Towards Vaccinating The World

Landscape of Current COVID-19 Supply Chain and Manufacturing Capacity, Potential Challenges, Initial Responses, and Possible “Solution Space”: a Discussion Document

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1 Annex 1 – Vaccine Manufacturing Process By Technology Platform
Inactivated virus-based vaccines manufacturing process

Upstream - Cell culture operations
1. Seed stock
   - Virus
   - Induction
2. Cell growth
   - Expansion
   - Cells
3. Harvest
   - Harvest
   - Media filtration
   - Media
   - WBS
   - Bionanovator
4. Neat injection/and/or clarification

Downstream - Purification
5. Bulk freeze
   - Frozen stock
   - Frozen stock
6. Chromatography separation 1
   - Chromatography separation 1
7. Chromatography separation 2
   - Chromatography separation 2
8. Concentrate waste filtration

Fill-and-Finish
9. Formulation
   - Adjunct addition
   - Formulated DDS
10. Fill
   - Filled bottles
11. Inspection
   - Inspection
12. Ship out

Distribution

Source: Expert opinion, own calculations

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2 Annex 2 – Global COVID-19 Vaccine Manufacturing Networks

Known Vaccine Manufacturing Capacity – Moderna

Known Vaccine Manufacturing Capacity – BioNTech/Pfizer

Annualised Capacity by YE 2021

Under embargo until 9th March, 18h00 CET
Known Vaccine Manufacturing Capacity – Novavax

Annual Capacity: 2.1B

- O: Drug substance
- C: Drug product
- F: Fill & finish
- S: Strategic partner (e.g., PharmaCo)

<table>
<thead>
<tr>
<th>Partner</th>
<th>Location</th>
<th>Capacity</th>
<th>New or existing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taiwacine</td>
<td>Japan</td>
<td>250M</td>
<td>New/repurposed</td>
</tr>
<tr>
<td>Serum Institute</td>
<td>Pune, India</td>
<td>1B</td>
<td>Repurposed</td>
</tr>
<tr>
<td>MAPELM</td>
<td>Morrisville, NC, USA</td>
<td>100M</td>
<td>Existing</td>
</tr>
<tr>
<td>SK Bioscience</td>
<td>Ansan, South Korea</td>
<td>Not disclosed</td>
<td>N/A</td>
</tr>
<tr>
<td>Biobalbi</td>
<td>South Korea</td>
<td>Not disclosed</td>
<td>N/A</td>
</tr>
<tr>
<td>PolyMedicine Group</td>
<td>US, Delaware</td>
<td>Not disclosed</td>
<td>N/A</td>
</tr>
<tr>
<td>ACC Biologics</td>
<td>Denmark</td>
<td>Not disclosed</td>
<td>N/A</td>
</tr>
<tr>
<td>Orbital Internaional</td>
<td>NY, USA</td>
<td>Not disclosed</td>
<td>N/A</td>
</tr>
</tbody>
</table>

1. For COVID-19 vaccine production, no mRNA vaccines are currently commercially available.

Under embargo until 9th March, 18h00 CET
3 Annex 3 – COVID-19 Vaccine Supply Capacity by manufacturer

Potential global capacity scenarios
Billion doses

Announced 2021 manufacturing capacity targets (billions of vaccine doses)

- Moderna
- Pfizer/BioNTech
- AstraZeneca/Oxford
- Bharat Biotech
- CanSino
- Gamaleya
- Johnson & Johnson
- Sinopharm
- Novavax
- Sinovac
- SinoVac

Authorised in both EU and US
- Moderna
- Pfizer/BioNTech
- Johnson & Johnson
- Novavax
- SinoVac

Submitted to both EU and US
- AstraZeneca/Oxford
- Bharat Biotech
- CanSino
- Gamaleya
- SinoVac

Authorised or under review by both EU and US
- Moderna
- Pfizer/BioNTech
- Johnson & Johnson
- AstraZeneca/Oxford
- CanSino
- Gamaleya
- SinoVac

Authorised in EU and UK
- Moderna
- Pfizer/BioNTech
- Johnson & Johnson
- AstraZeneca/Oxford
- CanSino
- Gamaleya
- SinoVac

Authorised in at least one geography
- Moderna
- Pfizer/BioNTech
- Johnson & Johnson
- AstraZeneca/Oxford
- CanSino
- Gamaleya
- SinoVac

Authorised or under review in at least one geography
- Moderna
- Pfizer/BioNTech
- Johnson & Johnson
- AstraZeneca/Oxford
- CanSino
- Gamaleya
- SinoVac

Pipeline
- Moderna
- Pfizer/BioNTech
- Johnson & Johnson
- AstraZeneca/Oxford
- CanSino
- Gamaleya
- SinoVac

Authorised and pipeline vaccines
- Moderna
- Pfizer/BioNTech
- Johnson & Johnson
- AstraZeneca/Oxford
- CanSino
- Gamaleya
- SinoVac

~3
0.6-1.0

1.0

1-2

5-6

3.0

0.7

~12

2.1

0.5

0.1

0.2

0.3

0.5

~14

1 Assumed that each vaccine requires two doses for a full regimen, except for Johnson & Johnson's vaccine (requires one dose for full regimen).

