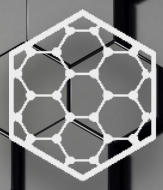

The Graphene Council

# The 2020 Graphene Survey

Produced by:
The Graphene Council
www.thegraphenecouncil.org

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# Introduction

The Graphene Council is the largest community in the world dedicated to the research, development and commercial application of graphene and related advanced materials. We directly connect more than 30k materials researchers, professionals, engineers and application developers, of which approximately 1/3 are in academia and 2/3 are from the commercial sector.

In 2016, The Graphene Council conducted the very first global survey of the graphene ecosystem and now in 2020, we have once again surveyed the graphene community, including companies that are not yet using this amazing material but that are evaluating its potential.

More than 800 individuals and organizations have contributed to this latest edition of the survey and their feedback has provided a rich set of data and insights that will help us to better understand where the graphene market stands today, and where it is headed.

As you will see from the results of our survey, graphene has an incredibly diverse universe of potential applications, a direct result of its very impressive range of performance characteristics. Graphene is really the only material that can claim it is simultaneously the thinnest, strongest, most thermally conductive, most electrically conductive, has the best barrier properties and still offers other positive attributes.

The range of applications includes coatings, plastics, energy storage, textiles, filtration, composites, printed electronics, biomedical, EMI shielding, corrosion control, films, lubrication, thermal transfer and many, many more.

In 2021, graphene is truly approaching an inflection point as quality improves, production is massively scaled, processing is mastered and better pricing makes this amazing material competitive.

Thank you to everyone that contributed to the survey, we appreciate your input and we value your interest and dedication to graphene as an important, advanced material.

Terrance Barkan

Executive Director | The Graphene Council | tbarkan@thegraphenecouncil.org

# About This Survey

The **2020 Graphene Survey** has benefited from more than 800 individual contributions from across the global graphene community, making it by far the most comprehensive and representative body of data and insight into the current state of graphene development available anywhere.

The primary objectives of the survey include;

- to understand which forms of graphene are being used for a given application.
- to correlate graphene performance characteristics with specific applications.
- to assess which applications are the most prevalent and important.
- to identify which standards, regulatory issues or industry practices are important.
- to highlight the primary obstacles to greater commercial adoption of graphene.

This version of the report provides a high-level overview of the results that are being made available to the public and to survey participants.

We will continue to make a deeper, detailed analysis of the vast amount of data we have collected to understand the implications for the sector. We will also make comparisons from the 2016 survey data to track how the sector is evolving and maturing.

**Definitions Used**

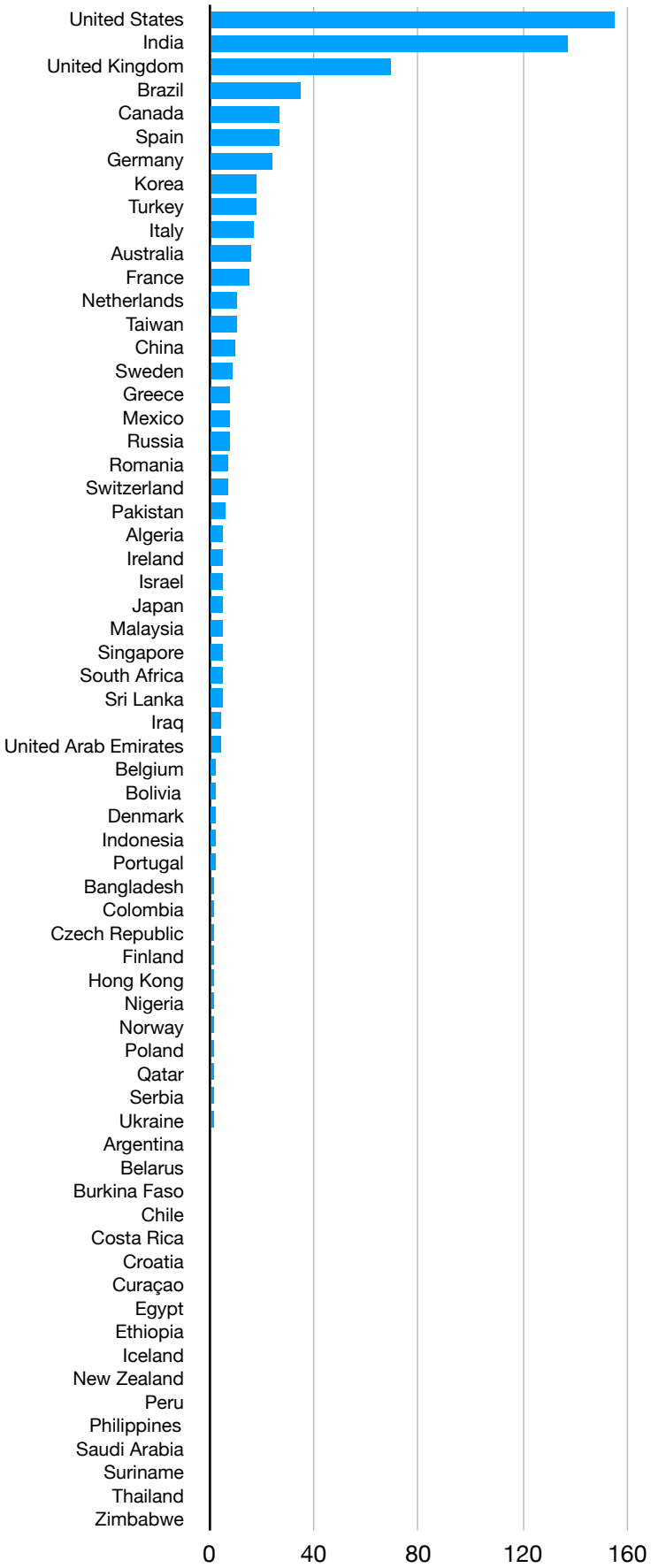
Each section of the survey will explain the terms used in that section and put the data into context. For the purposes of our report, the following general definitions apply:

**Applications** Includes functionality (e.g. “Thermal Management”) as well as some industry sectors (e.g. “Aerospace”).

**Commercial** Refers to any for-profit, private sector organizations and companies.

**Academic** Includes higher education institutions, government-related organizations, technical training centers or any non-commercial entity.

**NOTICE:**




# Survey Participants

We received input from no less than 65 different countries, ranging from Algeria to Zimbabwe, with the majority of the responses coming from countries with a strong engagement and experience with graphene materials.

The extremely wide distribution of countries that are represented is further evidence that graphene is maturing as a globally relevant commercial material. This theme will be echoed throughout the report.

Survey participants were asked to identify the types of activity related to graphene that best applied to their institution. Respondents were able to identify multiple responses depending on their scope of activity.

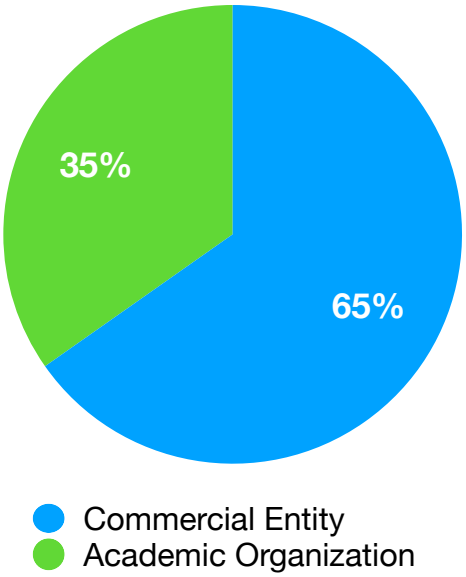
For example, a University (Academic Institution) may be a producer of certain forms of graphene while also developing applications and conducting research. Likewise, a Commercial Graphene Producer may be a developer of a graphene application while also conducting research, in addition to their primary graphene production business model.

