India

Underweight *(no change)*

Highlighted Companies

Ami Organics

REDUCE, TP Rs714, Rs1115 close

With the collapse in HFC prices and the continued headwinds in the demand for fluoropolymers, the near-term as well as long-term earnings of Gujarat. Fluorochemicals are at risk. Consensus estimates need a massive cut. 4QFY24F EPS will be below Rs10/share.

Gujarat Fluorochemicals

REDUCE, TP Rs1946, Rs3702 close

The much-vaunted vinylene carbonate will hardly add Rs0.4-0.6bn in EBITDA while operating at full capacity (i.e., 800t in sales). All the hopes are pinned on darulatamide, which suffers from heavy competition. Its fate can be akin to dolutegravir.

Summary Valuation Metrics

P/E (x)	Mar24-F	Mar25-F	Mar26-F
Ami Organics	50.96	48.84	46.28
Gujarat Fluorochemicals	74.54	68.87	54.69

P/BV (x)	Mar24-F	Mar25-F	Mar26-F
Ami Organics	6.24	5.73	5.27
Gujarat Fluorochemicals	6.7	6.11	5.49

Dividend Yield	Mar24-F	Mar25-F	Mar26-F
Ami Organics	0%	0%	0%
Gujarat Fluorochemicals	0%	0%	0%

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Chemicals - Overall

Battery chemical firms are stuck in the past

- While all potential Indian battery chemical makers prefer lithium-ion, industry leaders like BYD, CALT and Tesla are moving on to newer battery chemistries.
- Li-ion electrolytes ($LiPF_6$, LiFSi) & solvent (dimethyl/ethylene carbonate) are commodities seeing huge oversupply and thus, prices are below all-time lows.
- We reiterate our underweight stance on Indian chemical companies. GFL is our top REDUCE-rated stock. Its 4QFY24F EPS to remain under Rs10/share.

Chinese battery players are moving towards newer chemistries

Chinese battery manufacturers like BYD and CATL are exploring newer battery chemistries for electrical vehicles or EVs. This includes sodium-ion batteries, solid-state batteries and so on. BYD has signed a 10bn yuan (US$1.4bn) contract for setting up a new battery plant in Xuzhou, a city about halfway between Beijing and Shanghai. The annual output capacity of 30GWh will make it the world's largest sodium-ion battery plant. Sodium-ion batteries will be used in two-wheelers and lower-end EVs as they are cheaper but have a slightly lower energy density compared to their lithium-ion counterparts. Chinese companies are also exploring solid-state batteries, a kind of battery which replaces the liquid electrolyte with a solid electrolyte and has a much higher energy density in the range of 500-600 Wh/kg. Solid-state batteries, however, are expensive, and currently cost up to three times more. However, they make up for it as they can hold three times the charge and deliver thrice the range.

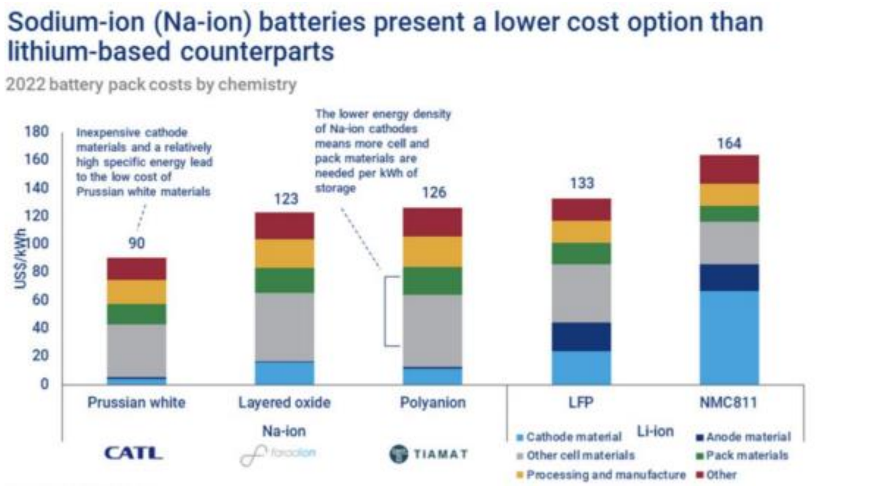
Chinese firms control majority supply chain & hence control prices

Chinese battery makers like BYD and CATL are global leaders in EV battery supply chain. However, both these companies have their unique strengths, like CATL has an advantage in NMC battery chemistry, whereas BYD leads in LFP battery chemistry. One thing which is important to note is that the chemicals required for these battery chemistries are not of specialty grade but commodity grade. Hence, they have significantly less barriers to entry. As a result, lithium-ion electrolytes ($LiPF_6$, LiFSi) and solvent (dimethyl/ ethylene carbonate) are commodities which are in huge oversupply and thus their prices are below all-time lows. Hence, manufacturing most of these chemicals will yield a negative EBITDA.

Retain our underweight sector stance; REDUCE GFL, Ami Organics

We reiterate our underweight stance on Indian chemical companies venturing into the EV chemicals space as we believe Chinese players have caused an oversupply, rendering this space almost unprofitable. For Indian chemical companies to make a profit, they need to be cost-competitive with Chinese players, which is highly unlikely. Hence, we don't believe these companies will generate value for their shareholders with their EV chemicals investments. For Gujarat Fluorochemicals or GFL, its investment in $LiPF_6$ doesn't make sense, as the chemical is already in oversupply and battery companies are moving into LiFSI, which has much better properties compared to $LiPF_6$. Similarly, for Ami Organics, vinylene carbonate is used as an additive for $LiPF_6$, which will lose market share to LiFSi in the coming years.

Figure 1: Lithium-ion will soon become a thing of the past but Indian companies are still investing in lithium-ion related chemistries



SOURCE: INCRED RESEARCH, COMPANY REPORTS

EV battery chemistries are changing fast

Most of the Indian companies are venturing into manufacturing the traditional lithium-ion salt – $LiPF_6$. Significant capex has been committed by multiple Indian companies like Gujarat Fluorochemicals or GFL, Neogen Chemicals, etc. These companies are also rewarded by markets and hence, there is a rush to set up capacities.

EV battery types

While lithium-ion battery is the leader, there are multiple batteries which are in contention for the EV space. In this section, we will cover all the batteries and their related chemistries in detail. Following are some of the popular batteries: lithium-ion battery, solid-state battery and sodium-ion battery.

