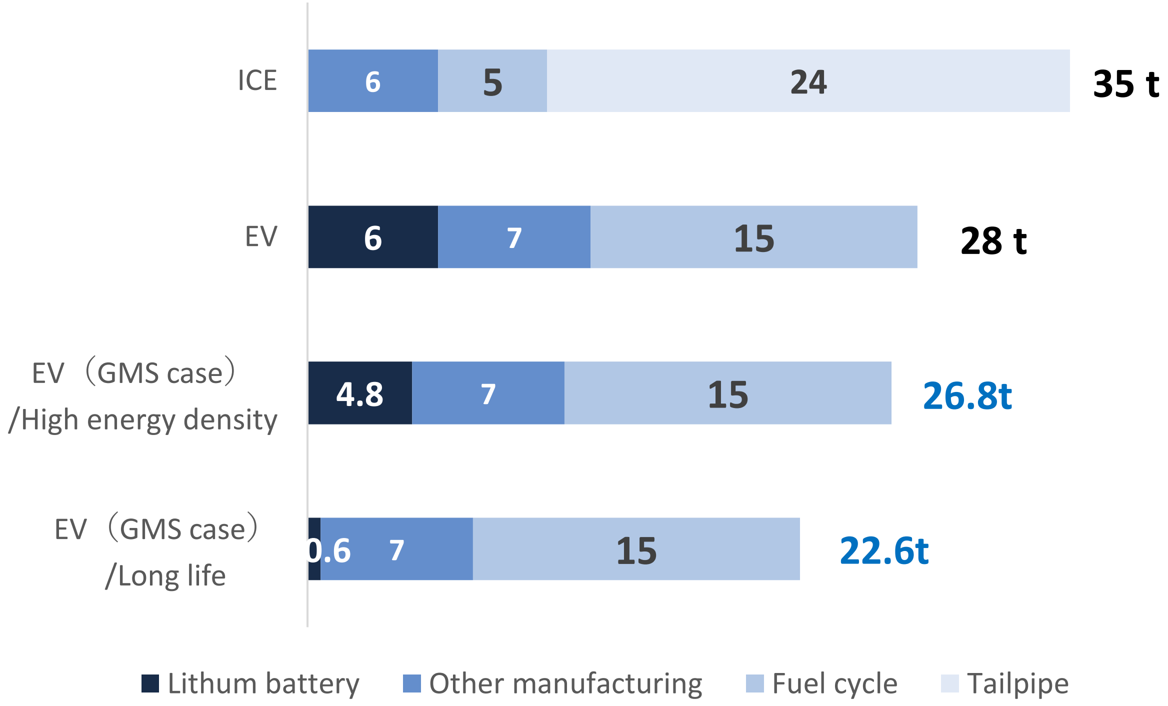
Features of GMS	Raw materials	Manufacture	Use	Impact on the industry
High capacity	• **20% reduction in the** amount of mining resources used in battery production • **20% reduction in** CO2 emissions from battery production		• EVs and ESS systems • Reduced life cycle CO2 emissions/Resources	• Accelerated decarbonization of the transportation sector as **EVs** become **less expensive** • Accelerated decarbonization of the energy sector due to **lower costs of energy storage systems** • Accelerate decarbonization of the entire industry with the **use of hydrogen**
High durability	• Improved battery durability **Up to 10 times* more durable** than **conventional**		• Reduced replacement frequency due to deterioration → **Reduced life cycle CO2 emissions/resources**	
Hydrogen production	• Reduction of CO2 emissions from hydrogen production (**10-30 kg/CO2**)		• Utilization of hydrogen without CO2 emissions (power generation, transportation, industry (iron, chemical, etc.), petroleum refining)	

*This is a current projection. Assumption is that a 10-fold increase in battery life will be achieved in the future through R&D to prove performance in collaboration with manufacturers of other materials used in storage batteries.