Survey respondents were drawn from Graphene Council Members, community contacts, partner organizations and the global graphene community. Respondents include large multi-national companies, leading academic institutions and a vast majority of the commercially active graphene producers and intermediary companies.

The distribution of commercial entities versus academic organizations almost perfectly reflects the distribution within The Graphene Council global community.

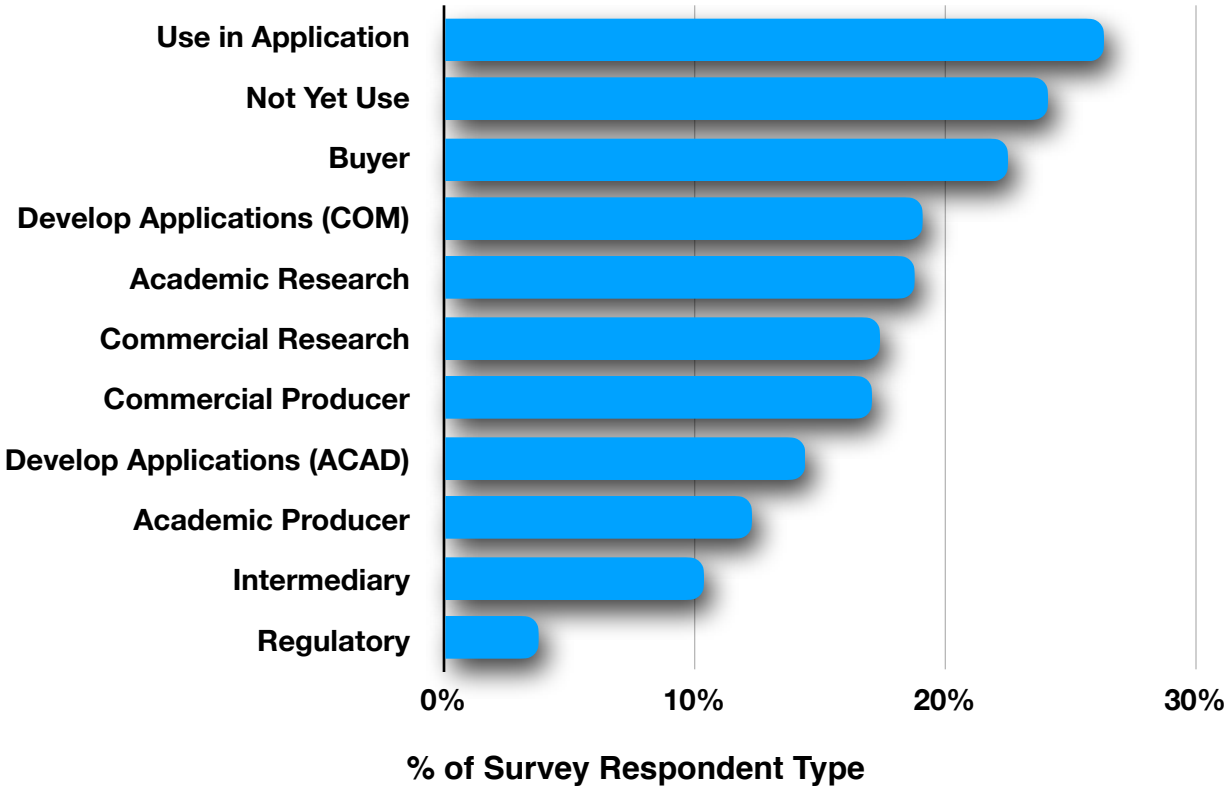
Of the more than 800 survey respondents, a full 2/3 operate in the commercial field while 1/3 are academic or governmental institutions.

Within the 30k graphene professionals that are in the global Graphene Council community, we see the same 1/3 - 2/3 distribution of academics versus commercial professionals.




We have further segmented the survey responses based on how people are working with graphene; are they producing graphene, using it in an application, conducting research, developing potential applications, etc.?

This year we included the option for respondents that are not yet working with graphene but that are evaluating its use to register their interests and comments. This is incredibly important to help understand the needs of future consumers and users of graphene.



Respondents were asked to select each option that applied to their organization, therefore, an organization might be a graphene producer as well as an application developer, for example.

In the graph listed above, we see that a full 26% of all respondents are already using graphene in at least one type of application. This is significant evidence that graphene is moving from the lab to the commercial sphere in a significant way. Another 24% of participants indicated that although they are not yet using graphene, they are interested in the material and are seeking to learn more about it. This is a very important indicator of potential future adoption and if combined with those that are already using graphene in at least one application, it brings us to an important 50% threshold.

Another strong indicator of commercial activity is that 23% of all survey participants report that they are buyers of graphene materials.

If we then look at research activities, we will see that academic organizations that are researching graphene represent 19% of the total responses, which translates into 78% of the more than 250 academic organizations that participated in the survey. Commercial organizations (which includes both producers and users of graphene materials) that are also researching graphene represent 17% of the total responses or 39% of all commercial organizations, a fairly high percentage.

Because we work with producers and users of graphene on a daily basis, The Graphene Council is keenly aware of the important amounts of research being driven by the commercial sector that is focused on developing real world commercial applications.

The survey results show us that application development is being pursued by 19% of commercial entities and a further 14% by academic organizations for a total of 33%, just slightly lower than the research activities. We fully expect that as graphene continues to mature, the percentage of organizations focused on application development will overtake the number that are research focused, especially as the issues of production scale, handling, dispersion and pricing are successfully addressed.

We likewise divided graphene producers into commercial and academic categories with a 17% and 12% respective distribution. It is important to make this distinction because while many academic institutions produce graphene, that material is primarily for internal use in research or application development. On the commercial side, we should note that some commercial producers in fact do not sell graphene but instead use their production 100% internally in value added products or master batch formulations.

An important 10% of the survey participants self-identified as “Intermediary” organizations which includes toll processors, functionalization services providers and other processes of enhancing graphene.

Finally, 4% of our survey participants represent regulatory bodies which can include standards setting organizations, regulatory agencies and governmental departments.

# Graphene Applications

Graphene materials are extremely versatile, with well over 40 distinct application areas that have been identified to date. This is in large part because of the unique combination of properties that graphene exhibits; strength, thermal conductivity, electrical conductivity, flex modulus, barrier properties, etc.

And while graphene is often selected for a particular property in a given application, we have consistently seen that the multi-functional nature of graphene imparts unexpected but beneficial secondary properties.

