Various ideas and technical foundations for achieving carbon neutral glass melting

Terutaka Maehara

AGC Inc., Innovative Technology Laboratories, Japan

AGC
Your Dreams, Our Challenge

Outline

AGC's history


Construction boom


Motorization


Coming of the era of TV


Expansion of environment-conscious businesses and products


Advancement of IT

Arrival of the IoT era

Strat of 5G communication

1907 1910s 1950s 1970s 1990s 2000s 2010s 2020s


Founded Asahi Glass Co., Ltd.
Started the flat glass business

Started manufacturing of refractories

Started manufacturing of soda ash


Started the automotive glass business


Started the business of glass valves for CRTs


Succeeded in the development of ion-exchange membrane


Started the business of alkali-free glass for LCD

Started the production of alternative CFC AK-225


Started the business of filters for tone correction for digital cameras


Started the business of chemically tempered glass for smartphones


Started the contract production business of pharmaceutical and agrochemical intermediates


Started the business of EUV mask blanks


Developed glass antenna that adds cellular base station capabilities to windows

AGC
Your Dreams, Our Challenge

AGC's position

Float flat glass
Top share worldwide

Automotive glass
Top share worldwide

Cover glass for car-mounted displays
No. 1 Worldwide

For TFT LCD/OLED Glass substrates
No. 2 Worldwide

Ultra-thin sheet for electronic equipment Soda lime glass
No. 1 Worldwide

Caustic soda PVC
No. 1 in Southeast Asia

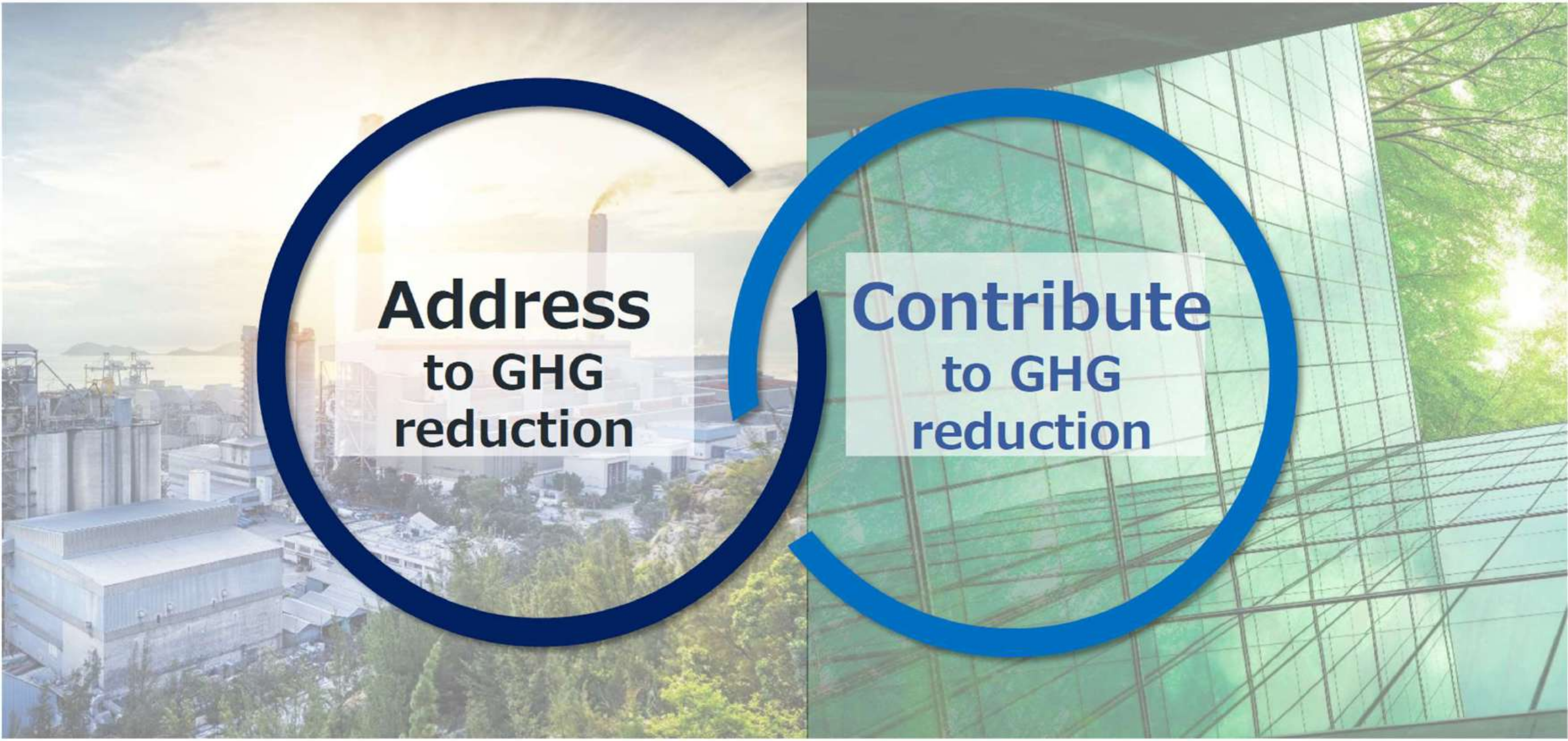
(Mountain of salt used as a raw material)

Fluoropolymer resin ETFE
No. 1 Worldwide

Fluoropolymer resin for on-site coatings
No. 1 Worldwide

*Based on AGC estimates.

Addressing Climate Change



AGC
Your Dreams, Our Challenge

Net zero carbon goal in 2050

FY2020 — FY2030 — FY2050

Net zero carbon emissions in 2050

(Scope 1+2)

2030 milestone (from the 2019 figure)

Scope 1 Scope 2	■ GHG emissions 30% reduction (Scope 1+2 emission) ■ GHG emissions per unit of sales 50% reduction (Scope 1+2emission/sales)
Scope3	■ GHG emissions 30% reduction (Total of Scope 3 emissions in categories 1, 10, 11, and 12)