Almost all EVs use lithium-ion batteries as they have multiple advantages ➤

There are a few key reasons why practically all EVs (electric vehicles) use lithium-ion batteries:

High energy density: Compared to other battery technologies like lead-acid or nickel-metal hydride, lithium-ion batteries offer a significantly higher energy density. This means they can store more energy in a smaller and lighter package. This is crucial for EVs as it allows for a longer driving range without needing an excessively large and heavy battery pack, which would negatively impact the vehicle's performance and efficiency.

Efficiency: Lithium-ion batteries have a high charge and discharge efficiency, which means they lose less energy during these processes. This translates into a longer driving range on a single charge and less wasted energy during charging cycles.

Versatility: Lithium-ion batteries can be tailored to prioritize different aspects like energy density, power density, or lifespan depending on the specific needs of the EV. This allows manufacturers to optimize the battery for the desired range, performance, or cost considerations.

Established technology: Lithium-ion batteries have been around for decades and have undergone continuous research and development. This led to significant improvement in their performance, reliability, and cost-effectiveness, making them the most mature and proven technology for EVs currently.

While alternative battery technologies are being explored and developed, such as solid-state batteries, lithium-ion batteries currently offer the best combination of these essential factors for their widespread use in EVs.

There are essentially two types of lithium-ion battery chemistries ➤

Lithium-ion batteries involve two battery chemistries:

1. LFP (lithium ferro phosphate)
2. NMC (nickel, manganese and cobalt).

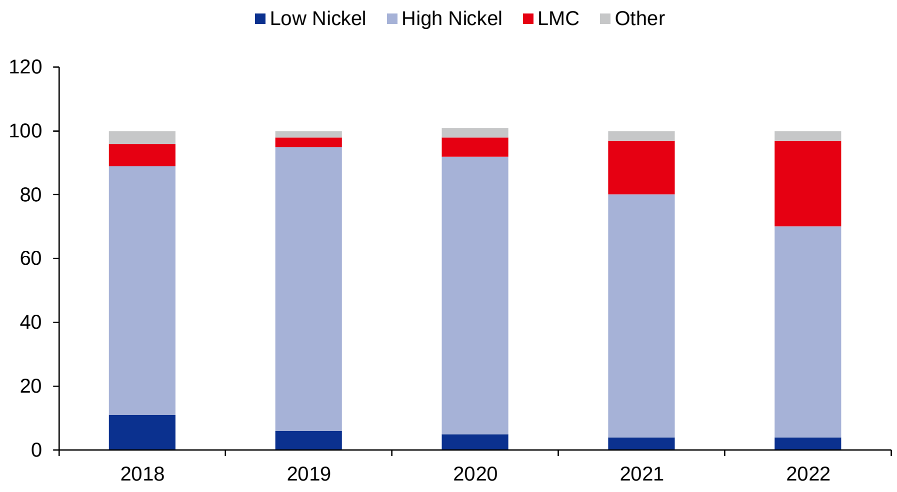
Advantages and disadvantages of both these chemistries are listed below ➤

1. LFP batteries have been around for a while now, and they have some brilliant advantages over regular lithium-ion NMC batteries, as they tend to be safer and far cheaper.
2. But LFP is far less energy-dense. This means that many EVs can’t switch to using LFP battery packs, as they simply don’t have enough space to install large-enough LFP batteries.

   a. For instance, take the example of Tesla Model 3 SR (Short Range) and Tesla Model 3 LR (Long Range). The SR uses a 50 kWh LFP pack and the LR uses a 64% bigger 82 kWh lithium-ion pack, but their batteries are roughly the same in size and weight.

3. By 2019, more than 60% of new EVs were equipped with NMC batteries, taking over the main market from LFP batteries.
4. The theoretical specific capacity of LFP is only 170 mAh/g, which is much lower than NMC (275 mAh/g).
5. On the flip side, although LFP batteries are much safer than NMC batteries, the latter, due to the presence of nickel and cobalt, are prone to catching fire very quickly compared to LFP batteries, which are relatively resistant to fire.

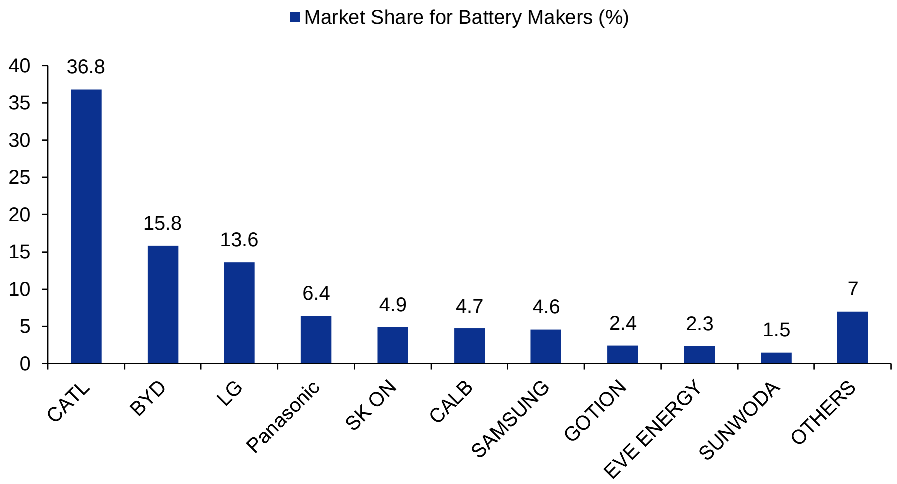
Figure 2: Market share (%) of different battery chemistries; LMC has been gaining market share consistently