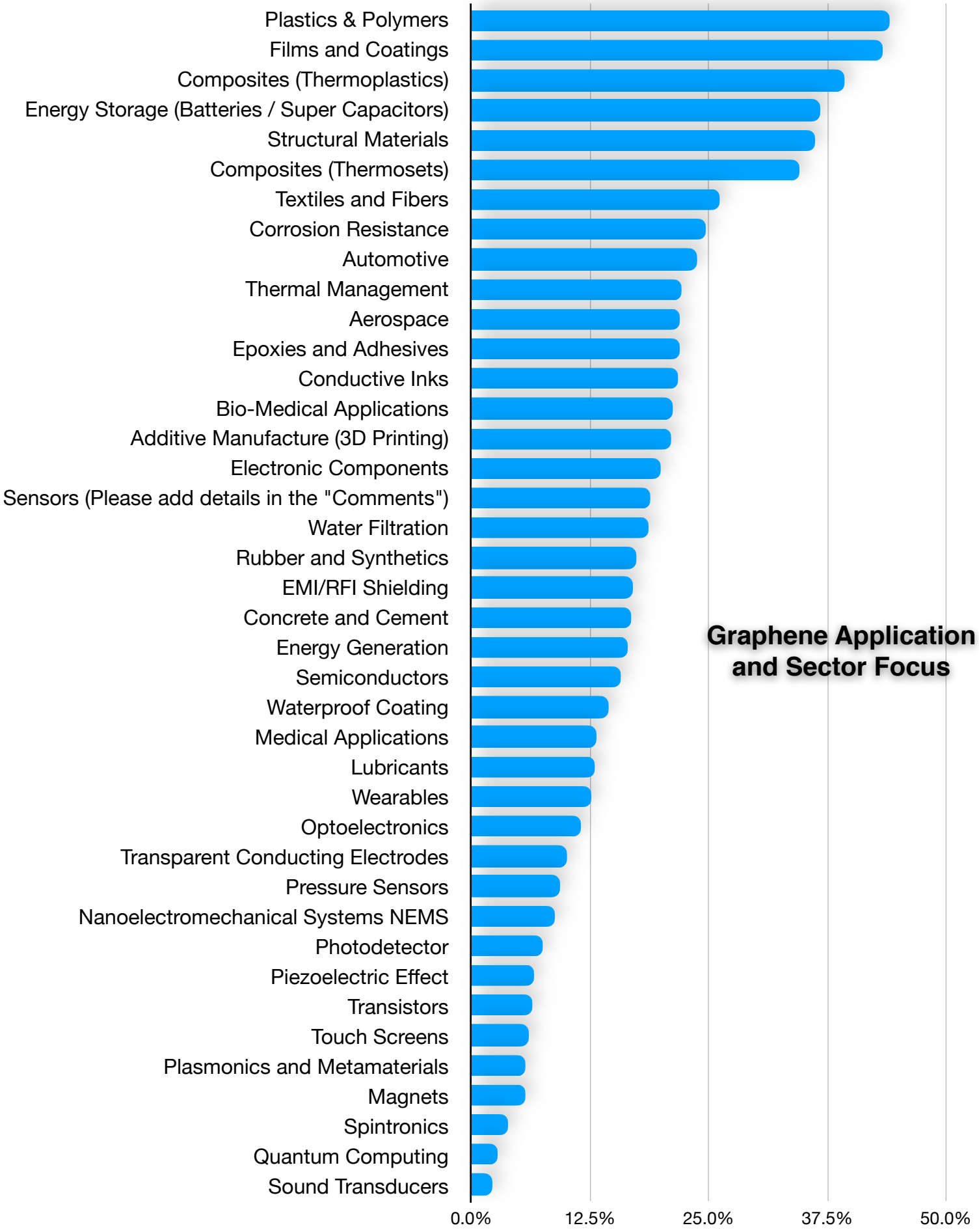
For example, graphene has been added to polyurethane for use in sacrificial liners in the mining industry to protect underlying metal parts. In this case, graphene's ability to improve abrasion resistance was the primary objective (which it did with an impressive 35% improvement). However, the addition of a small amount of graphene also made the material much more fire resistant, an important factor where welding equipment is often used in close proximity to plastic components.

In another example, extremely small amounts of graphene (as little as 0.02% by weight) have been added to cement and concrete to improve compressive and flexural strength properties (which it has in the 35% and 20% ranges respectively). However, the addition of graphene has also had the very beneficial effect of dramatically accelerating the cure rate of the material, saving valuable time on a construction site. In addition, graphene reduces water permeability after the cure, extending the life of the finished product, especially in harsh marine environments.

To drive the point home with a third example, graphene is often added to thermoplastic materials to make them stronger, add resistance to UV radiation or to elevate the thermal deformation point. In many cases, these materials are extruded. The unintended secondary benefit however is that the materials are able to be processed at a higher speed than non-graphene enhanced materials, increasing throughput and efficiencies.

The cost of adding graphene to a host material is just one side of the equation and because so little of graphene is often needed, that cost factor is not as large as many assume. What potential users of graphene should understand for their target applications is that the overall benefits of using graphene and the price/performance tradeoff should be taken into account.

In most cases when using graphene as an additive to improve a host material, there is little to no change in the capital equipment needed or the processes used, meaning there are few real barriers to making use of graphene materials.


Plastics & Polymers
Films and Coatings
Composites (Thermoplastics)
Energy Storage (Batteries / Super Capacitors)
Structural Materials
Composites (Thermosets)
Textiles and Fibers
Corrosion Resistance
Automotive
Thermal Management
Aerospace
Epoxies and Adhesives
Conductive Inks
Bio-Medical Applications
Additive Manufacture (3D Printing)
Electronic Components
Sensors (Please add details in the "Comments")
Water Filtration
Rubber and Synthetics
EMI/RFI Shielding
Concrete and Cement
Energy Generation
Semiconductors
Waterproof Coating
Medical Applications
Lubricants
Wearables
Optoelectronics
Transparent Conducting Electrodes
Pressure Sensors
Nanoelectromechanical Systems NEMS
Photodetector
Piezoelectric Effect
Transistors
Touch Screens
Plasmonics and Metamaterials
Magnets
Spintronics
Quantum Computing
Sound Transducers
0.0%
12.5%
25.0%
37.5%
50.0%
Graphene Application and Sector Focus

In a subsequent section of this report, we will discuss the various forms of commercially available graphene materials in more detail. In general, graphene can be divided into two very broad categories; Bulk and Monolayer.

Bulk Graphene refers to forms of the material that can include single or monolayer materials but are typically comprised of multi-carbon layered materials. This group of materials includes Graphene Nanoplatelets (GNPs), Graphene Oxide (GO), reduced Graphene Oxide (rGO) and other forms of graphene that are typically presented in the form of a black powder.