Source: Data disclosure by manufacturers and manufacturing partners.

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4 Annex 4 – Potential Ranges Of Capacity Ramp-Up Considering Variants

Ramp-up of monthly vaccine booster supply and total production capacity in the first 2 years

- Time to reach monthly baseline capacity of 1.2 billion doses, %
- Time to reach annual baseline capacity of 14 billion doses, %

Depicted scenario is based on current vaccine portfolio (authorised for emergency use and late stage candidates with allocated supply). It assumes all other parameters remain constant and does not consider possible repurposing of manufacturing capacity from one vaccine to another. It assumes all technology platforms can be adapted to relevant variant(s), with different assumptions on speed for each platform.
5 Annex 5 – Overview of Potential Gaps in the Value Chain of Cell Culture Media Manufacturing

<table>
<thead>
<tr>
<th>Level and nature of risks</th>
<th>Capacity constraint risk?</th>
<th>Consolidated supply risk?</th>
<th>Geographic constraint risk?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical value chain</td>
<td>Low expected risk of supply challenges</td>
<td>Couple of suppliers</td>
<td>China, U.S., China, U.S., Global</td>
</tr>
<tr>
<td></td>
<td>Median expected risk of supply challenges</td>
<td>Couple of suppliers</td>
<td>Australia, Mexico, New Zealand, U.K., U.S., Global</td>
</tr>
<tr>
<td></td>
<td>High expected risk of supply challenges</td>
<td>Several suppliers</td>
<td>Austria, Japan, Netherlands, U.K., U.S., Germany</td>
</tr>
</tbody>
</table>

*Source: Expert interview, company own analysis*
### Annex 6 – Overview of Potential Gaps in the Value Chain of Lipid Nanoparticles Manufacturing

<table>
<thead>
<tr>
<th>Supply Chain</th>
<th>Upstream Manufacturing of Key Components</th>
<th>Proprietary Lipid Blend for LNP’s</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Typical Value Chain</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Output Materials</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ethanol, cholesterol, DNA, cationic lipids, PEGylated lipids, excipients, surfactants and preservatives</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Level of Risk</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capacity Constraint Risk</td>
<td>No signs of major capacity challenge</td>
<td>Refining/purification capacity potentially constrained</td>
</tr>
<tr>
<td>Current suppliers are scaling up</td>
<td>No signs of major capacity challenge, and capacity is readily fungible</td>
<td>Supply of ethanol and non-animal-based cholesterol may be constrained</td>
</tr>
<tr>
<td><strong>Consolidated Supply Risk</strong></td>
<td>Many suppliers</td>
<td>1-2 suppliers for cGMP lipids at scale</td>
</tr>
<tr>
<td>1-2 suppliers for cGMP lipids at scale</td>
<td>Many suppliers</td>
<td>Generally formulated by multiple vaccine manufacturers</td>
</tr>
<tr>
<td><strong>Geographic Constraint Risk</strong></td>
<td>Global</td>
<td>U.S. Europe</td>
</tr>
<tr>
<td>U.S.</td>
<td>Europe</td>
<td></td>
</tr>
</tbody>
</table>

*Source: Expert interviews, company data release.*
7 Annex 7 – Overview of Potential Gaps in the Value Chain of Glass Vial Manufacturing

<table>
<thead>
<tr>
<th>Supply chain</th>
<th>Supplier Tier</th>
<th>Logistics from Tier 3 to Tier 1/2</th>
<th>Logistics to plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical value chain</td>
<td>Low expected risk of supply challenges</td>
<td>Median expected risk of supply challenges</td>
<td>High expected risk of supply challenges</td>
</tr>
<tr>
<td>Output materials</td>
<td>Sodium silicate</td>
<td>Aluminium</td>
<td>Sodium silicate</td>
</tr>
<tr>
<td>Level of risk</td>
<td>Low</td>
<td>Medium</td>
<td>High</td>
</tr>
<tr>
<td>Capacity constraint risk</td>
<td>Supplier available and sustainable across supply chains</td>
<td>No signs of major capacity constraints</td>
<td>Potential capacity constraints</td>
</tr>
<tr>
<td>Consolidated supply risk</td>
<td>Several suppliers</td>
<td>Several suppliers</td>
<td>Several suppliers</td>
</tr>
<tr>
<td>Geographic constraint risk</td>
<td>Australia, China, Norway, Russia, U.S.</td>
<td>Europe, India, Korea, Turkey, U.S.</td>
<td>Global</td>
</tr>
</tbody>
</table>

1. Borosilicate is the largest glass type used in the world, catering to more than 45% of the global demand for glass and used in vials. Borosilicate is made from a single mine in France.