SOURCE: INCRED RESEARCH, COMPANY REPORTS

CATL is the global leader in EV batteries

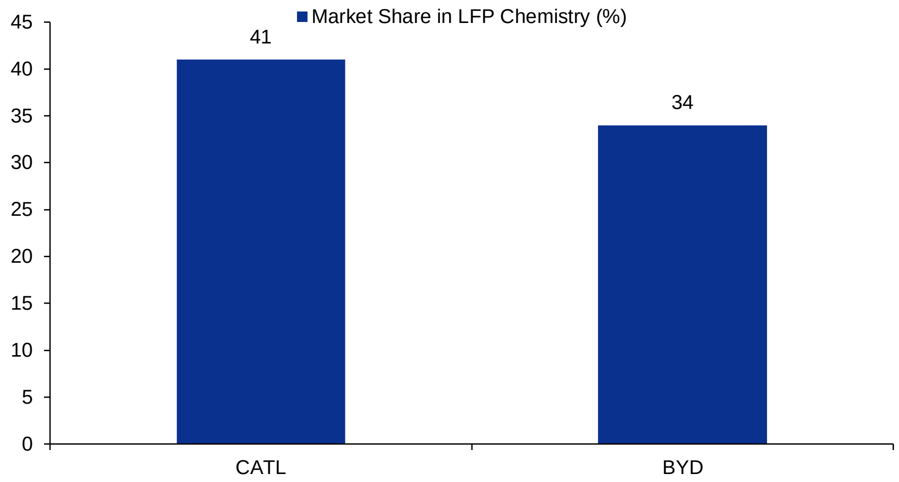
Figure 3: CATL is market leader in the global EV battery market



SOURCE: INCRED RESEARCH, COMPANY REPORTS

However, in LFP chemistry-based batteries, BYD leads CATL by a huge margin

Figure 4: However, in LFP battery chemistry, BYD leads CATL



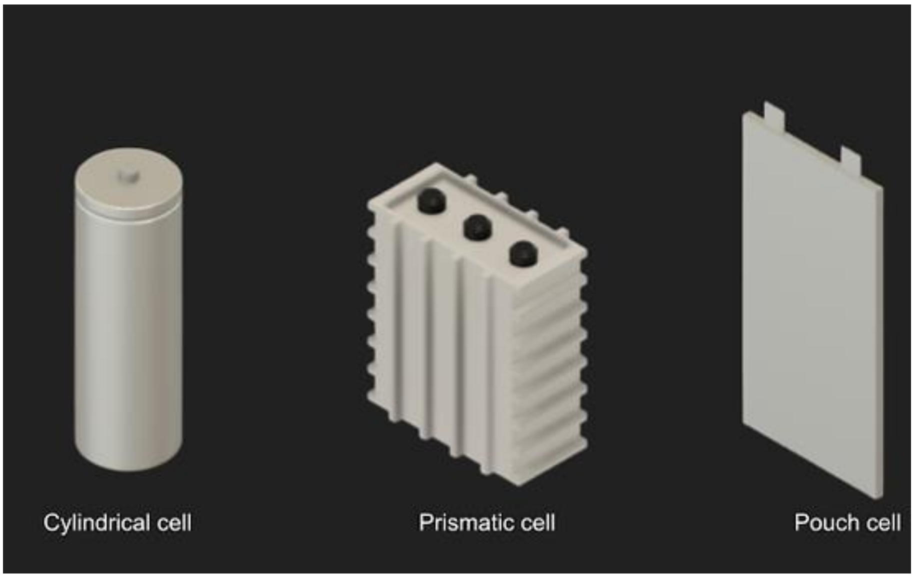
SOURCE: INCRED RESEARCH, COMPANY REPORTS

Not only battery chemistry, but even battery shape becomes important in the overall scheme

The cells used in lithium-ion batteries come in three shapes and sizes - cylindrical, prismatic and pouch.

1) **Cylindrical form factor**: A cylindrical cell consists of sheet-like anodes, separators, and cathodes that are sandwiched, rolled up, and packed into a cylinder-shaped can. This type is one of the first mass-produced types of batteries and is still very popular. These cells are suited for automated manufacturing. Another advantage is the mechanical stability. The round shape of the battery distributes the internal pressure from side reactions over the cell circumference almost evenly. This allows the cell to tolerate a higher level of internal pressure without deformation. When combining cylindrical cells into packs and modules, the cells' circular cross-section does not allow us to fully utilize the available space. As a result, the packaging density of cylindrical cells is low. However, thermal management of a pack of cylindrical cells can be easier because the space cavities let the coolant easily circulate around the cells within a battery pack. **Cylindrical form factor cells are used in Tesla EVs.** Other manufacturers use prismatic form factor.
2) **Prismatic form factor:** Lithium-ion prismatic cells consist of large sheets of anodes, cathodes, and separators sandwiched, rolled up, and pressed to fit into a metallic or hard-plastic housing in cubic form. Parts of the electrode and separator sheets of a prismatic cell that are close to the container corners can experience more stress. This can damage electrode coating and lead to non-uniform distribution of the electrolyte. When combining prismatic cells into packs, the cell box-like shape enables optimal use of the available space. However, this optimal space is achieved at the cost of more challenging thermal management. This is because there are no space cavities between the cells as there are in a pack of cylindrical cells.
3) **Pouch form factor:** Pouch cells do not have a rigid enclosure and use a sealed flexible foil as the cell container. This is a somewhat minimalistic approach to packaging; it reduces weight and leads to flexible cells that can easily fit the available space of a given product.

Figure 5: Various form factors for a lithium-ion battery



SOURCE: INCRED RESEARCH, COMPANY REPORTS

CATL has an upper hand over BYD in sodium-ion batteries while BYD is behind Toyota in solid-state batteries

BYD's new foray: Sodium-ion battery

BYD has signed a 10bn yuan (US$1.4bn) contract for setting up a new battery plant in Xuzhou, a city about halfway between Beijing and Shanghai. The annual output capacity of 30GWh will make it the world's largest sodium-ion battery plant. These sodium-ion batteries will be mainly used in two-wheelers and short-range EVs. Just like lithium, sodium belongs to the group of alkali metals. Thus, its electrochemical properties are quite similar to that of lithium. However, as sodium is a heavier atom than lithium, sodium-ion batteries are bound to have a lower energy density than lithium-ion batteries with a similar chemistry. It is because of this reason that research in sodium-ion battery chemistries has looked at adapting the existing lithium-ion chemistries to use sodium instead of lithium. There are many different battery chemistries for sodium - Layered Oxides, Polyanionic Compounds & Prussian Blue Analogues. BYD has chosen Layered Oxide chemistry for its sodium-ion battery while CATL has opted for Prussian Blue Analogues.