Monolayer graphene ( a single atomic layer of $SP^2$ bonded carbon) is typically, but not exclusively, produced by Chemical Vapor Deposition (CVD) processes and is presented in the form of a “sheet”, either on a substrate, wafer or free standing.

| Application | Type of Graphene |
|---|---|
| Additive Manufacture (3D Printing) | Bulk |
| Aerospace | Bulk/Monolayer |
| Automotive | Bulk |
| Bio-Medical Applications | Bulk/Monolayer |
| Composites (Thermoplastics) | Bulk |
| Composites (Thermosets) | Bulk |
| Concrete and Cement | Bulk |
| Conductive Inks | Bulk |
| Corrosion Resistance | Bulk |
| Electronic Components | Monolayer |
| EMI/RFI Shielding | Bulk |
| Energy Generation | Bulk/Monolayer |
| Energy Storage (Batteries / Super Capacitors) | Bulk |
| Epoxies and Adhesives | Bulk |
| Films and Coatings | Bulk/Monolayer |
| Lubricants | Bulk |
| Magnets | Bulk |
| Medical Applications | Bulk/Monolayer |
| Nanoelectromechanical Systems NEMS | Monolayer |
| Optoelectronics | Monolayer |

| Application | Type of Graphene |
|---|---|
| Photodetector | Monolayer |
| Piezoelectric Effect | Monolayer |
| Plasmonics and Metamaterials | Monolayer |
| Plastics & Polymers | Bulk |
| Pressure Sensors | Monolayer |
| Quantum Computing | Monolayer |
| Rubber and Synthetics | Bulk |
| Semiconductors | Monolayer |
| Sensors | Monolayer |
| Sound Transducers | Bulk |
| Spintronics | Monolayer |
| Structural Materials | Bulk |
| Textiles and Fibers | Bulk |
| Thermal Management | Bulk |
| Touch Screens | Monolayer |
| Transistors | Monolayer |
| Transparent Conducting Electrodes | Monolayer |
| Water Filtration | Bulk/Monolayer |
| Waterproof Coating | Bulk |
| Wearables | Bulk/Monolayer |

Each specific form of graphene has attributes that make it better suited for certain applications over others. For some applications, it is possible to make use of either bulk graphene or monolayer graphene.

The tables on the preceding page give a general indication of which types of graphene are able to be used for the different application areas identified.

In general, electronic and sensing applications will make use of monolayer forms of graphene while bulk graphene materials are typically the material of choice when used as an additive in a host material.

Please note that there are almost no cases where a device or product is entirely made from graphene itself. Instead, graphene should be viewed as an important enabling technology and advanced material. Even in the cases where monolayer graphene is used for delicate sensing applications, it is part of a larger device or system.

There are several points that we wish to stress regarding the use of graphene:

- An extremely small amount of graphene (often less than 1% by weight or even in the tenths or hundredths of a percent by weight) can have a dramatic impact on performance.
- There are significant differences in how graphene performs based on the specific morphology, any chemical groups and surface chemistry, functionalization, form factor (powder, paste or solvent) and other aspects. It is critical to identify the right graphene for a given application.
- The processing and handling of graphene is integral to achieving success in an application (i.e. dispersion techniques). While graphene is now widely available, it requires expertise in handling, so working with experts with these skills is critical.
- Even at very low loadings as a % by weight for most applications, significant volumes of graphene will be needed for major application areas. Therefore it is important to work with producers and suppliers that have the ability to scale production with repeatable and consistent quality.

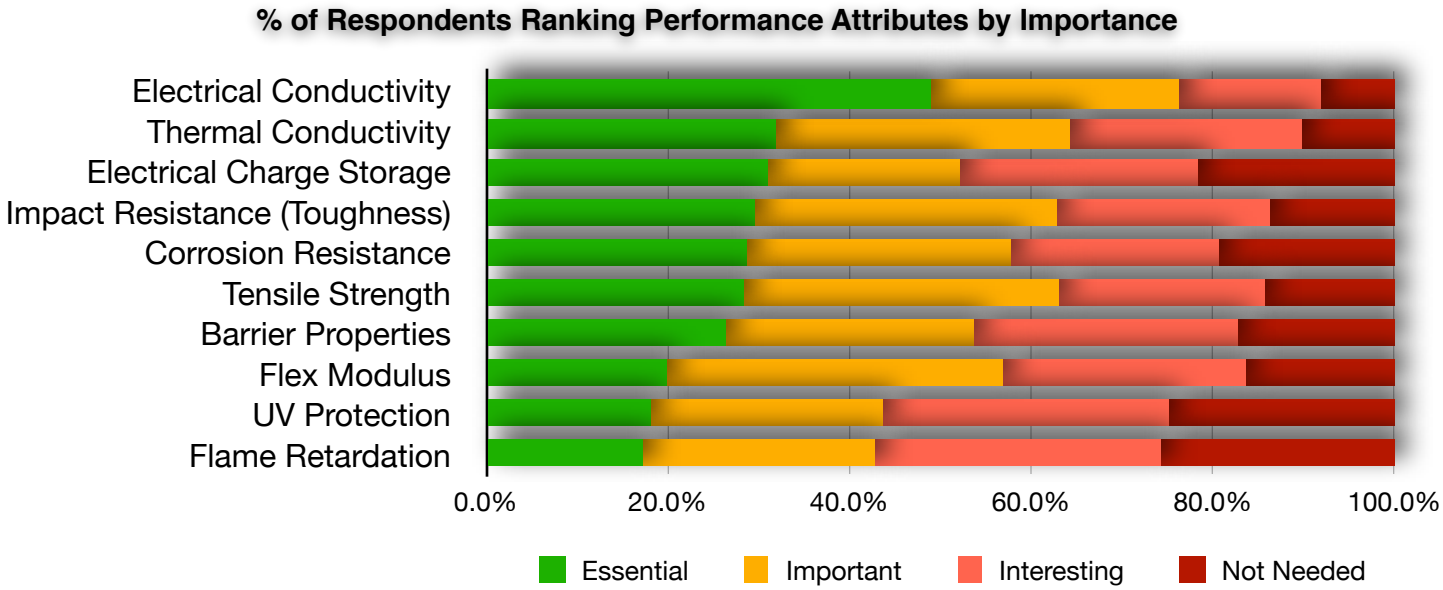
The Graphene Council works with leading graphene producers and application developers, including the Graphene Engineering Innovation Centre (GEIC) at the University of Manchester in the UK where The Graphene Council is a Tier 2 Member. The GEIC is designed to assist companies to rapidly design, build and test prototypes using graphene materials.

We also work in a similar fashion with the MackGraphe Institute at the Mackenzie Presbyterian University in Sao Paulo, Brazil.

If your organization is interested in exploiting the many properties of graphene materials to make your next generation products and applications, The Graphene Council can help connect you with qualified partners and provide you with expert advice that will save you time and money in the R&D process.

# Graphene Performance Attributes

Graphene has multiple positive attributes that almost always present themselves in combination. However, specific attributes are prioritized according to the target application. A much more detailed analysis will reveal which attributes are most appropriate for a given application. The table below gives an overview of which graphene performance attributes are most commonly desired.




Respondents were asked to rank 10 different graphene performance attributes on a scale from “Essential” to “Not Needed”.

Because graphene has near superconductor electrical mobility, it is not surprising to see that electrical conductivity was the most highly scored attribute. This is followed by thermal conductivity, which for many electrical applications would be a very complimentary performance factor. The third most desired attribute, electrical charge storage, is also complimentary to graphene’s electrical conductivity and thermal transport properties.

The next five properties (impact resistance, corrosion resistance, tensile strength, barrier properties and flex modulus) might be grouped as “physical” attributes. These are most often sought when graphene is used as an additive material to improve the host matrix, whether in an epoxy, plastic, composite or other similar application case.

Graphene’s ability to block UV radiation as well as its propensity to reduce flammability are another set of important performance attributes on their own accord or in combination.

