Flat Glass Industry Trends
[History, Current Status & Expectations]

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Bernard Savaëte
BJS.Différences
bernard.savaete@wanadoo.fr
The world drastically changed during these last 25 years (1/3):

- **Internet**
  - From 10 websites in 1992 to more than 1.8 billion sites today
    - Google (founded in 1998)
    - Linkedin (founded in 2003)
    - Facebook (founded in 2004)
    - Twitter (founded in 2006)

- **Portable telephone**
  - It took 75 years to get 100 million users on the telephone.
  - It took only 2 years to get the same amount of users for WhatsApp (founded in 2009) ...
  - By February 2018, WhatsApp had a user base of over one and a half billion.
The world drastically changed during these last 25 years (2/3):

- **Renewable energies**
  - Emergence of renewable energies
  - Development of a circular economy (where glass recycling is a key component)

- **Transition from mass production to customized “mass” production...**
  - Case of automobile

- **Planet climate change**
  - Vital signs of planet climate changes are obvious
The world drastically changed during these last 25 years (3/3):

- **Growth of income inequality** are influencing our societies
- **Terrorism**
  - Terrorism entered in Western world
- **2008 financial crisis**
- **Arab Revolutions (starting in 2010)**
  - Did modify equilibrium in Africa & Middle East
Our industry changed during these last 25 years (1/4)

<table>
<thead>
<tr>
<th>1992</th>
<th>2017/2018</th>
</tr>
</thead>
<tbody>
<tr>
<td>150 float lines</td>
<td>More than 500 lines</td>
</tr>
<tr>
<td>Mainly in Western world</td>
<td>More than 300 lines built</td>
</tr>
<tr>
<td></td>
<td>about 250 lines are running</td>
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<tr>
<td>25 lines in China</td>
<td></td>
</tr>
<tr>
<td>60% of production in EU + USA + Japan</td>
<td>Less than 20 % in EU + USA + Japan</td>
</tr>
<tr>
<td>4 Dominant companies</td>
<td>New principals:</td>
</tr>
<tr>
<td>Asahi</td>
<td>AGC, Fuyao, Guardian, Kibing, NSG, Saint</td>
</tr>
<tr>
<td>Pilkington</td>
<td>Gobain, Sisecam, Vitro, Xinyi, ...</td>
</tr>
<tr>
<td>PPG</td>
<td></td>
</tr>
<tr>
<td>Saint Gobain</td>
<td></td>
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</tbody>
</table>
Our industry changed during these last 25 years (2/4)

<table>
<thead>
<tr>
<th>1992</th>
<th>2017/2018</th>
</tr>
</thead>
<tbody>
<tr>
<td>322 Chinese patent applications on glass</td>
<td>More than 7 000 Chinese patent applications on glass</td>
</tr>
<tr>
<td>80 Korean patent applications</td>
<td>More than 1 000 Korean patent applications</td>
</tr>
<tr>
<td>word “glass” in the title or in the abstract</td>
<td></td>
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</tbody>
</table>
Our industry changed during these last 25 years (3/4)

<table>
<thead>
<tr>
<th>1992</th>
<th>2017/2018</th>
</tr>
</thead>
<tbody>
<tr>
<td>Producers were dominant</td>
<td>Downstream business is more crucial than before</td>
</tr>
<tr>
<td>Several fabricators wished to become glass producers</td>
<td>Downstream business is defining the expectations and the design and sometimes dictating sizes, performances and functionalities...</td>
</tr>
<tr>
<td></td>
<td>While all fabricators were local in the past, some are becoming regional and even global...</td>
</tr>
</tbody>
</table>
Our industry changed during these last 25 years (4/4)

Selling prices decreased

Clear glass is, today, a cheap commodity, more expensive than cement but less expensive than rice, sugar or potatoes...

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A changing industry in the world...

- Many engineering companies became able to build float lines during 1990’s
- Several large “old” companies were and are facing poor profitability and low growth
- Some new comers (getting good profitability and large growth) are becoming the new leaders
- China became the main producer of float glass
- Middle East, South East Asia & South America became key market players
The flat glass industry & business is very fragmented...