Figure 6: Different types of sodium-ion cathode chemistries

Cathode type	Structure	Category	Cathode material	Potential (V)	Discharge capacity (mAh g^{-1})	Energy density (kWh g^{-1})	References
Transition metal oxides	Cubic close-packed arrangement with 1D-, 2D- or 3D-type tunnels	P2-layered	$Na_{2/3}Mn_{1-y}Mg_yO_2$	1.5–4.0	140	—	Clément et al. (2016)
		P2-layered	$Na_{2/3}[Mn_{2/3}Ni_{1/3}]O_2$	2.9–4.0	161	—	Lu and Dahn (2001)
		O2-layered	$Na_{2/3}[Mn_{0.8}Ni_{0.2}]O_2$	2.0–4.3	162	—	Konarov et al. (2018)
		O3-layered	$Na_{0.78}Li_{0.18}Ni_{0.25}Mn_{0.583}O_w$	1.5–4.5	240	675	Liu et al. (2015)
		P2-layered	$Na_{2/3}[Mn_{0.72}Mg_{0.28}]O_2$	1.5–4.4	~180	—	Yabuuchi et al. (2014)
		P2-layered	$Na_{2/3}Mn_{0.7}Zn_{0.3}O_2$	1.5–4.6	190	—	Konarov et al. (2019)
		P2-layered	$Na_{2/3}M_{n0.8}Fe_{0.1}Ti_{0.1}O_2$	2.0–4.0	144.16	399.32	Han et al. (2016)
Transition metal fluorides	Weberite-type	Sodium metal fluorides	Na_2FeTiF_7	3.26	190	GED 620	Euchner et al. (2019)
Polyanionic compounds	Olivine structure with rhombohedral R-3 symmetry	Phosphates and NASICON type	$NaFePO_4$	3	150	450	Hasa et al. (2017)
			$Na_3V_2(PO_4)_3$	3.3	117	394	Guo et al. (2017)
			$Na_3V_2(PO_4)_2O_2F$	3.8	128	486	Guo et al. (2017)
		Fluorophosphates	NASICON-type $Na_3V_2(PO_4)_2F_3$	1.6–4.6	111	—	Song et al. (2014)
		Sulfates	$Na_2Fe_2(SO_4)_3$@C@GO	3.8	107.9	400	Chen et al. (2018)
Prussian blue analogs	Face-centered cubic geometry and open-framework lattice	Binder free cathode - Fe-HCF NSs@GRs	Sodium iron hexacyanoferrate (Fe-HCF)	2.0–4.2	110	—	Luo et al. (2017)
		High-quality PB nanocrystals	$Na_{0.61}Fe[Fe(CN)_6]_{0.94}$	4.0–2.7	170	—	You et al. (2014)
		Ferrocyanide	$Na_{1.92}Mn[Fe(CN)_6]_{0.98}$	3.34	105.7	—	Peng et al. (2019)
		Poly (hexaazatrinaphthalene)	PHATN	1.0–3.5	Reversible capacity of 220	440	Mao et al. (2019)
		$C_6R_4O_2$ molecules (R = F, Cl, Br)	Quinone-derivative, $C_6Cl_4O_2$	~2.72 V vs. Na/Na+	161	420	Kim et al. (2015)

SOURCE: INCRED RESEARCH, COMPANY REPORTS

Figure 7: Key raw materials required for a sodium-ion battery

Na-ion battery candidate material		Material characteristics and main advantages and disadvantages
Cathode material	Layered oxides (e.g., NaxMO2, 0<X≤1, M (transition metals) = Mn, Fe, Cr, Ni)	Large theoretical capacity. However, it has a short cycle life because its structure is easily destabilized by the adsorption/desorption of sodium ions during charging and discharging.
	Polyanionic compounds (e.g., NaFePO4, Na3V2(PO4)3, etc.)	High voltage and structural stability. However, gravimetric energy density and ionic conductivity are lower than layered oxides. In addition, vanadium compounds are toxic.
	Prussian blue analogues (Na2M'[M(CN)6]1-y-zH2O, M and M' (transition metals) = Fe, Co, Mn, Ni)	High gravimetric energy density. However, volumetric energy density is lower than layered oxides, and there is a risk of generating toxic hydrogen cyanide (HCN).
Anode material	Hard carbon	High capacity and low cost. However, there are safety issues because the charge reaction potential is very close to the deposition potential of metallic sodium. R&D is underway to enable storage of more sodium ions.
	Soft carbon	Higher voltage than hard carbon, but has the disadvantage of lower capacitance.
	Prussian blue	Characterized by high current and long cycle life. However, it has the lowest energy density of the various candidates.
Cathode current collector	Aluminum foil	Materials for currently available LiBs can be used.
Anode current collector	Aluminum foil	As aluminum does not react with sodium in an alloying reaction, it can be used as an alternative to the costly copper foil used in LiBs.
Separator	Polyolefin	Materials for currently available LiBs can be used.
Electrolyte	Sodium salts such as NaClO4 and NaPF6	NaClO4 comes with the risk of explosion, and NaPF6 comes with the risk of reacting with water to generate toxic hydrogen fluoride.
Electrolytic solution	Organic solvents such as dimethyl carbonate (DMC)	Materials for currently available LiBs can be used.

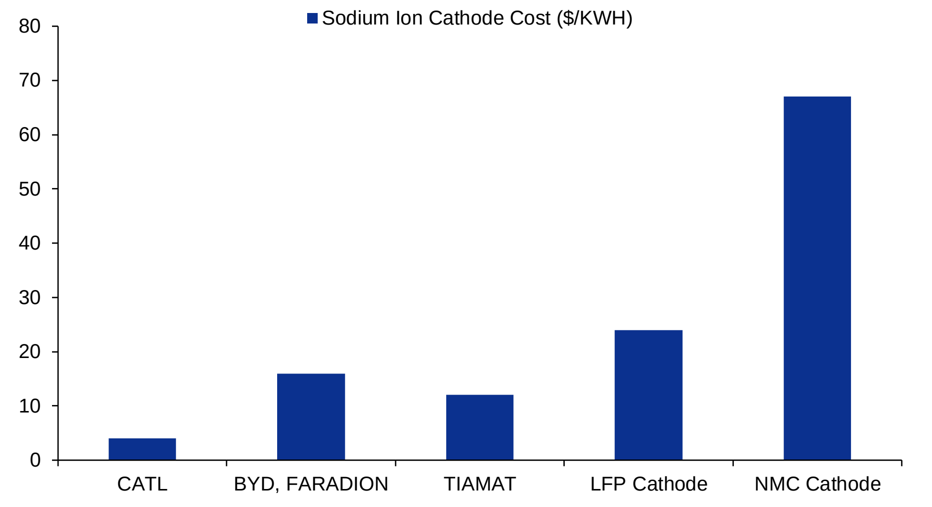
SOURCE: INCRED RESEARCH, COMPANY REPORTS