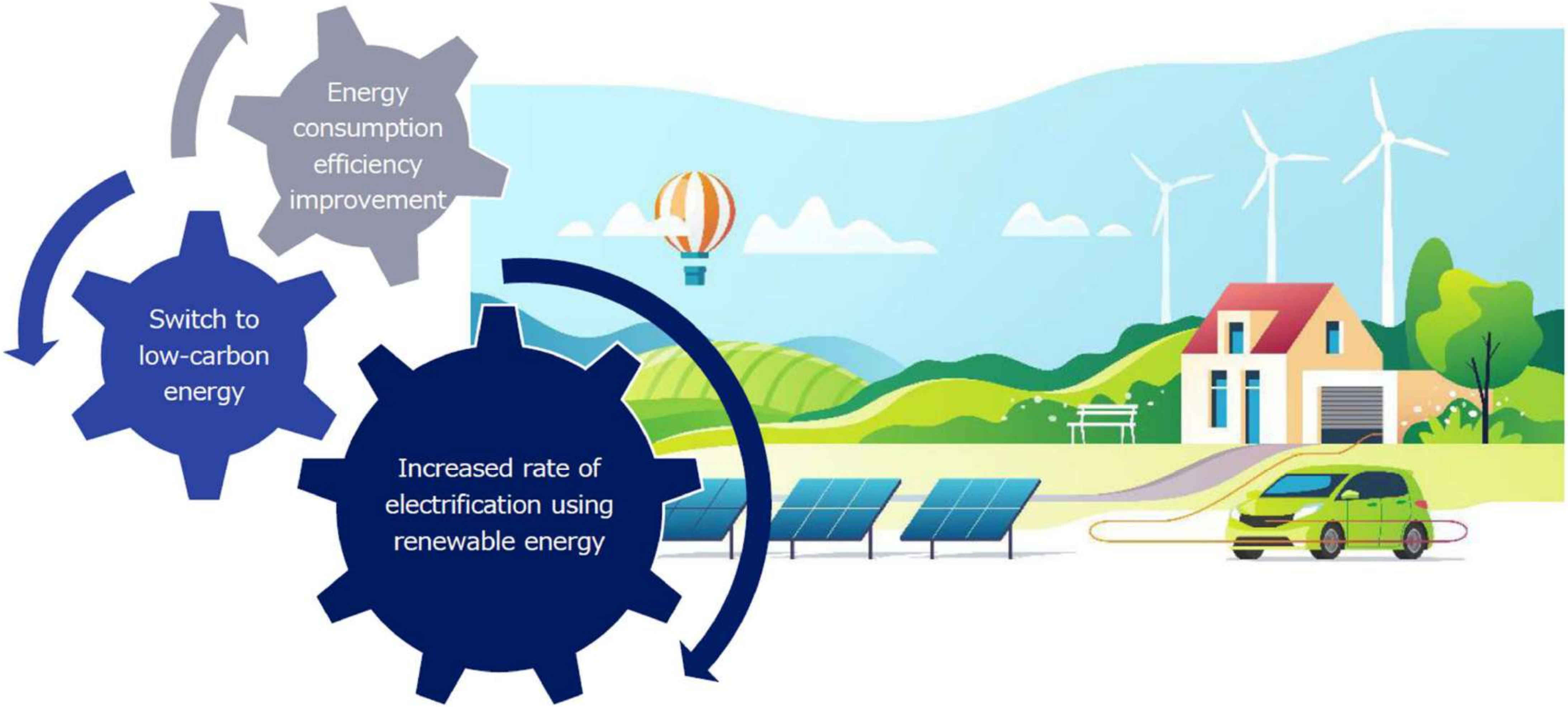
Business portfolio transformation

Expansion of strategic businesses improves carbon efficiency at a faster pace than emissions reductions

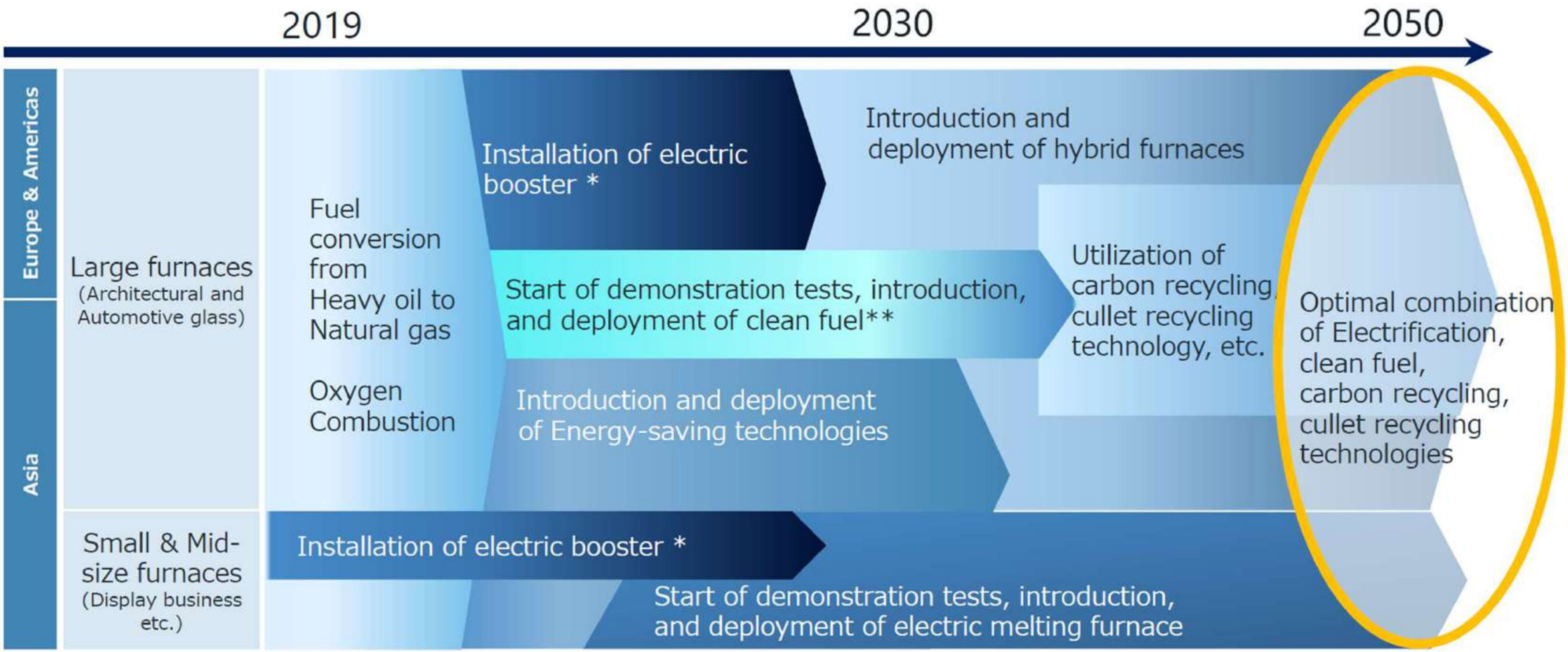
- In 2021, we formulated medium- to long-term GHG reduction targets.
- Applied for SBT certification by SBTi*, an international climate change initiative

AGC Your Dreams, Our Challenge

Global efforts to address climate change



AGC's Technology roadmap for glass furnaces



*Energized auxiliary heating **Ammonia, Hydrogen etc.

Outline

1. **Introduction**
2. **CO_2 reduction from melting energy**

   Electrification is the top priority

   → Hybrid furnace or Full-electric furnace?