- More fragmented than many other industries
- More than 100 companies are producing flat glass in the world
  Every year we got new ones...
- Consolidations & mergers have modified equilibriums
The key influencers (1/2)

- The Chinese producers with special mention for Fuyao who is going to become, very soon, the main producer of automobile glass parts in the world, well positioned to supply the local booming market
- Saint Gobain for the automobile business and the outstanding network of fabricators in Europe (Glassolutions) - a rare successful vertical integration
- AGC for the noticeable development of AGC Glass Europe during these last 25 years
The key influencers (2/2)

- Guardian for the development of their business from 1992 to 2017 (moving from 11 float lines to 28 float lines in the world)
- Sisecam moving from 2 float lines to 11 float lines, between 1992 and 2017.
- Euroglas, Cardinal, Vitro (now the main flat glass producer in North and South America), Taiwan Glass, China Southern Glass, Xinyi, and also PPG (even if nowadays, PPG is fully outside the glass business) and also Corning.
- NSG with the acquisition of Pilkington faced difficult times... and lost influence...
To complete a review of key influencers ...(1/3)

- New independent companies: Düzce Cam (Turkey), MFG (Algeria), Obeikan (Saudi Arabia), Sphinx (Egypt), Vivix (Brazil) and the new producers of glass for LCD such as Avanstrate & LG Chem.

- During these 25 Years, several fabricators have influenced the business and the industry, through their technologies and commercial successes: Interpane (in Germany), Sedak (in Germany), North Glass (in China), Viracon (in USA), Saint Gobain Sekurit (in the World), Fuyao Automobile Fabrication (in China, Russia & USA), Xinyi (for Automobile), AGC (for automobile & architectural), China Southern Glass (in China), Oldcastle (in USA), Trösch (in Switzerland), Tecnoglass (in Colombia)…
To complete a review of key influencers…(2/3)

- The suppliers of the glass industries have also shown, during these last 25 years, their capabilities to modify practices. Especially the Engineering companies with special reference for China Triumph (CTIEC) involved in many new projects during last 10 years…
- Producers of tempering equipment with horizontal furnaces & full convection (such as Glaston) and North Glass, becoming, in a short period of time, the main supplier of tempering lines, in the world (supplier of more than 4000 lines).
To complete a review of key influencers...(3/3)

• Large restructuring of PVB producers with the development of Kuraray & Eastman.
• Several eponym companies have been successful and faced a pretty good development (such as Fenzi and Lisec, ...).
• Logistic companies such as Lannutti (in Europe) and producers of inloaders have also influenced our industry.
During the 25 Years we did not enjoy breakthrough innovations

• Several key improvements and market development of several products
• One word is almost cited by everybody, the word “Coating” and five key words could characterize products which were on the stage: “Triple” (for triple silver) – “low” (for low-e or low iron) – “Temperable” (mainly for temperable coatings) – “Extra” (Extra-thin or Extra-clear or Extra-large sizes) – “Ultra” (Ultra thin & Ultra clear, …)
• Development of electrochromic, of switchable glazing and of easy maintenance surfaces (thanks to coatings).
During these 25 years float glass processes have evolved:

- **Float lines nominal tonnage**
  Maximum moving from 800 tons per day to 1200 or even 1400 tons per day

- **Furnace campaign life**
  From 8 years in average to 15 years in average, with several lines producing during 20 years...

- **Oxy-combustion**
  And pre-heating of components

- **Extra-thin glass**
  Down to 0.1 mm

- **Special compositions**
  Borosilicates & even recently glass ceramics
During these 25 years we have observed several improvements in the fabrication processes (1/2):

- **Tempering line able to temper below 3 mm**
  Horizontal lines / better heating (forced convection)
- **Heat soak process to drastically reduce spontaneous breakage**
  Heat soak being integrated inside the process of full tempered glass production
- **Complex bending for building & automobile**
- **Lamination with or without autoclave**
  With many types of interlayers (PVB, EVA, …)
- **Digital printing on glass**
- **Cold bending**
- **Large usage of warm edge**
  Spacers for insulating glazing
- **New sealants**
  Especially transparent structural silicone from Dow
During these 25 years we have observed several improvements in the fabrication processes (2/2):

- Processing of XXL sizes
- Vacuum Insulating Glass production
- Machinery able to process soft coatings
  - Without damaging the coatings
  - Efficient edge deletion of soft coating
- Automatic assembling of insulating glass units
- Quality control on line during fabrication process
- More automatization
- Better focus on energy consumption for production
- Better focus on environment, with concern about air emissions and reduction of water consumption.
  - ....
A review of the past 25 years would not be complete without an evaluation of men and women who influenced our industry during that period of times...