Cathodes which use Prussian Blue Analogs (PBA) have the cheapest raw material costs and can accept high rates of charge, allowing such batteries to reach 80% charge within 15-20 minutes. The downside is that they have lower energy density and hence, wouldn't have a very high range. Lithium-ion batteries use graphite anodes. However, sodium ions are larger than lithium ions and hence, they cause structural damage on the atomic scale in the graphite anode's microstructure. This reduces the life, durability of the anode and hence, the life of the battery as a whole. Hard carbon is being considered as an anode material because it can be made from biomass, waste, etc. and it can absorb and hold the larger sodium ions better. **The range provided by an EV battery pack is determined by its volumetric energy. Most sodium-ion battery manufacturers advertise the gravimetric energy density of their products. They prefer not to talk about the volumetric energy density of the battery. While Na-ion battery manufacturers have achieved a gravimetric energy density on par with LFP batteries, the volumetric energy density is around 35% lower than that of LFP batteries.**

CATL has an advantage over BYD in sodium-ion batteries

The cathode is also the primary energy-carrying element in the battery. This is why it is often the most expensive part of the battery and hence, the primary cost driver of the battery. CATL's sodium-ion batteries use Prussian White (a PBA material), which is quite cheap and has a relatively high energy density. This allows such batteries to be among the cheapest sodium-ion batteries.

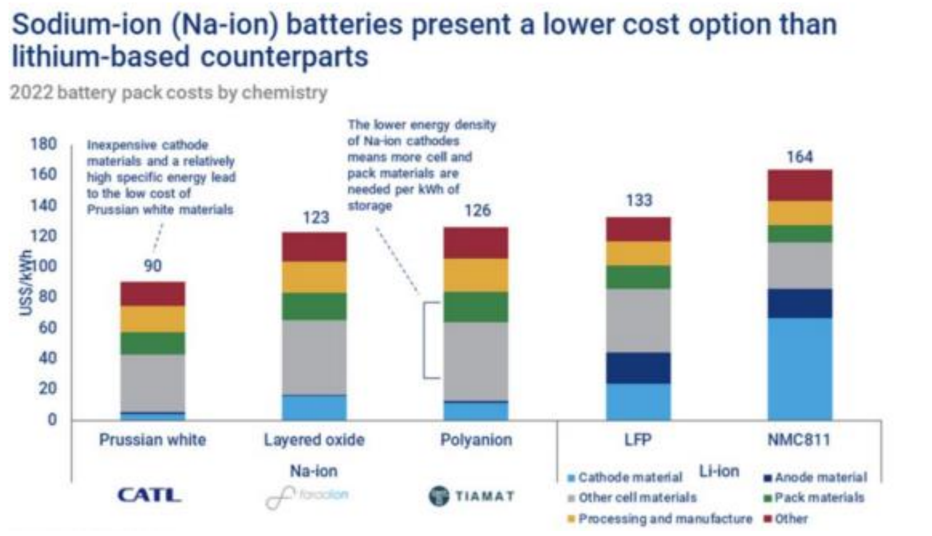
Figure 8: CATL cathode cost is the least due to Prussian White as cathode material



SOURCE: INCRED RESEARCH, COMPANY REPORTS

As of now, sodium-ion batteries are not viable as lithium-ion batteries are cheap but as this changes, sodium-ion batteries can become a viable option

Figure 9: Even though LFP Blade battery cost for BYD is lesser than US$90/KwH, it is because lithium prices are quite low currently; once that changes, Na is viable



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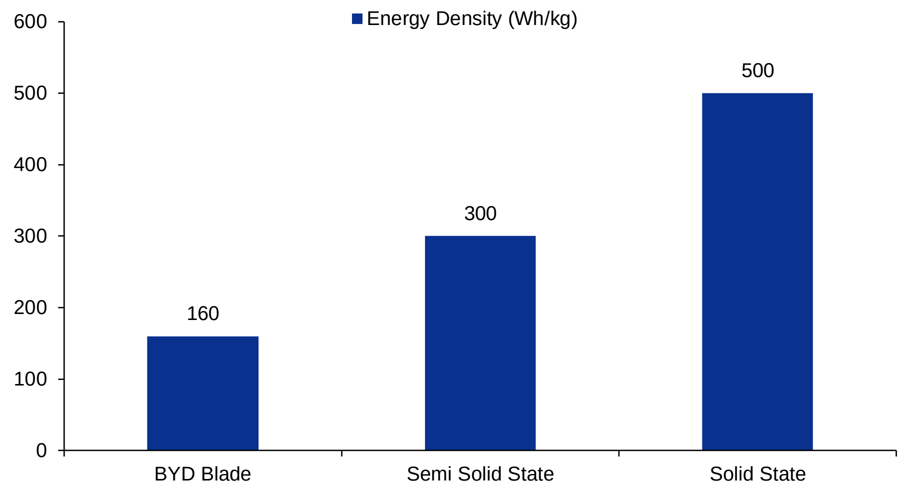
Solid-state batteries - characteristics of these batteries

The lithium-ion batteries that we use in cars use a liquid electrolyte to help transfer electrons from one side of the battery to the other. As the electrolyte is in liquid form, this makes the battery large, heavy, and sensitive to thermal runaway. This is why, in comparison to a conventional lithium-ion battery, solid-state battery technology has the potential to increase energy density, reduce charge time and make it more stable when it comes to thermal runaway. Solid-state batteries, however, are expensive, and currently cost up to three times more. But they make up for it as they're capable of holding three times the charge and delivering thrice the range.

What are the different types solid-state batteries?