   CO_2 emission factor of electricity

   → Regional strategies

   If need green combustion source

   → Ammonia just for Japan?
3. **CO_2 reduction from raw materials**

   Cullet recycling is the top priority

   Quick lime, dolime and then NaOH?
4. **CO_2 capture from glass melting furnace**

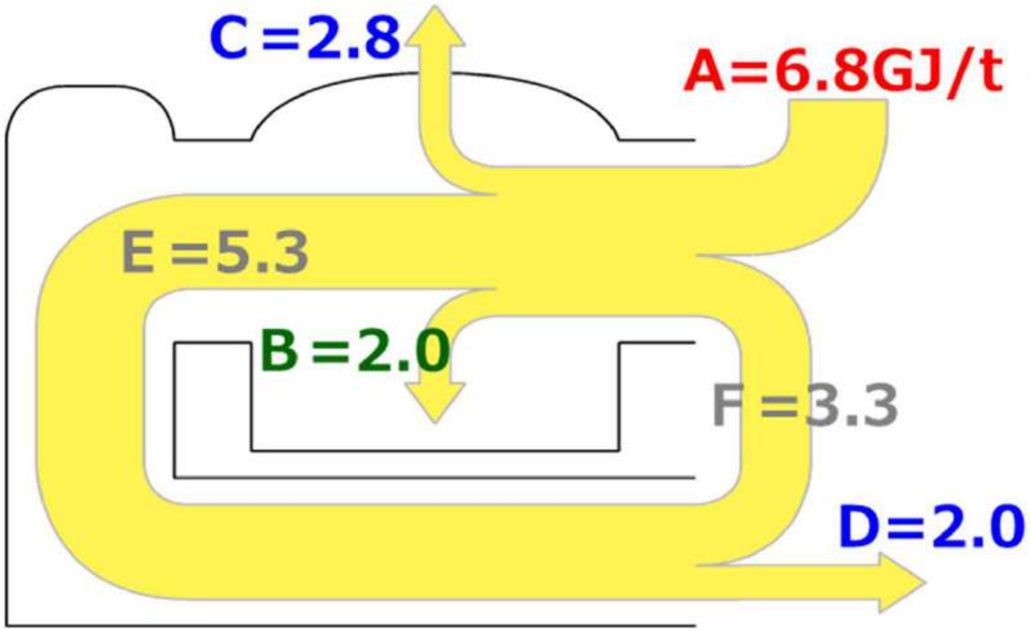
   Utilization, Storage

   or closed cycle in the factory?
5. **Ideas stand on fundamental studies**

   Briquette preheat × Cold top melting **→?**

CO_2 emission from float glass melting

0.50 t_{CO2}/t_{glass} = 0.34 from combustion + 0.16 from carbonates

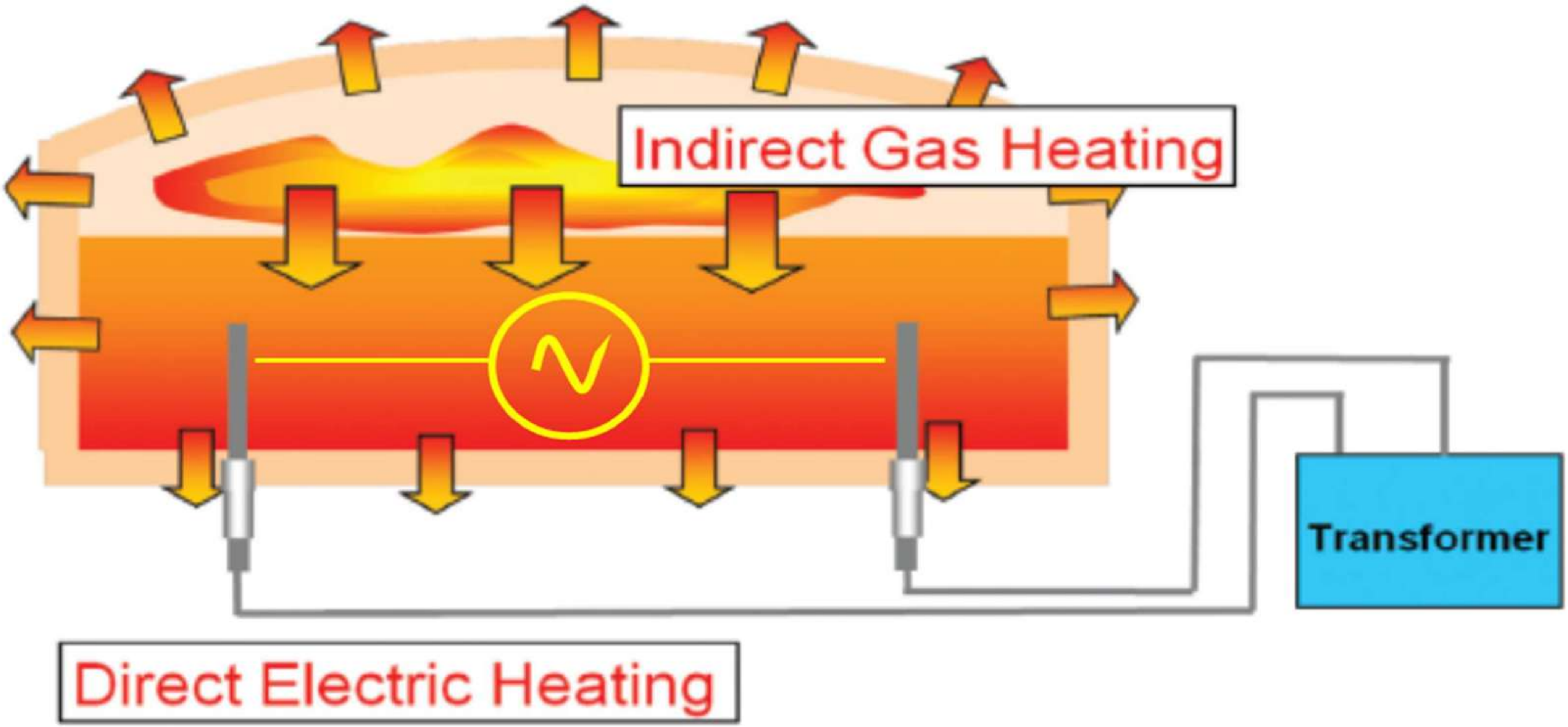


(0.051 t of CO_2 emission from 1GJ of NG combustion)

A) Heat from Gas combustion
B) Melting energy and sensible heat increase melt
C) Entire wall heat loss
D) Sensible heat waste flue gas
E) Sensible heat into regenerator
F) Sensible heat preheated air

Your Dreams, Our Challenge

Direct Electric Heating is more efficient than combustion



"Electric melting and boosting for glass quality improvement" GLASS WORLDWIDE
http://www.electroglass.co.uk/articles/2010-09%20Electric%20Melting%20&%20Boosting%20for%20Glass%20Quality%20Improvement.pdf

Measures to reduce CO_2 emission from glass melting

CO_2 emission from the combustion of fossil fuels	Energy saving	Efficient combustion: Oxy-fuel
		Waste heat recovery: WHB, ORC, BCP
		Heat loss reduction: strengthening insulation
	Energy transformation	**Electric heating (Joule heating)**
		Hydrogen, Ammonia, Biogas
CO_2 emission from the raw materials	RMs transformation	Carbon free Na, Mg, Ca sources
		Increasing recycled cullet
CCUS		Utilize the CO_2 or its derivatives
		Store the captured CO_2 underground

AGC
Your Dreams, Our Challenge

SAINT-GOBAIN

AGC and Saint-Gobain Partner for the Decarbonization of Flat Glass Manufacturing

Tokyo, February 6, 2023 - AGC and Saint-Gobain, worldwide flat glass manufacturers leading in sustainability, announce that they are collaborating on the design of a **pilot breakthrough flat glass line** that is expected to reduce very significantly its direct CO_2 emissions.

As part of this R&D project, AGC's patterned glass production line in Barevka, Czech Republic, will be entirely refurbished into a high performing & state-of-the-art line that targets to be 50% electrified and 50% fired by a combination of oxygen and gas. This is a technical breakthrough compared to current technology used in flat glass furnaces fired by natural gas. It will be **the most sustainable flat glass line design** contributing to both companies' paths towards carbon neutrality and to the necessary acceleration of the flat glass industry decarbonization.

AGC
Your Dreams, Our Challenge

Measures to reduce CO_2 emission from glass melting

CO_2 emission from the combustion of fossil fuels	Energy saving	Efficient combustion: Oxy-fuel
		Waste heat recovery: WHB, ORC, BCP
		Heat loss reduction: strengthening insulation
	Energy transformation	Electric heating (Joule heating)
		Hydrogen, Ammonia, Biogas
CO_2 emission from the raw materials	RMs transformation	Carbon free Na, Mg, Ca sources
		Increasing recycled cullet
CCUS		Utilize the CO_2 or its derivatives
		Store the captured CO_2 underground

Ammonia Combustion Technology Development Project including AGC Selected as NEDO-Commissioned Project

—Aiming to achieve net zero carbon by 2050 with innovative glass melting technology—

Tokyo, January 13, 2022—AGC Inc.(AGC), a world-leading manufacturer of glass, chemicals and high-tech materials, has been selected by the New Energy and Industrial Technology Development Organization (NEDO) as a contractor for the project: "Development of Fuel Ammonia Combustion Technology for Industrial Furnaces". AGC will develop this project jointly with Taiyo Nippon Sanso Corporation, National Institute of Advanced Industrial Science and Technology (AIST), and Tohoku University from the end of December 2021 to March 2026.