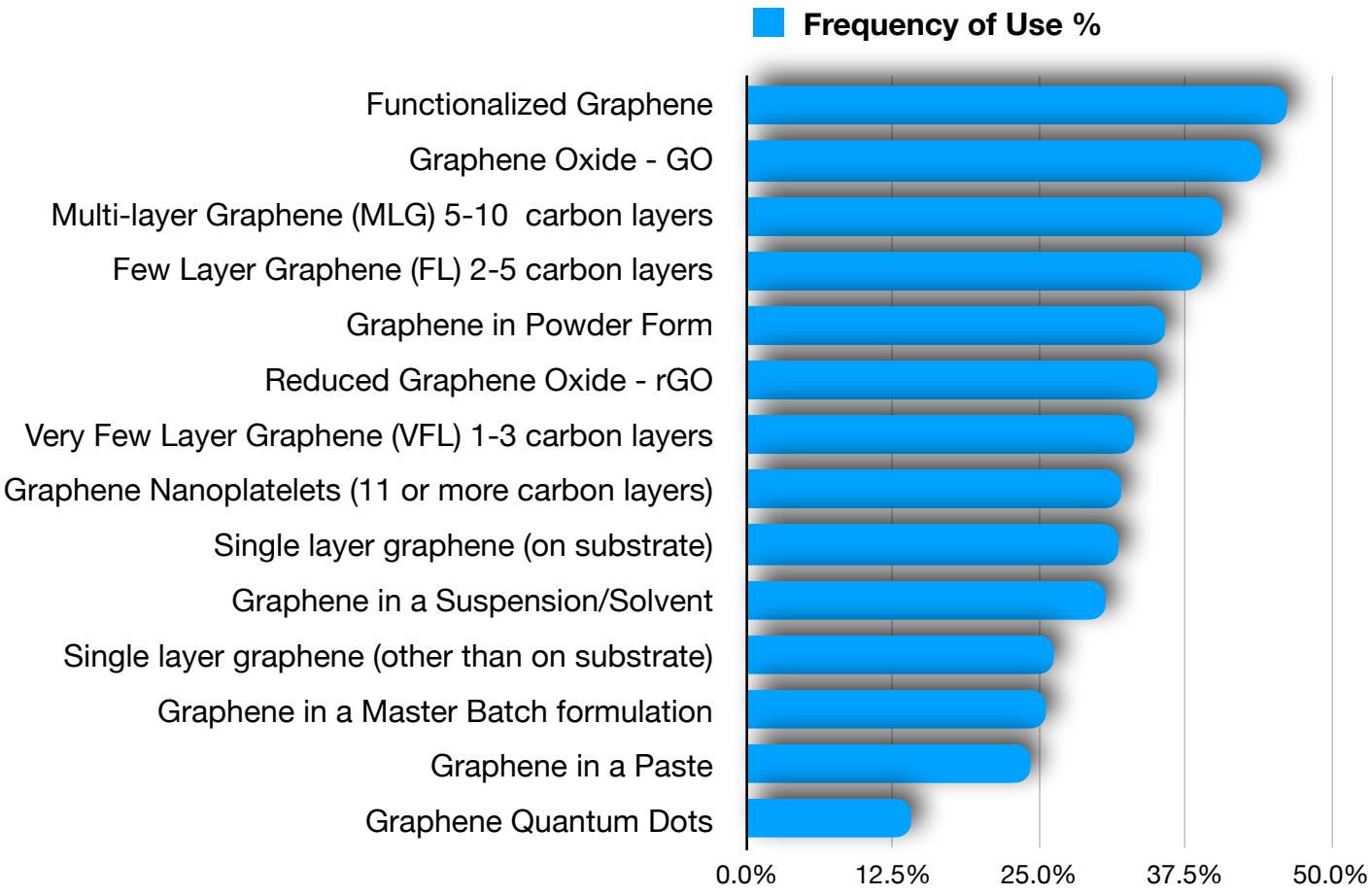
The extremely broad range of performance attributes of graphene are precisely why it is being used in more than 40 distinct applications and industry sectors.

As we will see in the next section, graphene is not one material but is really a family of advanced materials that are based on $SP^2$ bonded carbon atoms. The specific form of graphene determines which of the above attributes that material is best suited to deliver, making the selection of the most appropriate form of graphene essential.

# Commercial Forms of Graphene

As stated in the prior section, graphene is not a single material from a commercial perspective but is instead a family of advanced materials that ranges from a single atomic layer of carbon atoms to material that can be up to 10 carbon layers or more in thickness.

The carbon atomic layer count is but one aspect of classifying different forms of graphene. The lateral size of graphene flakes, the presence or absence of defects in single atomic layered crystals, the inclusion of oxygen or other elements, and the form factor (dry powder, paste, solvent, etc.) all are critical aspects of determine what type of graphene we are working with.



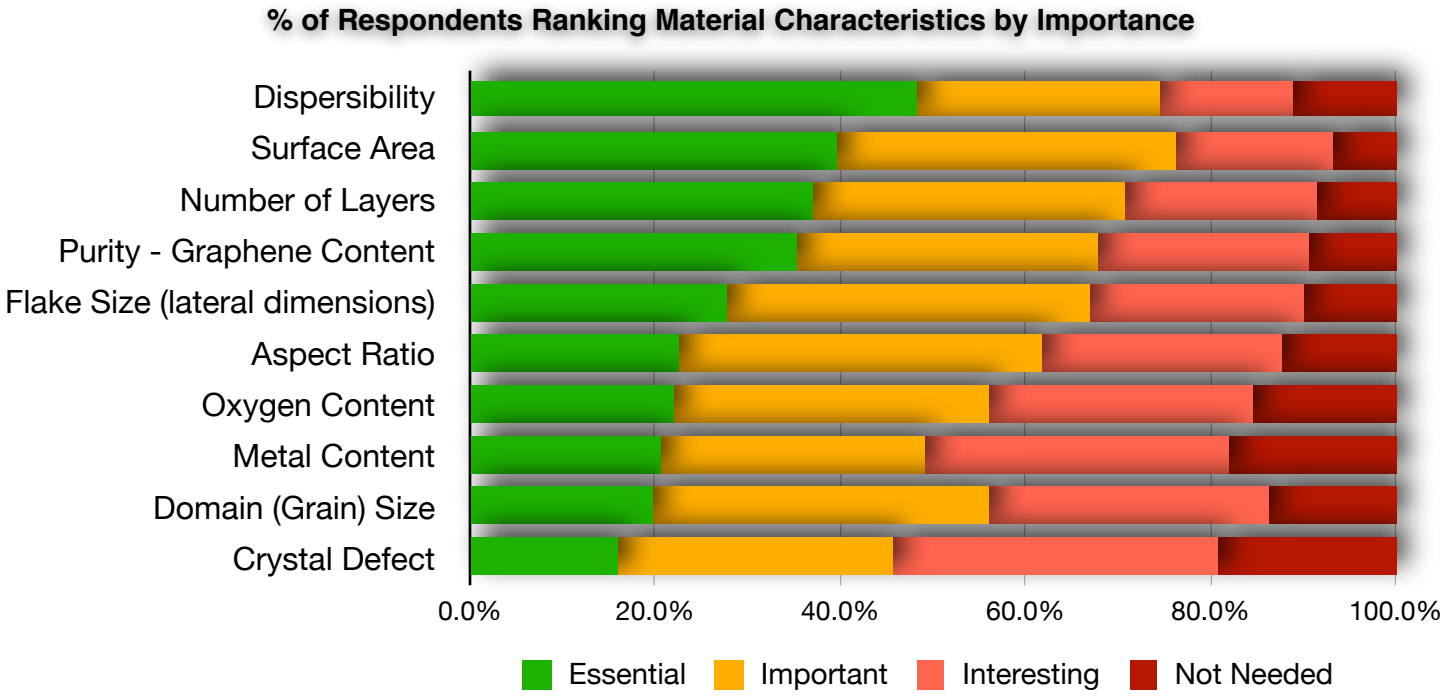

The chart above gives an indication of the complex range of formats and forms that graphene is available in from a commercial perspective. Within the categories listed above, there are even more ways of defining a specific graphene material leading to literally thousands of permutations.