According to the different materials, there are three technology routes for solid-state electrolytes: sulphide, oxide and polymer, and the types of batteries are divided into semi-solid-state and all-solid-state batteries, according to the weight of the liquid electrolyte. Considering the energy density, charging and discharging efficiency and safety requirements of EVs, sulphide and oxide are considered the most suitable materials for solid-state batteries for EVs. Japanese automakers are currently focusing on the sulphide route, with Toyota having many patents in the field and a joint venture with Panasonic to develop solid-state batteries. Toyota recently announced that it will be mass-producing all-solid-state battery vehicles in 2027F, making it the fastest-paced among Japanese automakers. European and American automakers are involved in all three technology routes, with Mercedes-Benz expecting to launch EVs with solid-state batteries in 2025F. Chinese automakers are focusing on the oxide route.

Figure 10: Energy density of a solid-state battery is significantly higher than that of a lithium-ion battery

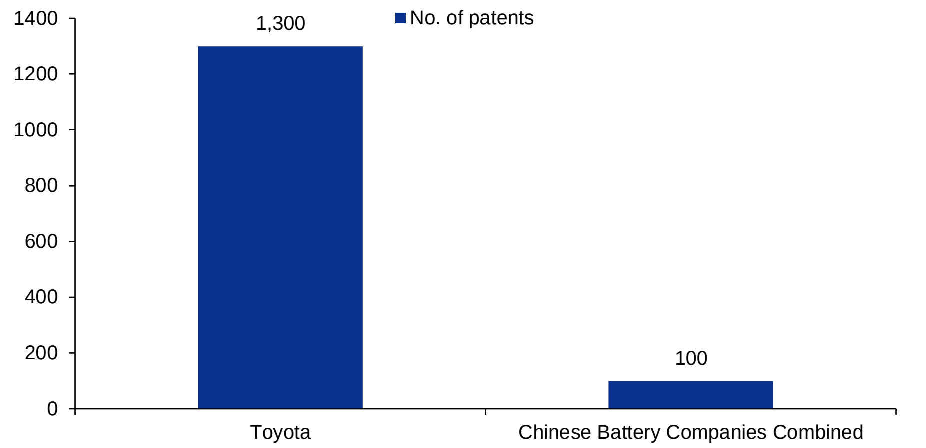


SOURCES: INCRED RESEARCH, COMPANY REPORTS

Chinese government and industry are trying hard but they are still behind Toyota in this technology

1. After lithium-ion and sodium-ion, Chinese companies are partnering for solid-state batteries, which have a much higher energy density compared to the former.
2. China's battery and car makers have united as a part of the government-led drive to commercialize all solid-state batteries, challenging Japan, and the Western countries in an area of technology that could revolutionize the electric vehicle market.
3. Aiming to build a supply chain for solid-state batteries by 2030F, Beijing has set up a consortium called the China All-Solid-State Battery Collaborative Innovation Platform (CASIP), which brings together government, academia, and industry, including EV battery rivals CATL and BYD.
4. How far will EVs with solid-state batteries be able to go? Toyota says that by 2027F, its EVs will be able to travel around 1,400km on a single charge.

Figure 11: Toyota leads the race as of now in solid-state batteries



SOURCE: INCRED RESEARCH, COMPANY REPORTS

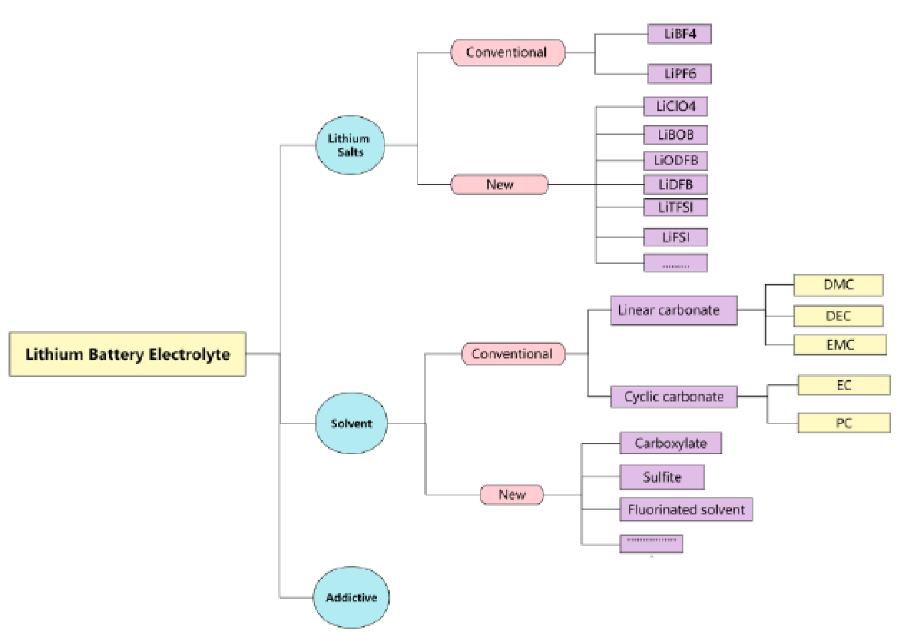
Electrolytes and solvents of lithium-ion batteries

There are seven kinds of lithium salts which are listed below:

1) LiBF4 - lithium tetrafluoroborate
2) LiPF6 - lithium hexafluoro phosphate
3) LiClO4 - lithium perchlorate
4) LiBOB - lithium bis(oxalato)borate
5) LiODFB - lithium difluoro(oxalato)borate
6) LiDFB - lithium difluoro(oxalate)borate. LiDFB, also known as lithium difluoro(oxalato)borate, is the same compound as LiODFB (lithium difluoro(oxalate)borate). They both have the same chemical formula, Li(ODFB), and share the same properties and applications. The difference in notation (DFB vs. ODFB) likely arises from different ways of representing the same chemical structure.
7) LiFSi: lithium bis(fluorosulfonyl)imide.

Out of these, LiPF6 is the most widely used salt commercially. BYD's Blade Battery also uses LiPF6 as an electrolyte**.** LiPF6 stands for lithium hexafluorophosphate, made up of a lithium cation and hexafluorophosphate anion. It accounts for 43% of the total electrolyte cost and is manufactured by reacting phosphorus pentachloride with hydrogen fluoride and lithium fluoride. In comparison to the older electrolyte salts like LiBF4, LiAsF6 and LiClO4, LiPF6 has a better performance with respect to solubility, conductivity, safety, and environmental friendliness in organic solvents. Hence, it became widely popular among battery electrolytes even though some of the newer salts like LiFSi have better properties.