NEDO New Energy and Industrial Technology Development Organization

TAIYO NIPPON SANSO The Gas Professionals

AIST

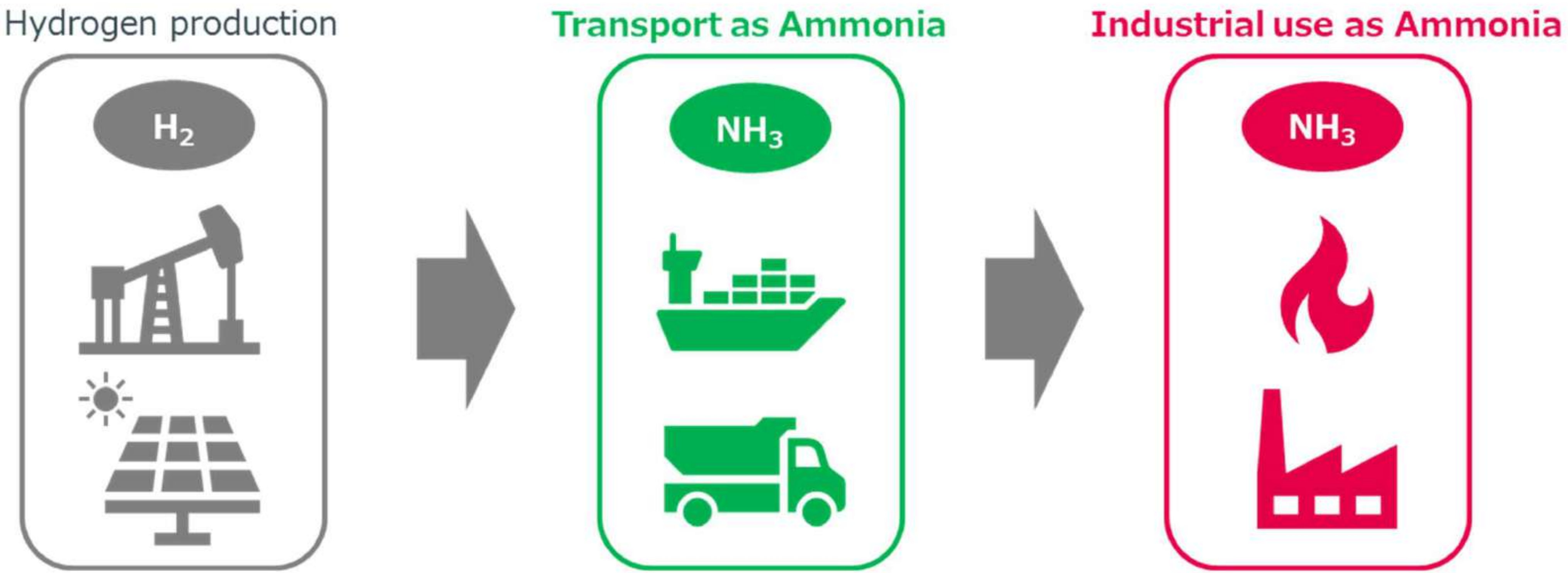
TOHOKU UNIVERSITY

AGC Your Dreams, Our Challenge

Ammonia Combustion Technology Development Project including AGC Selected as NEDO-Commissioned Project

—Aiming to achieve net zero carbon by 2050 with innovative glass melting technology—

Tok
has
for
this
Tecl



Your Dreams, Our Challenge

Ammonia Combustion Technology Development Project including AGC Selected as NEDO-Commissioned Project

—Aiming to achieve net zero carbon by 2050 with innovative glass melting technology—

Tok
has
for
this
Tecl

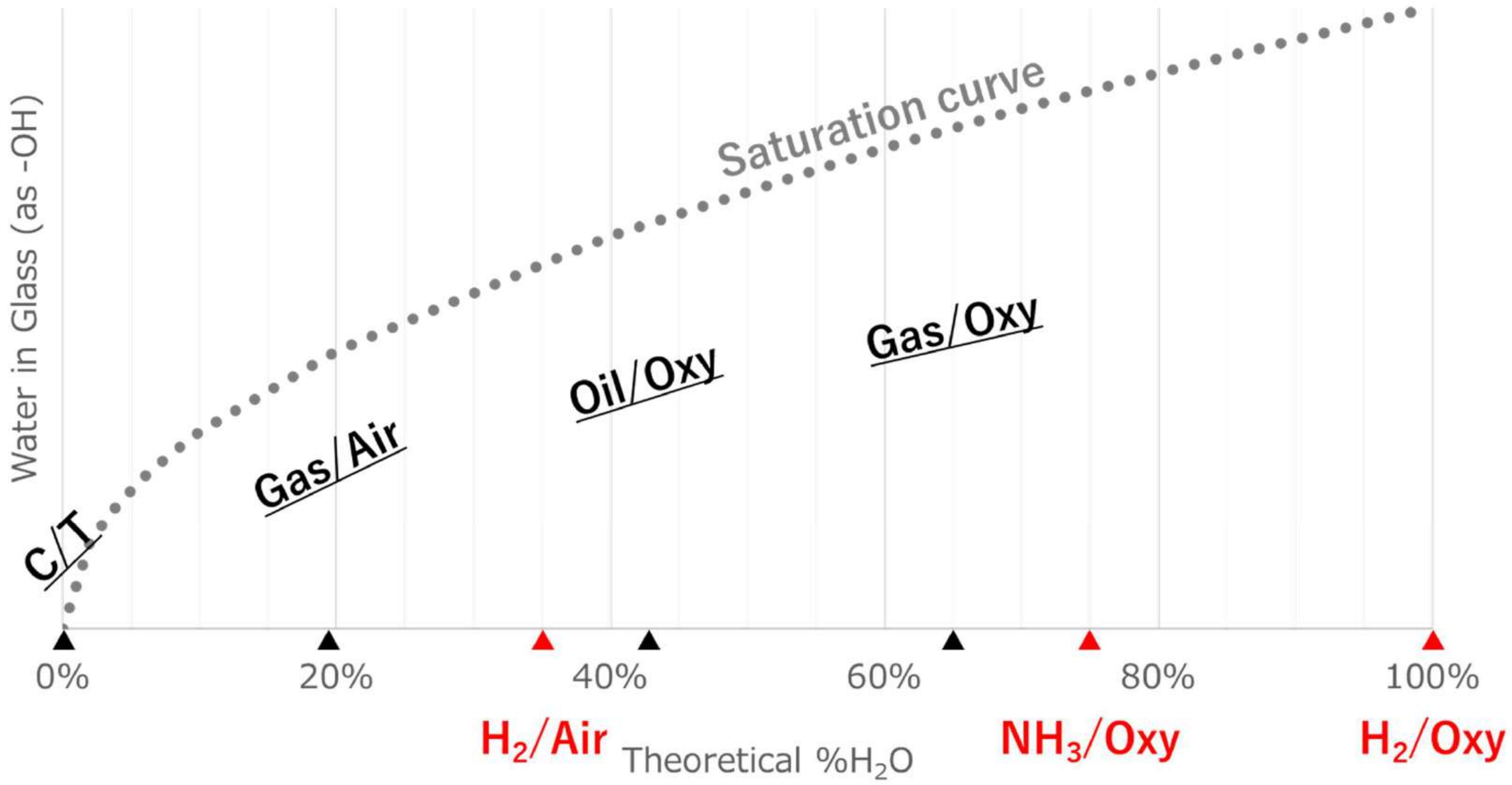
Natural gas 100%

Ammonia 100%

(Ammonia flames are hard to see because of low brightness)

Storage tank for ammonia fuel

Ammonia combustion just for Japan?