This is one reason why it is critical that buyers or users of graphene work with experienced and knowledgeable producers and suppliers to make sure that the material used is “tuned” or matched to the target application.

# Graphene Material Characteristics

In contrast to the performance attributes sought from using graphene materials, the actual graphene material characteristics refer to why and how a particular graphene will perform and which performance attributes it will display.

For example, Graphene Nano-Platelets (GNP's) are hydrophobic while Graphene Oxide is hydrophilic. This in turn dramatically affects how easy or difficult it is to disperse one or the other in a particular host material or solvent.




The above 10 listed graphene material characteristics are what one would typically find included (at least in part) on a Material Specification Sheet. The actual amount of detail and items declared will differ from producer to producer and will differ depending on the type of graphene material.

At present, there is a great deal of work being done in international standards setting bodies like the International Standards Organization (ISO), American National Standards Institute (ANSI), International Electrotechnical Commission (IEC), and others, to agree which test methods are to be used to measure for a given graphene material characteristic.

For example, RAMAN Spectroscopy is often used to determine if $SP^2$ bonded carbon is present, confirming the material is graphene, or Atomic Force Microscopy (AFM) to measure the actual number of carbon layers.

The current challenge is to identify a set of consistent measurement procedures and processes that are economical, reliable and sufficiently rapid to be used in an industrial production setting.

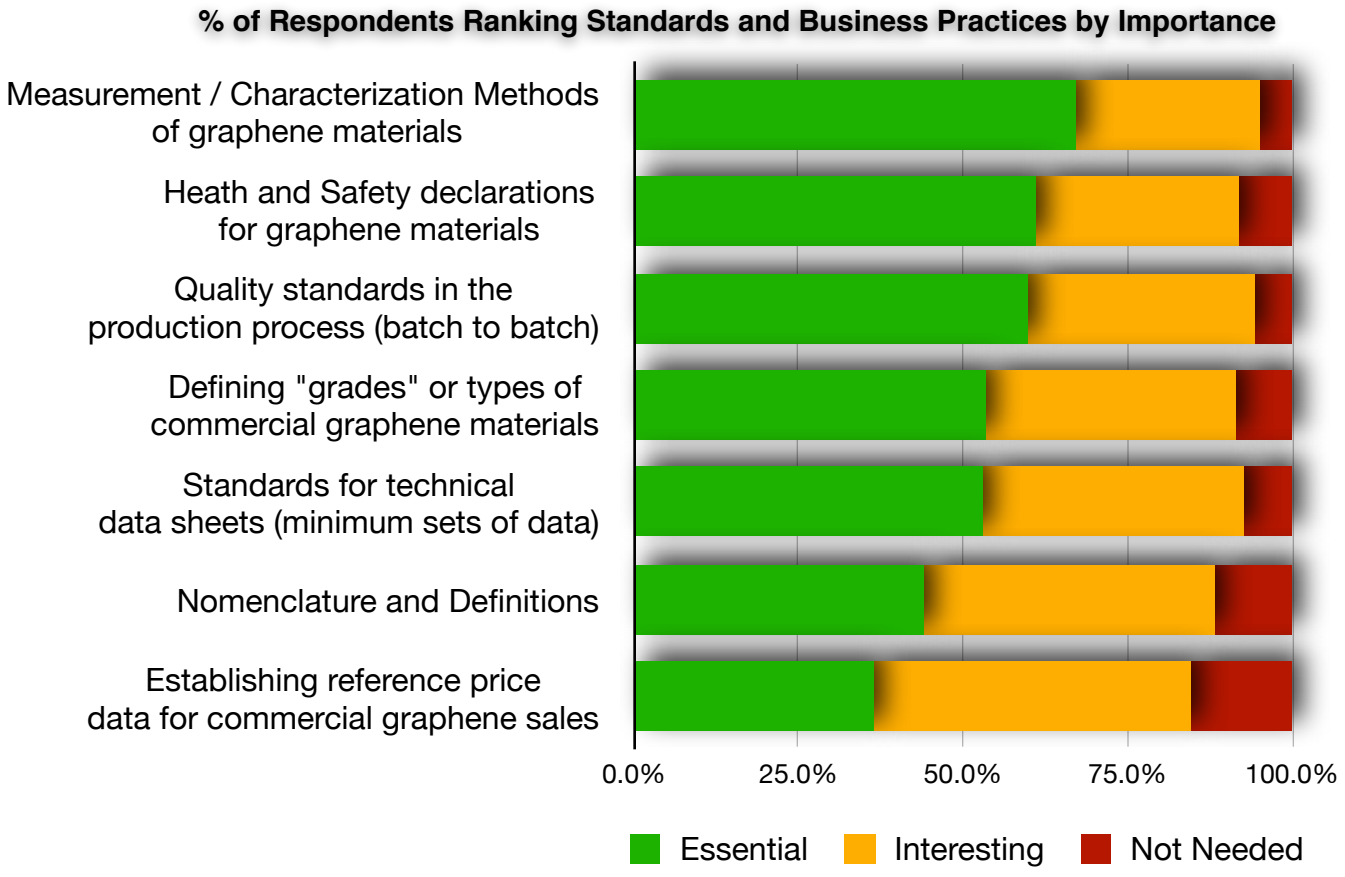
# Standards and Business Practices

If there is one topic that most frequently comes up concerning graphene materials, it is the lack of “standards”. Unfortunately, this single, clear term hides a set of very complex topics that includes the need to set standards for;

- Nomenclature, definitions and terminology
- Differing grades and types of graphene materials (and what is not graphene)
- How to measure for the different attributes and characteristics
- Verification and certification of materials, producers and products
- Health and safety related disclosures, testing and handling processes

As a new industry and material, these types of standards and best practices are in the forming and development stage. As graphene matures and becomes more widely used, the need for agreed standards across all of these domains will become essential as part of the commercialization and adoption process.

This will be an area of intense focus for The Graphene Council and member companies during 2021 as the lack of established standards, together with existing and new regulatory requirements, is seen as the next major choke point for the graphene sector.



# Obstacles to Commercial Graphene Adoption

As with any new material or technology, there are barriers to adoption and obstacles to commercialization. Graphene materials are no different and we received highly consistent feedback resulting in a prioritized list of perceived obstacles.