Figure 12: Different lithium salts used as an electrolyte



SOURCE: INCRED RESEARCH, COMPANY REPORTS

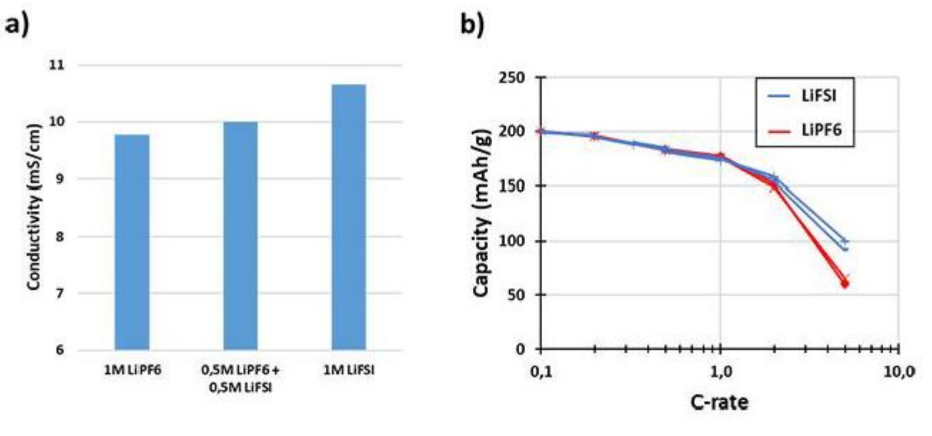
Electrolytes for lithium-ion batteries: LiFSi vs. LiPF6 - LiFSi is a better salt but the world is still taking baby steps in its adoption

1. LiPF6 still dominates the market because standardized processes exist for it, enabling the refinement of the manufacturing process, thus lowering the cost. However, the trend is likely to change in the future.
2. Currently, the global demand for LiPF6 stands at 67kt and Chinese capacity now is 2x of this, with another 100kt capacity in the pipeline.
3. Meanwhile, a new contender for LiPF6 is around the block: lithium bis(fluorosulfonyl)imide (LiFSI).

4. LiPF6 has limitations such as poor performance in both low & high temperatures, a harsh preparation process, and inadequate thermal stability.
5. LiFSI has the potential to address most of these bottlenecks, not just due to its better physical & chemical properties but also due to the continuous investments from Chinese companies in its research & development.
6. Currently, LiFSI is mainly used in a small quantity as an electrolyte additive mixed with LiPF6.
7. Several major Chinese players are investing in new supply of LiFSI besides LiPF6 plants. The primary hindrance to widespread adoption of LiFSI is its high application cost.
8. The price disparity between the two is gradually narrowing. Notably, EV giant Tesla is already deploying LiFSI salt into its 4680 batteries. Companies like Contemporary Amperex Technology (CATL), Panasonic, and LG Chem are actively involved in the production of these batteries, having inked sourcing agreements with domestic LiFSI manufacturers in China.
9. LiPF6 decomposes easily in heat, has hydrolysis resistance, and crystalizes easily at low temperatures.
10. LiPF6 electrolyte's performance is not optimal at high and low temperatures, and humidity because it is unstable and sensitive to humidity and temperature. It is susceptible to decomposition when the temperature and humidity are high. Hydrogen fluoride is produced under these conditions, and it severely affects battery life.
11. LiPF6 also crystalizes under low temperature, thereby decreasing the electrical conductivity of the electrolyte.
12. As a result, LiFSI could potentially be the answer. It is a hydrophyphic lithium salt that is used to make electrolytes for lithium-ion batteries as a safer alternative to the conventionally used LiPF6. It is made up of one li cation and a bistriflimide anion. The fluorine atom in LiFSi has strong electron absorption ability, because of which it has high conductivity. FSI- anion in LiFSi has better hydrolysis resistance. LiFSi has a lower crystallization point than LiPF6 and hence, it is more stable at lower temperatures.

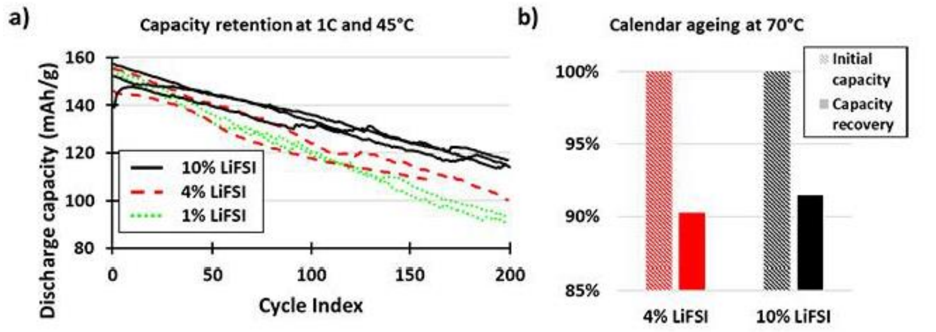
Overall, in comparison to LiPF6, LiFSi has the plus side of better thermal stability, strong hydrolysis resistance, and high conductivity. Owing to its superior properties, LiFSi can significantly improve a battery's life, its range, and charge & discharge power in the summer and winter seasons. Due to these reasons, it is expected to become the next-generation mainstream lithium salt. China is rapidly expanding its LiFSi capacity. A lot of downstream players like LG, Tesla, Volkswagen, etc. are beginning to use LiFSi. Even though LiPF6 dominates the market now, with the mass production of 4680 batteries and Qilin batteries, the trend is likely to change.

Figure 13: a) LiFSI batteries have improved fast charging and high-power delivery; b) batteries with LiFSI have higher capacity compared to LiPF6



SOURCE: INCRED RESEARCH, COMPANY REPORTS

Figure 14: Capacity retention of NMC532/graphite cells cycled at 1C (charge & discharge) at 45°C; b) initial capacity and capacity recovery at C/10 after two weeks of calendar ageing at 100% SOC at 70°C



SOURCE: INCRED RESEARCH, COMPANY REPORTS

What is the use of solvent in batteries? Solvents play a critical role in the electrochemistry of electrolytes ➤

1. Solvents are used in batteries to dissolve lithium salt and other active materials. They also provide a medium for ion transport and can affect the diffusion coefficient of lithium ions and the dissociation of lithium salts. Small solvent molecules can enable a previously unknown ion-transport mechanism in battery electrolytes. This can speed up charging and increase the performance at low temperatures.
2. The choice of solvent and salt is the main descriptor of the electrolyte in lithium-ion batteries (LIBs). Different solvents and salts can have varying effects on the performance of LIBs. For example, the use of isoxazole as the main solvent in the electrolyte has been found to significantly increase the ionic conductivity at low temperatures.