AGC
Your Dreams, Our Challenge

Measures to reduce CO_2 emission from glass melting

CO_2 emission from the combustion of fossil fuels	**Energy saving**	**Efficient combustion: Oxy-fuel**
		Waste heat recovery: WHB, ORC, BCP
		Heat loss reduction: strengthening insulation
	Energy transformation	Electric heating (Joule heating)
		Hydrogen, Ammonia, Biogas
CO_2 emission from the raw materials	RMs transformation	Carbon free Na, Mg, Ca sources
		Increasing recycled cullet
CCUS		Utilize the CO_2 or its derivatives
		Store the captured CO_2 underground

AGC
Your Dreams, Our Challenge

Outline

1. **Introduction**

2. **CO_2 reduction from melting energy**

   Electrification is the top priority

   → Hybrid furnace or Full-electric furnace?

   CO_2 emission factor of electricity

   → Regional strategies

   If need green combustion source

   → Ammonia just for Japan?

3. **CO_2 reduction from raw materials**

   Cullet recycling is the top priority

   Quick lime, dolime and then NaOH?

4. **CO_2 capture from glass melting furnace**

   Utilization, Storage

   or closed cycle in the factory?

5. **Ideas stand on fundamental studies**

   Briquette preheat × Cold top melting **→?**

CO_2 emission from float glass melting

0.50 t_{CO2}/t_{glass} = 0.34 from combustion **+ 0.16 from carbonates**

	Amount (t)	CO_2 emission (t)
Sand	0.535	0
Feldspar	0.020	0
Soda ash	0.165	0.070
Dolomite	0.140	0.065
Limestone	0.050	0.025
Salt cake	0.010	0
Cullet	0.250	0

(75%Batch/25%Cullet)

AGC Your Dreams, Our Challenge

Burned dolomite, Burned lime

$0.50\ t_{CO2}/t_{glass}$ = 0.34 from combustion **+ ~~0.16~~ from carbonates**

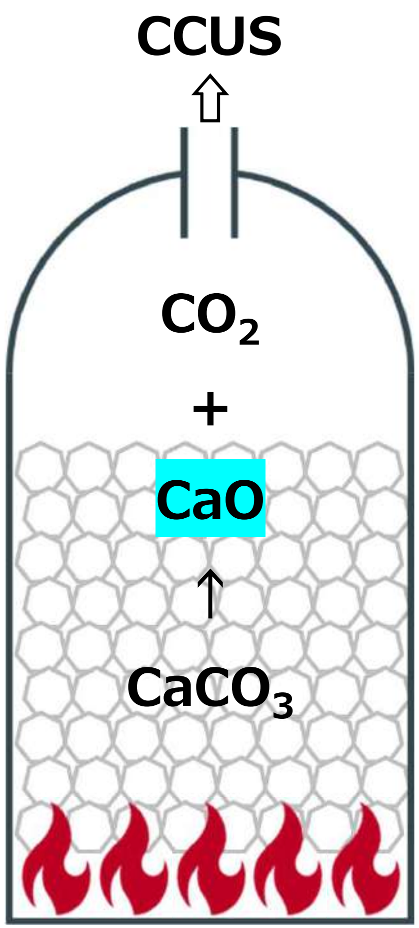
0.07 from soda ash

	Amount (t)	CO_2 emission (t)
Sand	0.535	0
Feldspar	0.020	0
Soda ash	0.165	0.070
~~Dolomite~~	~~0.140~~	0
~~Limestone~~	~~0.050~~	0
Salt cake	0.010	0
Cullet	0.250	0

Burned dolomite

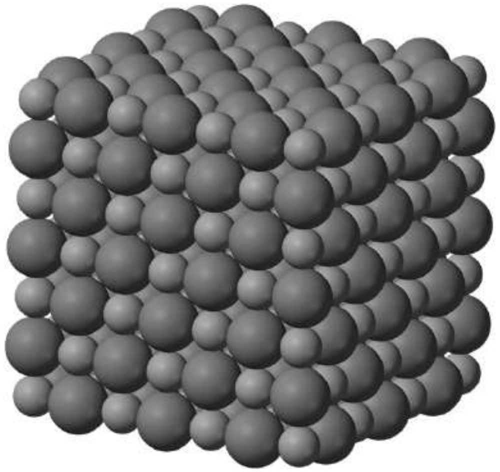
Burned lime

can replace carbonates

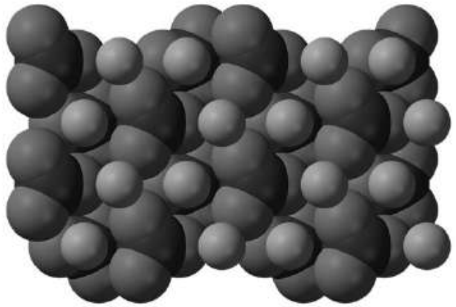


Na_2O in float glass composition, alternatives?