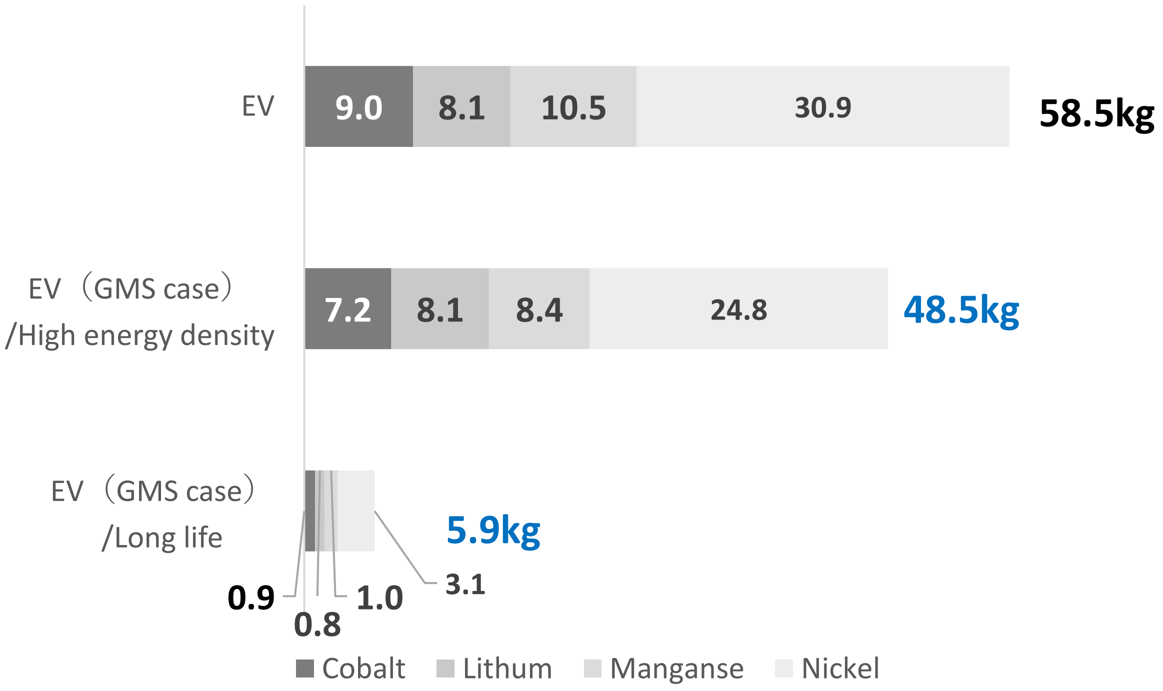
Solution: Innovations of carbon materials to increase battery capacity and lifetime

Compared to conventional gasoline vehicles, EVs can reduce life cycle CO2 emissions by up to 12 tons per vehicle and use one-tenth the mining resources.

Life cycle CO2 emissions per vehicle*.[1]



Life cycle mining resource use per EV*.[2]



1: ICE, EV lifecycle CO2 emissions: IEA Global EV Outlook 2020, GMS Case/High energy density: Assumed to be 0.8 times lower than conventional EVs, GMS Case/Long life: Assumed conventional EV life is 10 years. Life-cycle CO2 emissions from battery production are estimated assuming that the life of a conventional EV can be extended 10 times.

2：ICE, EV Life Cycle Mining Resources Use : Estimate the amount of resources used per vehicle based on the total amount of resources used in 2019 in the IEA Global EV Outlook 2020 and the number of EVs sold; GMS Case/High energy density: Assume that the amount of cobalt, manganese, and nickel used can be reduced by 0.8 times compared with conventional EVs. GMS Case/Long life: Assumed conventional EV life is 10 years. Life-cycle mining resource use associated with battery production are estimated assuming that the life of a conventional EV can be extended 10 times

Impact: Reducing 720M ton CO2 emissions by 2050

By extending battery life, increasing their capacity, and reducing their cost, GMS will reduce CO2 emissions by approximately 720M tons, or 2% of global CO2 emissions, by 2050.

High capacity/longer life time CO2 reduction effect*.[1]

170M t-CO2

+

Reduction of CO2 emissions by expanding the use of EVs/ESSs through lower costs*.[2]

360M t-CO2

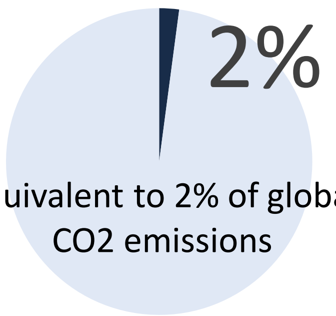
+

Reduction of CO2 emissions associated with hydrogen production*.[3]

190M t-CO2

CO2 reduction by GMS (by 2050)