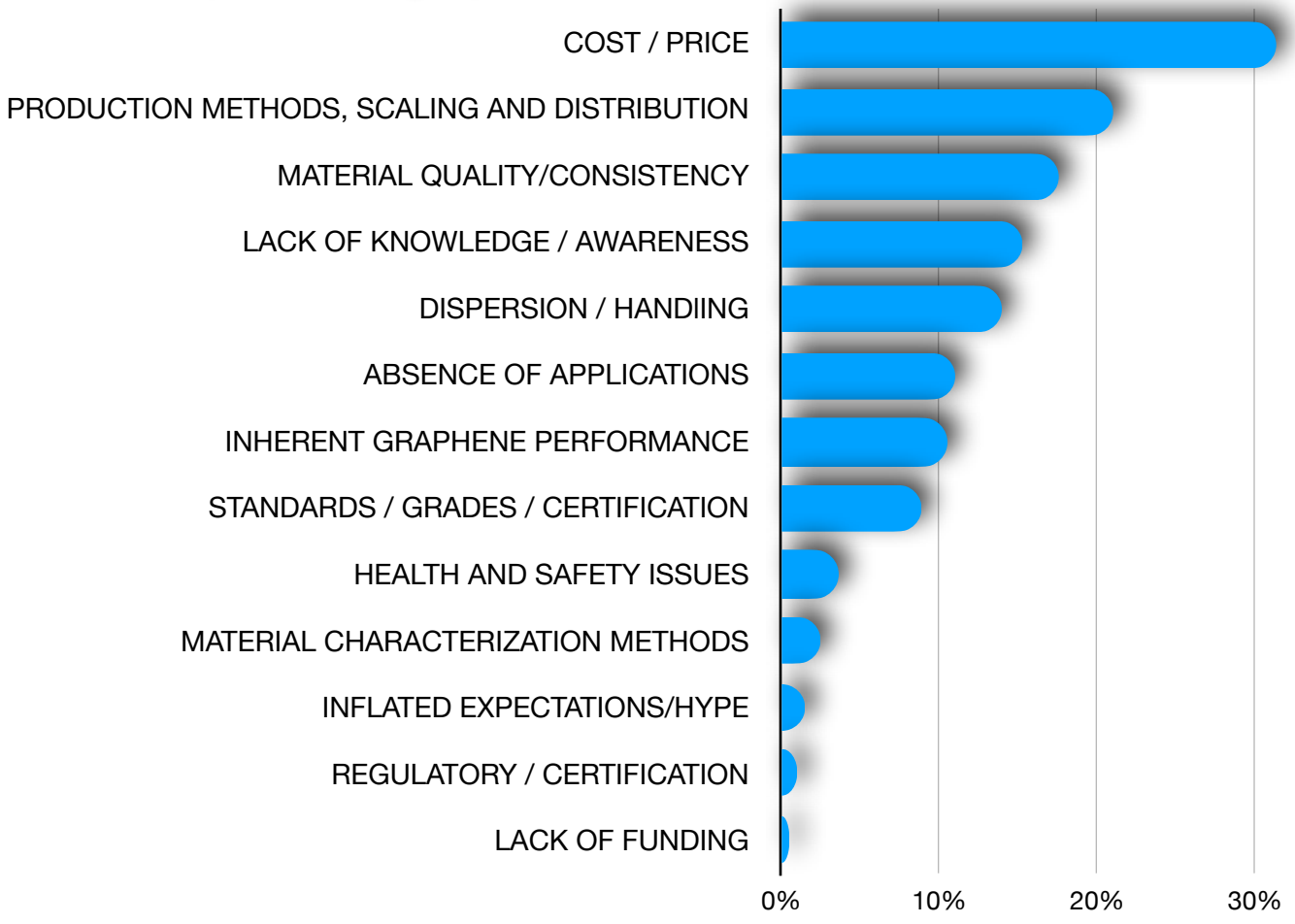
Respondents provided one or more primary obstacles to graphene adoption, many of which are to be expected along with some notable outliers out of the 14 issues identified.

The top three (3) most frequently cited obstacles to graphene adoption were;

1. The price or cost of the material on a per unit basis (see bottom of p.17 for detail).
2. The ability to either produce the material, or the availability of graphene materials on a large, industrial scale.
3. The ability to produce graphene on a repeatable basis of the required quality.

The price, scale and quality obstacles (at least one or more of these three) were cited by no less than a full 70% of respondents to this question. These three are also closely intertwined and related topics that are top of mind with virtually every graphene producer today.

**% of Respondents Citing Major Obstacles to Commercial Adoption**



4. The next most cited obstacle (4.) was a lack of knowledge or awareness. This included a lack of awareness by end-users concerning what graphene is capable of in a particular application area (samples include wide ranging sectors such as construction, healthcare, transportation, or architecture), or a lack of specific knowledge about how to handle and manipulate graphene materials (a workforce training issue).

The next four listed obstacles are in many ways related to one another.

5. Dispersion and handling of graphene materials, in particular, how to integrate graphene into a host material. In the case of single layer graphene, transfer techniques would also fall into this category.
6. The lack of obvious and numerous commercial applications was seen as an obstacle. As one participant stated; “Nobody wants to be first, everybody wants to be third, with the first 2 taking the risk.”. As more applications are announced (including many that are currently unknown because they are under Non-Disclosure Agreements), we expect a period of rapid commercial adoption.
7. The next set of comments referred to various aspects that are integral to graphene materials themselves and how they act. For example, the lack of a natural band-gap in graphene for electronics was cited as an example. This is where collaboration between researchers and commercial entities can bear fruit.
8. A lack of standards, definitions of material “grades”, verification or certification of materials or suppliers, and use of common nomenclature were all listed as significant obstacles to adoption

We see items 5-8 as having some overlap and interrelatedness. Identifying the right material for the target purpose or application is key and a lack of tools to correctly identify which graphene to use will cause potential consumers to pause, in turn causing others to wait and see what happens.

9. Health and safety related issues were the next most frequently cited obstacle to graphene commercialization, and in many cases are related to regulatory and licensing or certification listed at number 12.

Interestingly, material characterization methods, inflated expectations or “hype” and a lack of funding are all ranked quite low as significant obstacles, quite contrary to past perceptions. Further proof that graphene is moving to a new stage of maturity.

*While the nominal price of graphene may seem to be high, the fact that often a very small amount, often well less than 1% by weight, greatly reduces the direct cost impact of using graphene material. For example, a high quality graphene material that sells for $3,000 a Kg would add only $15 to a kilo of host material at a 0.5% by weight loading. For large scale uses like cement and concrete, a GNP material that sells for $50 Kg and that is added at 0.02% by weight in the finished product adds a mere 1 cent a Kg or $10 per metric ton. Depending on the end application, the type of graphene required and the load factor, graphene can impart significant performance improvements for very sustainable costs.

# Summary

This report provides an important snapshot of the state of the global graphene sector as of the end of 2020, a year in which the world was turned upside down by the global COVID-19 pandemic. Despite these challenges, much progress has continued to be made in the field of advanced materials, of which graphene is the leading player.

It is abundantly clear that graphene offers real world, game changing advances that align with the world's need for better, more sustainable solutions. To paraphrase a well known maxim, "What got you here won't get you to where you are going".

To meet the challenges of tomorrow, society will need a new class of materials, just as the industrial age relied on new industrial materials, processes and innovation to achieve new levels of human achievement.

Instead of scaling up however, we must look to materials that are engineered at the atomic level so that they are more effective, efficient and sustainable.

In the last years, carbon has come to be seen as the bane of our modern society. Through graphene, it can now be the solution.

We are moving beyond the question of "Can graphene work?", to "How do we deploy graphene on an industrial scale?".

# About The Graphene Council

The Graphene Council was founded in 2013 with a mission to serve the global community of graphene professionals. Today, The Graphene Council is the most effective and comprehensive global platform for all stakeholders with an interest in the commercial application of graphene and related materials.