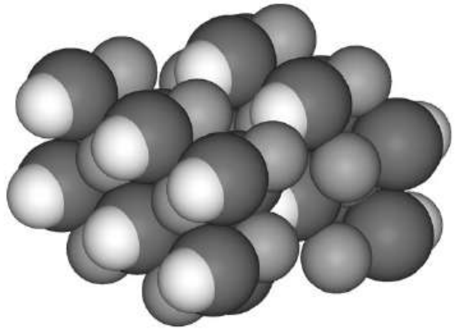
Salt
NaCl



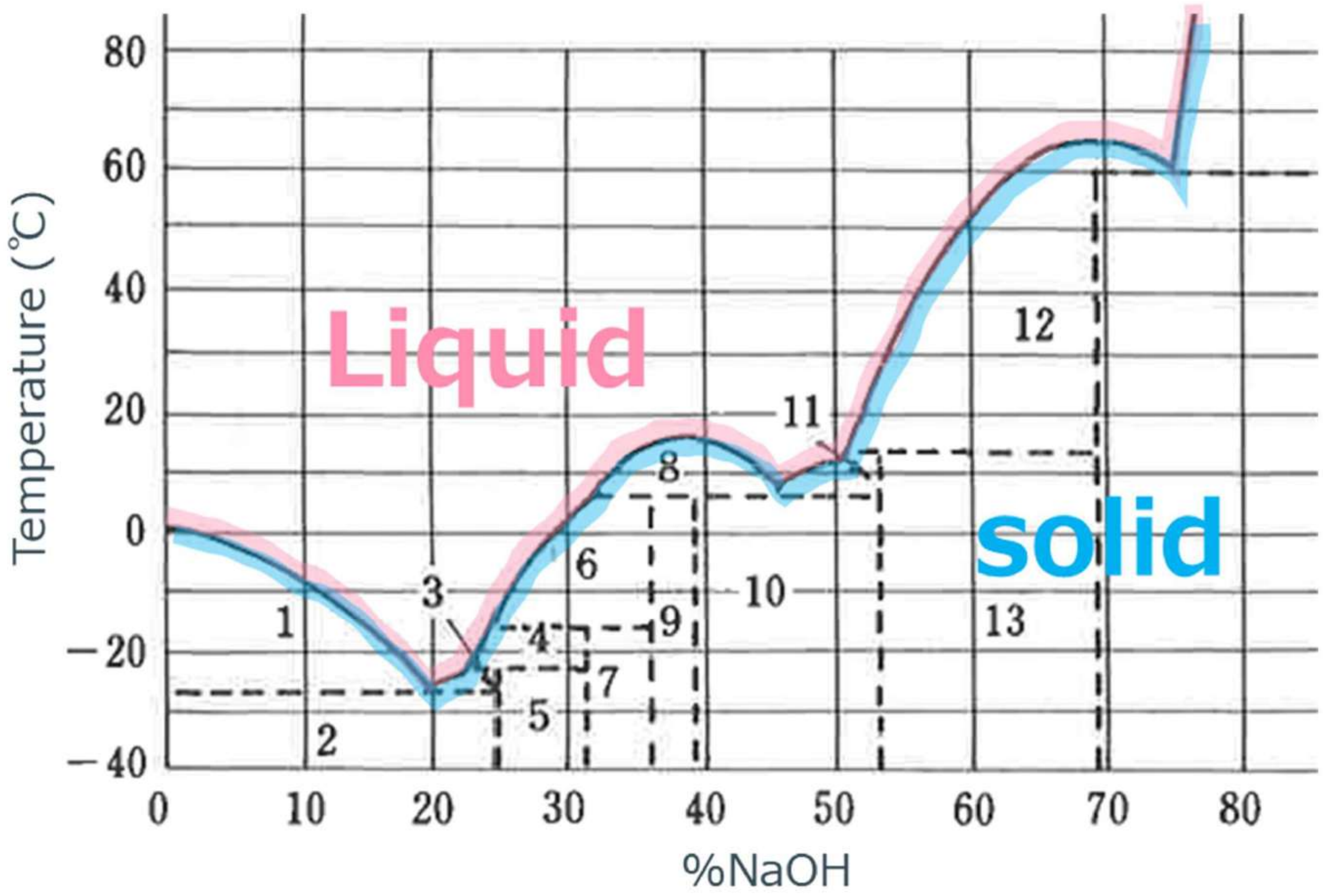
Soda ash
Na_2CO_3



Caustic soda
NaOH



Difficulty handing of NaOH



Old patents for using NaOH in glass melting

How to obtain a batch mixture that can be handled on an industrial line using NaOH aqueous solution, which is a common distribution form?

- JP-A-Sho49-31717 (1974, AGC) describes a method for vaporizing water from NaOH aqueous solution by mixing with preheated cullet.
- US4211568A (1978, PPG) describes a method for obtaining ‘dry’ glass batch mixtures by properly choosing the concentration of NaOH aqueous solution.

Since NaOH has a high vapor pressure, and its vapor is highly corrosive to bricks, batch containing NaOH would not suit for combustion furnace other than cold-top melting furnace.

Measures to reduce CO_2 emission from glass melting

<table>
<tr><td rowspan="5">CO_2 emission from the combustion of fossil fuels</td><td rowspan="3">Energy saving</td><td>Efficient combustion: Oxy-fuel</td></tr>
<tr><td>Waste heat recovery: WHB, ORC, BCP</td></tr>
<tr><td>Heat loss reduction: strengthening insulation</td></tr>
<tr><td rowspan="2">Energy transformation</td><td>Electric heating (Joule heating)</td></tr>
<tr><td>Hydrogen, Ammonia, Biogas</td></tr>
<tr><td rowspan="2">CO_2 emission from the raw materials</td><td rowspan="2">RMs transformation</td><td>Carbon free Na, Mg, Ca sources</td></tr>
<tr><td>Increasing recycled cullet</td></tr>
<tr><td colspan="2" rowspan="2">CCUS</td><td>Utilize the CO_2 or its derivatives</td></tr>
<tr><td>Store the captured CO_2 underground</td></tr>
</table>

Outline

1. **Introduction**

2. **CO_2 reduction from melting energy**

   Electrification is the top priority

   → Hybrid furnace or Full-electric furnace?

   CO_2 emission factor of electricity

   → Regional strategies

   If need green combustion source

   → Ammonia just for Japan?

3. **CO_2 reduction from raw materials**

   Cullet recycling is the top priority

   Quick lime, dolime and then NaOH?

4. **CO_2 capture from glass melting furnace**

   Utilization, Storage

   or closed cycle in the factory?

5. **Ideas stand on fundamental studies**

   Briquette preheat × Cold top melting **→?**

Measures to reduce CO_2 emission from glass melting

CO_2 emission from the combustion of fossil fuels	Energy saving	Efficient combustion: Oxy-fuel
		Waste heat recovery: WHB, ORC, BCP
		Heat loss reduction: strengthening insulation
	Energy transformation	Electric heating (Joule heating)
		Hydrogen, Ammonia, Biogas
CO_2 emission from the raw materials	RMs transformation	Carbon free Na, Mg, Ca sources
		Increasing recycled cullet
CCUS		Utilize the CO_2 or its derivatives
		Store the captured CO_2 underground

or Closed CO_2 cycle in the factory

- Reaction with NaOH
- Reaction with H_2

AGC Your Dreams, Our Challenge

Outline

1. **Introduction**

2. **CO_2 reduction from melting energy**

   Electrification is the top priority

   → Hybrid furnace or Full-electric furnace?

   CO_2 emission factor of electricity

   → Regional strategies

   If need green combustion source

   → Ammonia just for Japan?

3. **CO_2 reduction from raw materials**

   Cullet recycling is the top priority

   Quick lime, dolime and then NaOH?

4. **CO_2 capture from glass melting furnace**

   Utilization, Storage

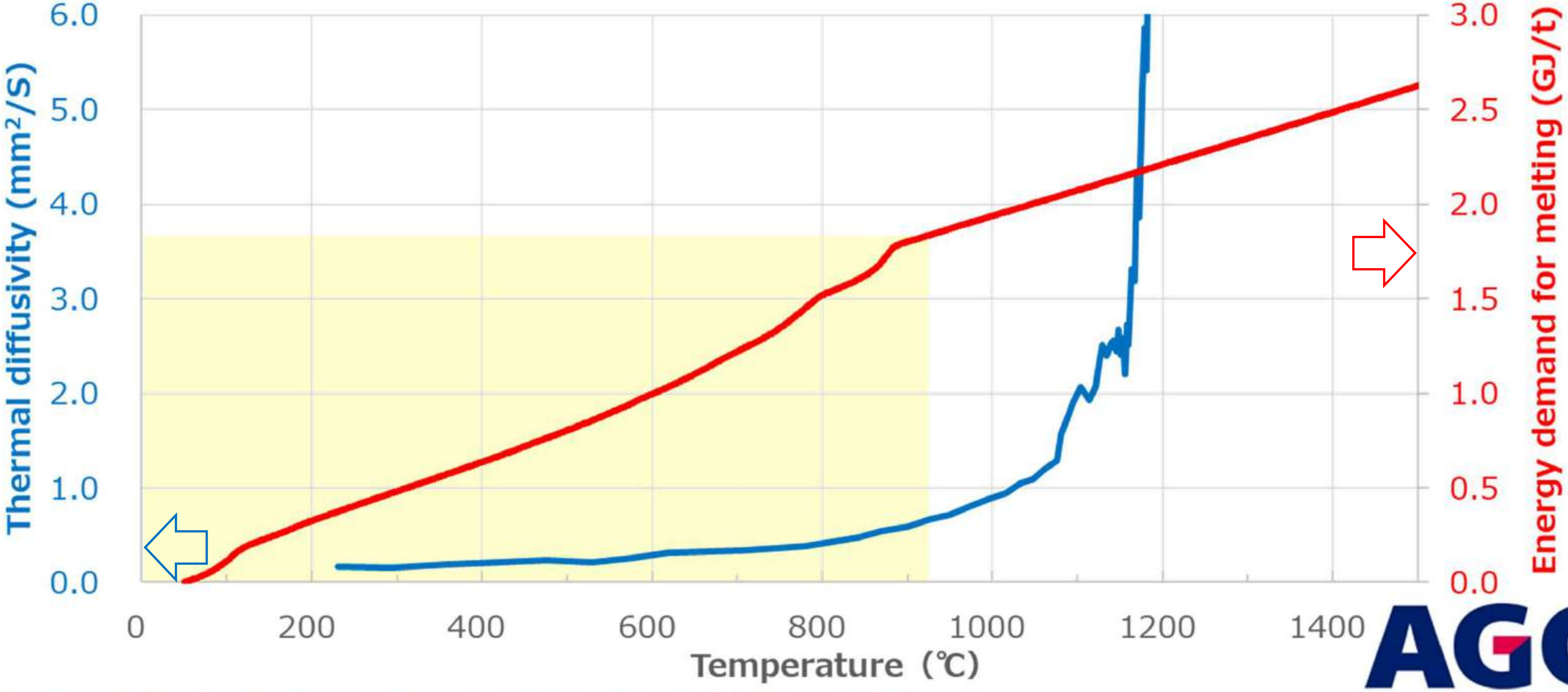
   or closed cycle in the factory?