Some commonly used solvents include: 1)N-methyl-2-pyrrolidone, 2) dimethyl carbonate, and 3) ethylene carbonate.

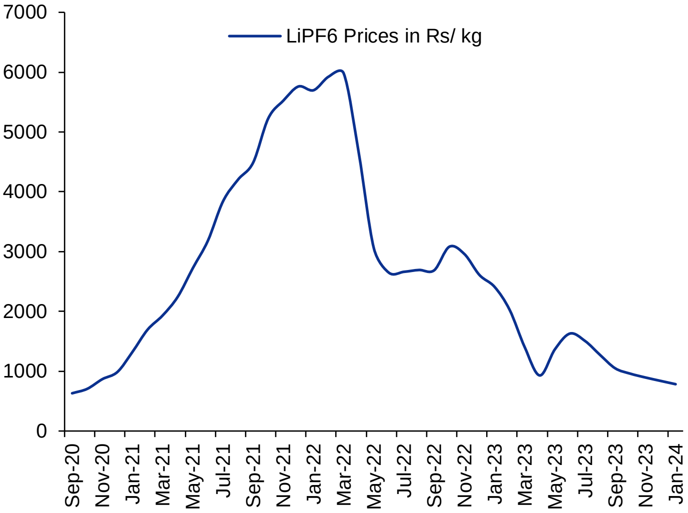
Solvent mixtures are used because a high relative permittivity and low viscosity commonly cannot be integrated into a single molecule

Is making ethylene carbonate, N-methyl-2-pyrrolidone or dimethyl carbonate a specliased skill which can not be mastered by all? The answer is an emphatic NO ➤

All these chemicals are manufactured by multiple companies in India. For example- N-methyl-2-pyrrolidone is exported by at least 150 different companies from India. Ethylene carbonate and di methyl carbonate are simple chemicals.

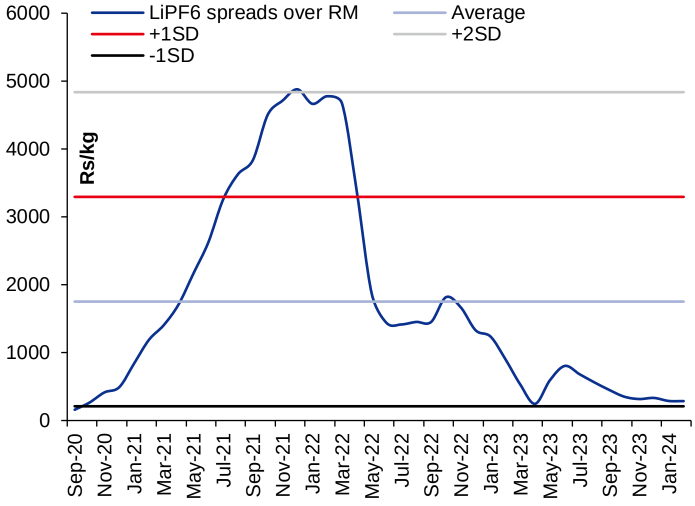
Is $LiPF_6$ making money now? No, it will be EBITDA negative

Figure 15: Prices of $LiPF_6$ have collapsed by ~85%...



SOURCE: COMPANY REPORTS, INCRED RESEARCH

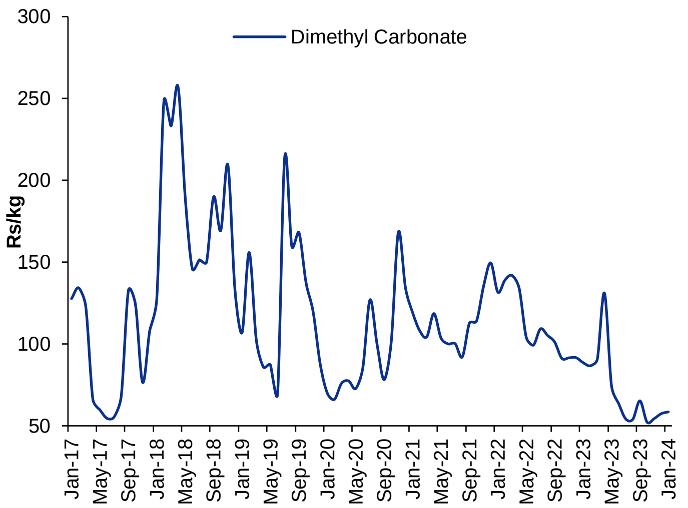
Figure 16: ...and EBITDA has nearly vanished



SOURCE: COMPANY REPORTS, INCRED RESEARCH

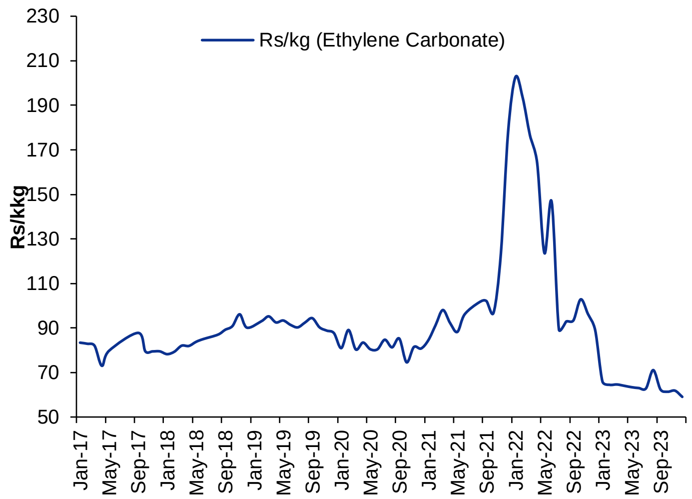
What about the prices of solvents? They too are falling rapidly

Figure 17: Dimethyl carbonate prices are near their all-time low



SOURCE: INCRED RESEARCH, COMPANY REPORTS

Figure 18: Ethylene carbonate prices have fallen below their all-time low



SOURCE: INCRED RESEARCH, COMPANY REPORTS

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