720M t-CO2



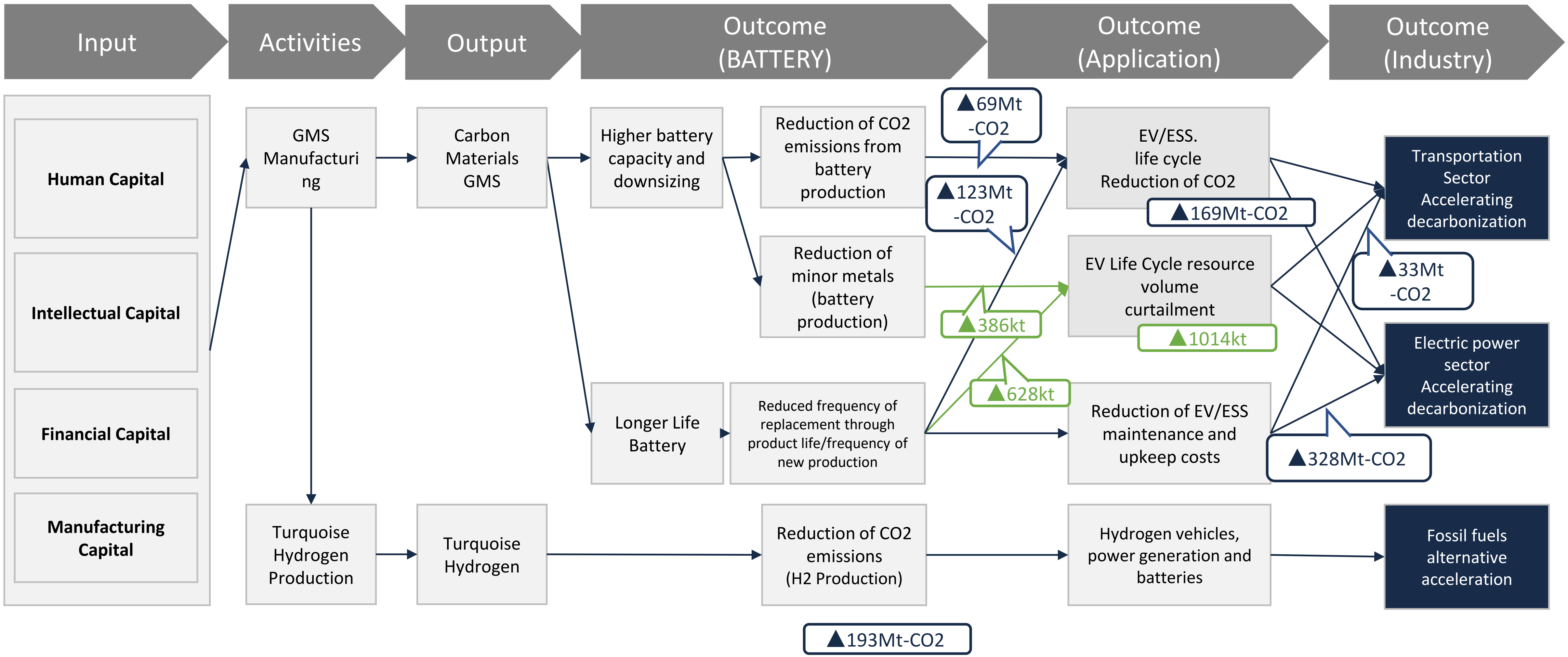
1: EVs: Calculated based on CO2 emission reductions per vehicle (see previous page), assuming that about 35% of EVs in 2050 will be equipped with storage batteries using GMS. ESS: Assuming that the need for longer service life is greater than the need for higher capacity in energy storage systems, only the effect of longer service life is estimated. Assuming that storage batteries using GMS will be used for 1% of the expected demand for energy storage systems in 2050, and that the frequency of battery replacement can be reduced to one-tenth as long as the battery life of the corresponding energy storage system is extended, the life cycle CO2 emissions per 1 kwh were used in the estimation.

2: The longer life of storage batteries reduces the amount of storage batteries installed in anticipation of degradation, thereby reducing initial costs. In addition, the operating costs associated with replacement due to deterioration are also reduced. Based on these factors, it is assumed that the EV penetration rate will increase by 20% over the conventional rate. However, since factors other than this technology are also expected to contribute, the contribution of this technology is estimated to be 30%.

*3: Calculated based on the average CO2 emiissions from the production of 1 kg of hydrogen from natural gas and petroleum sources, assuming that the production of GMS requires virtually 0 kg of these CO2 emissions, and based on the amount of hydrogen expected to be produced by the 3DCs in 2050.

Impact story: Accelerating Decarbonization through Battery Innovation

Aiming to become an **indispensable** player in the **decarbonization of the** entire industry by leveraging the know-how accumulated through more than 10 years of GMS R&D, including researchers who have been leading R&D of lithium-ion batteries in Japan for almost 40 years.



Feasibility: Issues for practical application

To contribute to decarbonization by 2050, 3DC will firstly prove the performance of GMS as a material. Then, we will establish production facilities and prove cost competitiveness.

Performance Verification	• Improvement of not only carbon materials but also other battery materials is important to realize long life batteries • Therefore, it is necessary to collaborate with battery and material manufacturers to prove their performance
Mass Production	• Scale-up of equipment, establishment of manufacturing process for stable supply, and production system for mass production without compromising performance as a material
Cost	• Mass production system needs to be improved so that costs can be in line with market needs
Rule Making	• As for measures to reduce the environmental impact of storage batteries, recycling tends to be the main issue, rather than reuse or leasing due to the longer service life of batteries. • Need to be involved in rulemaking while proving the environmental impact reduction benefits of leasing and reuse over recycling