5. **Ideas stand on fundamental studies**

   Briquette preheat × Cold top melting **→?**

Energy demand for batch to melt conversion

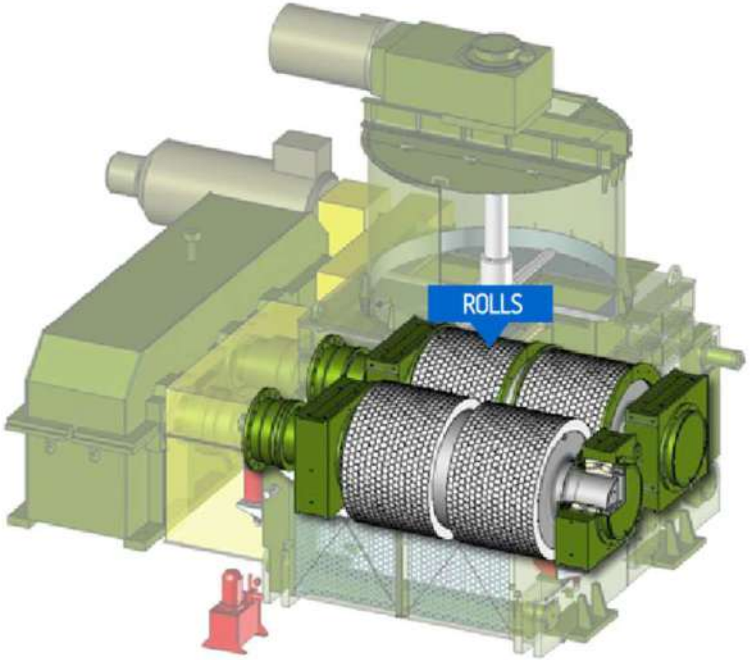
- 60-75% of the energy required to obtain 1500°C glass melt is used for ramping the temperature of the glass batch before melting.
- Thermal conductivity of the glass batch before melting (<1000°C) is as low as that of insulation bricks.



AGC
Your Dreams, Our Challenge

Glass batch briquet

www.koeppern-international.com



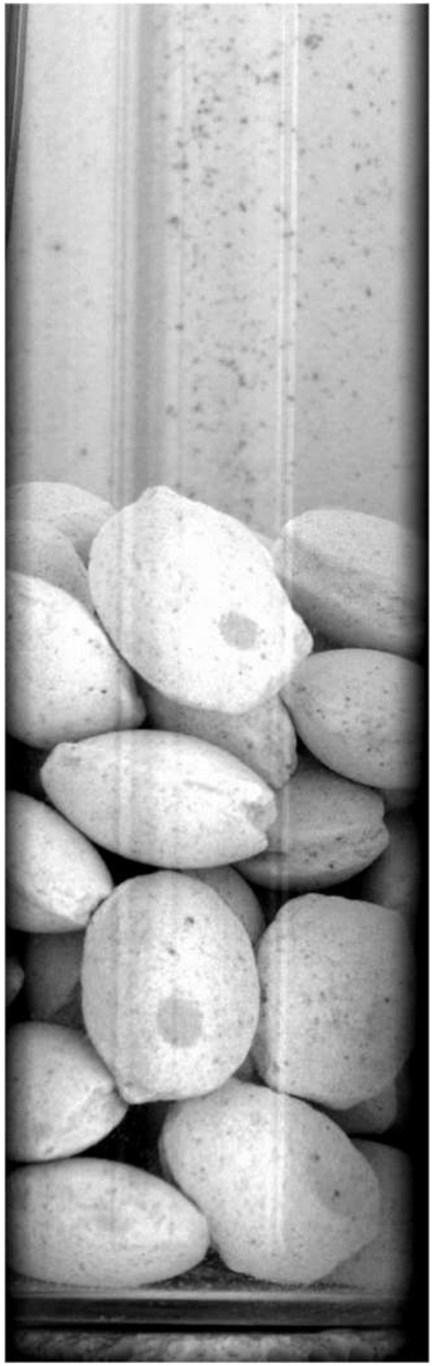
www.sahutconreur.com

A briquette is a compressed block of materials formed by twin roller presses.

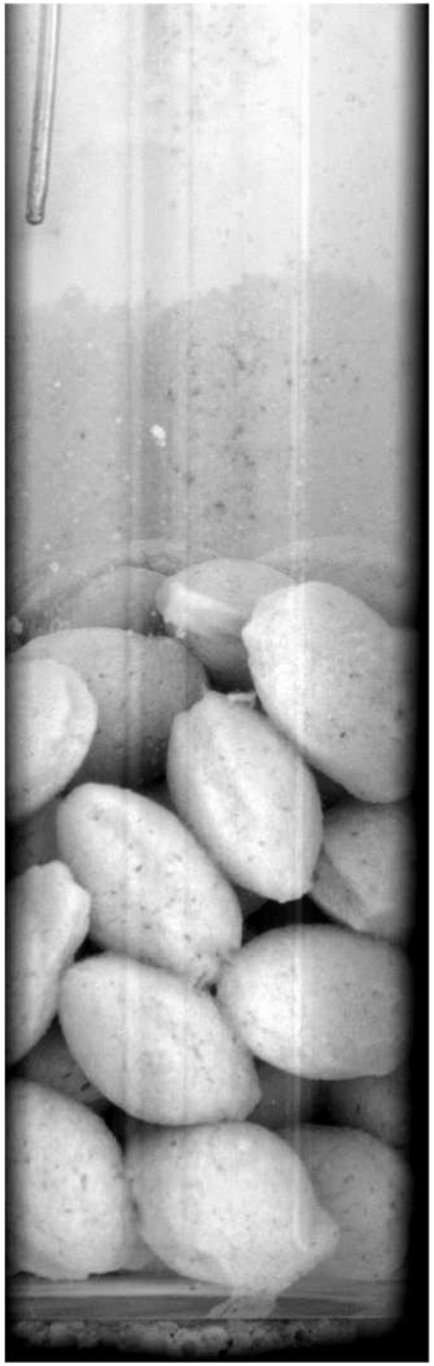
- Less moisture and binders are required than granulation process.
- No need for the drying process before feeding into the furnace.