I have selected
5 people from flat glass production
3 people from the processing sector
3 people from companies providing services to glass industry.
Russ Ebeid retired on 2011, with Guardian Industries. He has deeply influenced the flat glass business model.

Alev Yaraman Chief Executive of the Sisecam Flat Glass Group between 1998 and 2007. She was president of the International Commission on Glass from 2003 to 2006.

Cho Tak Wong Current Chairman of Fuyao who should become main producer of automobile glass parts in the world
Luc Willame
For the development of AGC Glass Europe during 90's & early 2000's.
He made 3 main acquisitions: Czech Republic flat glass, Russia Klin & PPG Flat Glass Europe

Roger O'Shaughnessy
For the development of Cardinal, in USA
3 People coming from processing sector

**George Hesselbach**
(Interpane) For his vision about development of low-e and the development of Interpane.

**Eric Trösch**
(Trösch) For the development of Trösch and the successful implementation of Euroglas in the flat glass industry.

**Jacques Scheuten**
(Scheuten) for his influence in the European flat glass business during the last 40 years.
3 people from companies providing services to glass industry

**Peter Lisec**
(Lisec) for the development of the family business into a key supplier of the IG industry.

**James O’Callaghan**
For his contribution in pushing the glass industry to new heights through the design of his glass structures.
He got the 2017 Phoenix Award.

**Peng Shou**
Past chairman of ICG & President of China Triumph, for his influence on the global glass industry.
Information & Education (1/3)

Many organizations have influenced our industry during these last 25 years. Development of internet has strongly modified the information and education processes.

Management of information and Knowledge (with “Big Data”, “Internet of Thing” and “Artificial Intelligence”) is nowadays a key component of companies management and strategies.
Information & Education (2/3)

Internet is providing access to many books and thesis in pdf searchable format, offering access to a huge amount of knowledge, making our industry more transparent than before...
Some of the thesis to mention during last two years

<table>
<thead>
<tr>
<th>Year</th>
<th>Thesis</th>
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</thead>
<tbody>
<tr>
<td>2016</td>
<td>Antireflective coatings for multi-junction solar cells</td>
</tr>
<tr>
<td></td>
<td>Windshield Defrost and Deice Using Carbon Nanotube Composite</td>
</tr>
<tr>
<td></td>
<td>Antibacterial surface coatings for biomedical applications</td>
</tr>
<tr>
<td></td>
<td>Economic study on recycling of building glass in Europe</td>
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<tr>
<td></td>
<td>Thermal breakage of glass</td>
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<tr>
<td></td>
<td>Laminated glass: dynamic rupture of adhesion</td>
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<tr>
<td></td>
<td>The use of building integrated photovoltaics (BIPV) towards ultra-energy efficient building</td>
</tr>
<tr>
<td></td>
<td>The effect of windows on thermal comfort</td>
</tr>
<tr>
<td></td>
<td>Improved fire performance of windows by low emissivity coatings</td>
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<tr>
<td></td>
<td>Behaviour of multi-layered laminated glass under blast loading</td>
</tr>
<tr>
<td></td>
<td>Structural Adaptive Façades</td>
</tr>
<tr>
<td>2017</td>
<td>Developing a tool to access the business concept of solar thermal façades</td>
</tr>
<tr>
<td></td>
<td>Glass melting using concentrated solar heat</td>
</tr>
<tr>
<td></td>
<td>Amorphous mirror coating for ultra-high precision interferometry</td>
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<tr>
<td></td>
<td>Glass Sandwich Panel</td>
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<tr>
<td></td>
<td>Kinetic thin glass façade</td>
</tr>
<tr>
<td></td>
<td>Post-tensioned glass beams</td>
</tr>
<tr>
<td>2018</td>
<td>Analysis of hybrid steel-glass beam</td>
</tr>
<tr>
<td></td>
<td>Feasibility study thin glasses for greenhouse roof design</td>
</tr>
</tbody>
</table>
We made some mistakes during these 25 years:

• Breakage of competition compliance rules with price fixing in Europe
• Underestimation of China capabilities
• Overinvestment & overestimation of glass for solar needs in Europe
• Commoditization of too many products
• Absence of cooperation
  
  To develop new processes & new products
• Inability to create several grades of quality (through international standards)
• Poor, inefficient R & D (no breakthrough innovation in processes and products)
Some information about current status with China (1/5)

- Until now there are totally 362 float glass production lines and a capacity of 1.295 billion boxes.
- Among them, the in-process production line takes up 231 and a capacity of 906 million boxes while that of suspending and cold repairing is 131 and 389 million boxes.
- 64 % of lines are running
- 70 % of production capacity is utilized

Reference : 20 December 2017
Some information about current status with China (2/5)

- Consolidation in China (Step by step we are moving toward a country with around 220 lines in operation, 30 of them providing product for exports)

Poor producers are disappearing...

From Xinyi by BOC International
2 June 2017
Page 8
In 2016, exports from China (Float + Safety Glass + Mirrors) was about 5.3 million ton (about production of 30 float lines)
Some information about current status with China (4/5)
Some information about current status with China (5/5)
My expectations for tomorrow...

“Change is the law of life. And those who look only to the past or present are certain to miss the future.”

John Kennedy
My expectations for tomorrow...

Macro trends will continue to influence our industry:

• Global population growth & urbanization increase
• Development of the building and construction industry
• Focus on CO2 emission
• Driverless cars
• Increased connectivity and new functionalities will appear
My 5 main expectations for business

1. Consolidation & Restructuring
   With new comers in the flat glass industry
2. China will have to reduce number of lines
3. Chinese companies will develop their business outside China
4. Many suppliers of glass producers & glass fabricators will be located outside Europe & USA (China, Korea, Turkey, ...)
5. India, South East Asia & Africa should become key development markets
My 5 main expectations for processes

1. **Focus on energy & environment**
   More electricity & oxy-fuel glass melters (stop of heavy fuel & petcoke) – $CO_2$ emission focus

2. **Dream of a new better melter**
   (or alternate melting more flexible or requiring less energy)

3. **Flat glass recycling**
   More recycled cullet (from current 15% to expected 30 to 40%)

4. **Increased furnace life to about 25 years**

5. **More expert system control for production management**
My main 5 expectations for products:

1. Each IGU produced in the world will get, at least, a low-e coating
2. Products will be bigger, thinner & more complex
3. Durability will be improved (reduced breakability, improved surface durability, ...)
4. We will have a low price smart glazing
5. Focus on comfort, will be a must (thermal comfort, visual comfort, ...) in relationship with energy management (with smart glazing)
Fabricators will face challenges during years to come.

I expect:

- Consolidation creating new large group of fabricators (some becoming regional and global)
- Complex regulations and codes
- Expensive equipment to process complex products (thin glass, large sizes, complex shapes) and to satisfy final customer
- Shorter delivery time demand
- Efficient mass customization
I expect some growth markets

- India / Africa / Asia / South America
- China (as a supplier of fabricated products)
- Glass for energy production (renewables)
- Glass for light & energy
- Renovation of existing buildings (especially in low growth regions)
- Glass recycling

I believe that glass industry will have to add 4 to 5 float lines per year to only serve the new population (within next 14 years).
The flat glass industry should invest more in several areas:

- **Research & Development**
  including cooperation with universities & others
- **Marketing**
- **Glazing for BIPV**
- **Logistic & transportation**
- **Energy efficiency**
- **A new melter**
12 bullet points to conclude

- Flat glass is a global business
- Flat glass is a commodity business
- More restructuring & consolidations
- Changing hierarchy in industry/business
- More suppliers outside western world
- Lack of breakthrough innovations
- Building, automobile, solar are key markets
- Coated glass will remain a key product
- Glass & energy will remain a focus
- Renovation - a focus for low growth regions
- Thinner glass & bigger & complex lites
- Circular economy
“A low-e coating in every insulating glass unit, for the whole world and everywhere, when useful and affordable, a smart glazing”
Do not hesitate to be in touch with myself during that NGA/GANA meeting to discuss more deeply the subject...

bernard.savaete@wanadoo.fr