The Graphene Council facilitates networking and information exchange for graphene researchers, academics, producers, developers, investors, nanotechnologists, regulatory agencies, research institutes, material science specialists and end-users. Directly, and through strategic partnerships with industry organizations, we reach hundreds of thousands of materials scientists, engineers and R&D professionals.

Our strategy has been to connect the entire ecosystem, from university based researchers to innovative graphene producers, to established end-user industry companies looking for the next advancement in materials.

The result is that we have successfully engaged a cross section of leading universities, graphene producers and industry sector companies from around the world as members of The Graphene Council.

With a global presence through offices and entities in the US, UK, Switzerland and Brazil, we invite you to **join The Graphene Council** and to take advantage of our bespoke expert advisory services and resources.

Terrance Barkan, Executive Director, **tbarkan@thegraphenecouncil.org**

## Graphene Council Members

# Appendix - Sample Survey Questions


The Global Graphene Survey 2020

*Required Question(s)

This short survey consists of just 9 questions.

Everyone that completes the survey will receive a complimentary report with the aggregated and summarized results.

Thank you for your participation!

Terrance Barkan, Executive Director, The Graphene Council


*1. Mark **EACH** category that applies to you and your organization.

- [ ] We produce graphene material
- [ ] We purchase graphene material
- [ ] We use graphene in one or more end-products
- [ ] We develop applications and uses for graphene
- [ ] We are an intermediary that modifies or supplies graphene (e.g. functionalize)
- [ ] We conduct research on graphene materials
- [ ] We are a regulatory agency or governmental body
- [ ] We do not yet use graphene but want to learn more
- [ ] Other

Comment:

500 characters left.

2. Please indicate the main uses or applications that you are working on.
Mark **EACH** that applies. **Note: The list continues on the following question.**

- [ ] Additive Manufacture (3D Printing)
- [ ] Aerospace
- [ ] Automotive
- [ ] Bio-Medical Applications
- [ ] Composites (Thermosets)
- [ ] Composites (Thermoplastics)
- [ ] Concrete and Cement
- [ ] Conductive Inks
- [ ] Corrosion Resistance
- [ ] Electronic Components
- [ ] EMI/RFI Shielding
- [ ] Energy Generation
- [ ] Energy Storage (Batteries / Super Capacitors)
- [ ] Epoxies and Adhesives
- [ ] Films and Coatings
- [ ] Lubricants
- [ ] Magnets
- [ ] Medical Applications
- [ ] Nanoelectromechanical Systems NEMS
- [ ] Optoelectronics

3. Cont'd - Please indicate the main uses or applications that you are working on.
**Please add any major uses not listed**.

- [ ] Photodetector
- [ ] Piezoelectric Effect
- [ ] Plasmonics and Metamaterials
- [ ] Plastics & Polymers
- [ ] Pressure Sensors
- [ ] Quantum Computing
- [ ] Rubber and Synthetics
- [ ] Semiconductors
- [ ] Sensors (Please add details in the "Comments")
- [ ] Sound Transducers

- [ ] Spintronics
- [ ] Structural Materials
- [ ] Textiles and Fibers
- [ ] Thermal Management
- [ ] Touch Screens
- [ ] Transistors
- [ ] Transparent Conducting Electrodes
- [ ] Water Filtration
- [ ] Waterproof Coating
- [ ] Wearables
- [ ] Other

Comment:

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4. Please rate the material performance characteristics you trying to improve with graphene?

| | Essential | Important | Interesting | Not Needed |
|---|---|---|---|---|
| **Tensile Strength** | ○ | ○ | ○ | ○ |
| **Flex Modulus** | ○ | ○ | ○ | ○ |
| **Impact Resistance / Compressive Strength (Toughness)** | ○ | ○ | ○ | ○ |
| **Thermal Conductivity** | ○ | ○ | ○ | ○ |
| **Barrier Properties** | ○ | ○ | ○ | ○ |
| **Corrosion Resistance** | ○ | ○ | ○ | ○ |
| **UV Protection** | ○ | ○ | ○ | ○ |
| **Electrical Conductivity** | ○ | ○ | ○ | ○ |
| **Electrical Charge Storage** | ○ | ○ | ○ | ○ |
| **Flame Retardation** | ○ | ○ | ○ | ○ |

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5. Which forms of graphene are of the most importance / interest to you?

Mark **EACH** that applies.

If you do not know which form applies, just answer "Not Sure" in the comments.

- [ ] Single layer graphene (on substrate)
- [ ] Single layer graphene (other than on substrate)
- [ ] Very Few Layer Graphene (VFL) 1-3 carbon layers
- [ ] Few Layer Graphene (FL) 2-5 carbon layers
- [ ] Multi-layer Graphene (MLG) 5-10 carbon layers
- [ ] Graphene Nanoplatelets (11 or more carbon layers)
- [ ] Functionalized Graphene
- [ ] Graphene Quantum Dots
- [ ] Graphene Oxide - GO
- [ ] Reduced Graphene Oxide - rGO
- [ ] Graphene in a Suspension/Solvent
- [ ] Graphene in Powder Form
- [ ] Graphene in a Paste
- [ ] Graphene in a Master Batch formulation
- [ ] Other

Comment:

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6. Please rate the level of importance to you for each of the following properties for graphene material. If you do not know, just mark "Not Sure" in the comments.

| | Essential | Important | Interesting | Not Needed |
|---|---|---|---|---|
| **Number of Layers** | ○ | ○ | ○ | ○ |
| **Aspect Ratio** | ○ | ○ | ○ | ○ |
| **Flake Size (lateral dimensions)** | ○ | ○ | ○ | ○ |
| **Domain (Grain) Size** | ○ | ○ | ○ | ○ |
| **Surface Area** | ○ | ○ | ○ | ○ |
| **Dispersibility** | ○ | ○ | ○ | ○ |
| **Crystal Defect** | ○ | ○ | ○ | ○ |

| | | | | |
|---|---|---|---|---|
| **Purity - Non-Graphene Contents and Residue** | ○ | ○ | ○ | ○ |
| **Oxygen Content** | ○ | ○ | ○ | ○ |
| **Metal Content** | ○ | ○ | ○ | ○ |

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7. **STANDARDS and PRACTICES**- Several international and national standards bodies are working on the development of graphene related standards such as nomenclature, metrology and other aspects. Please rank the level of importance of different standards and practices for you and your organization.

| | Essential | Interesting | Not Needed |
|---|---|---|---|
| **Nomenclature and Definitions** | ○ | ○ | ○ |
| **Measurement / Characterization Methods of graphene materials** | ○ | ○ | ○ |
| **Defining "grades" or types of commercial graphene materials** | ○ | ○ | ○ |
| **Heath and Safety declarations for graphene materials** | ○ | ○ | ○ |
| **Quality standards in the production process (batch to batch)** | ○ | ○ | ○ |
| **Standards for technical data sheets (minimum sets of data)** | ○ | ○ | ○ |
| **Establishing reference price data for commercial graphene sales** | ○ | ○ | ○ |
| **Other - please explain** | ○ | ○ | ○ |

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8. In your opinion, what is the single greatest barrier or obstacle to greater use and adoption of graphene materials?

9. What can The Graphene Council do to help you to better understand, develop or deploy graphene related materials and applications?