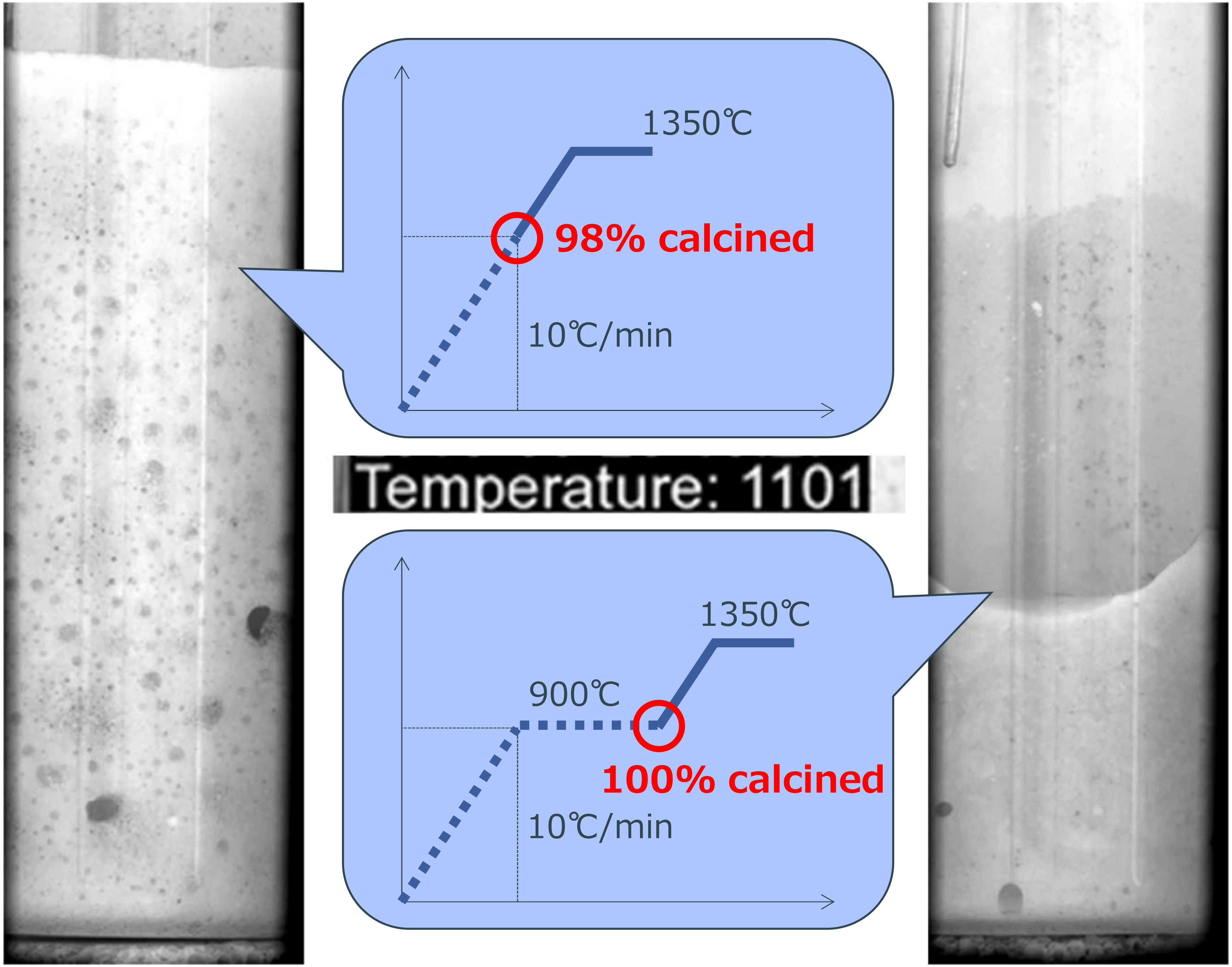
AGC

Your Dreams, Our Challenge



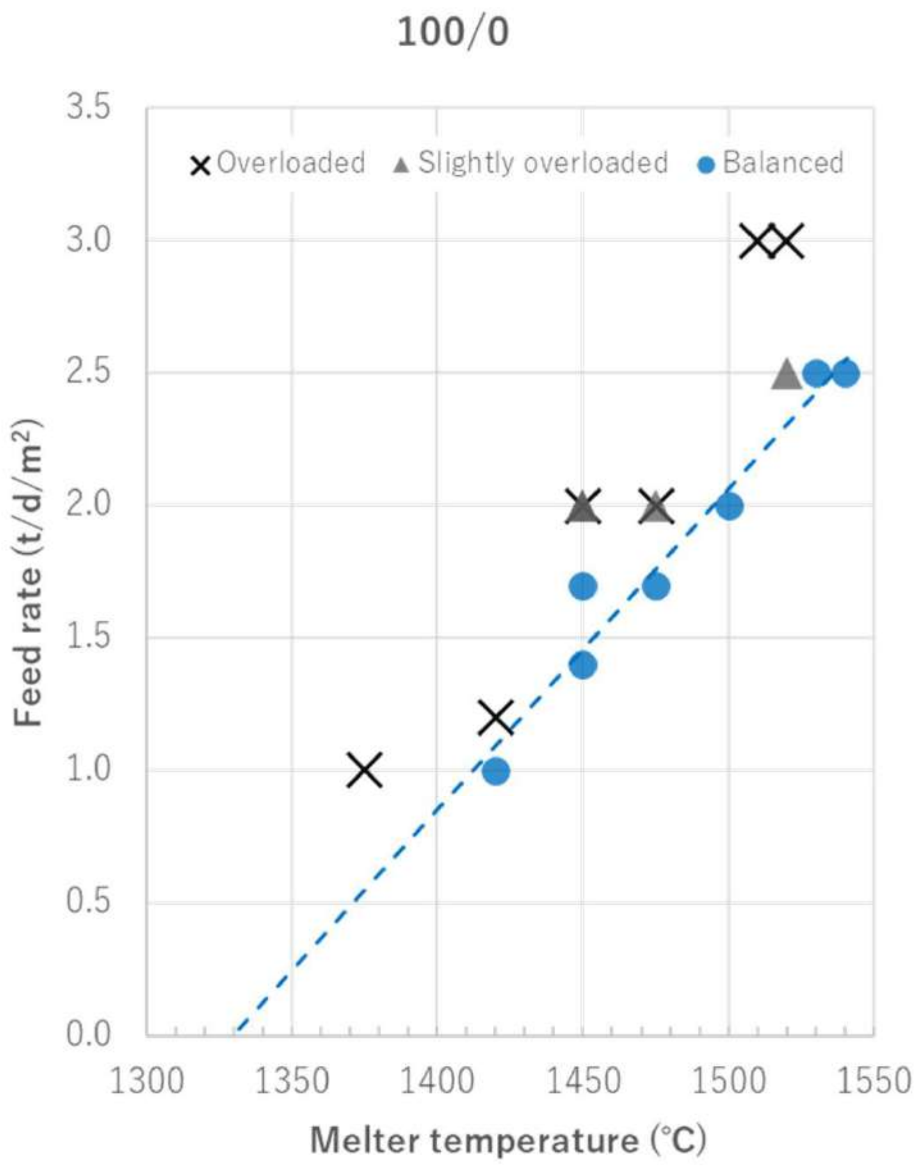
Melting-in process
900~1350℃

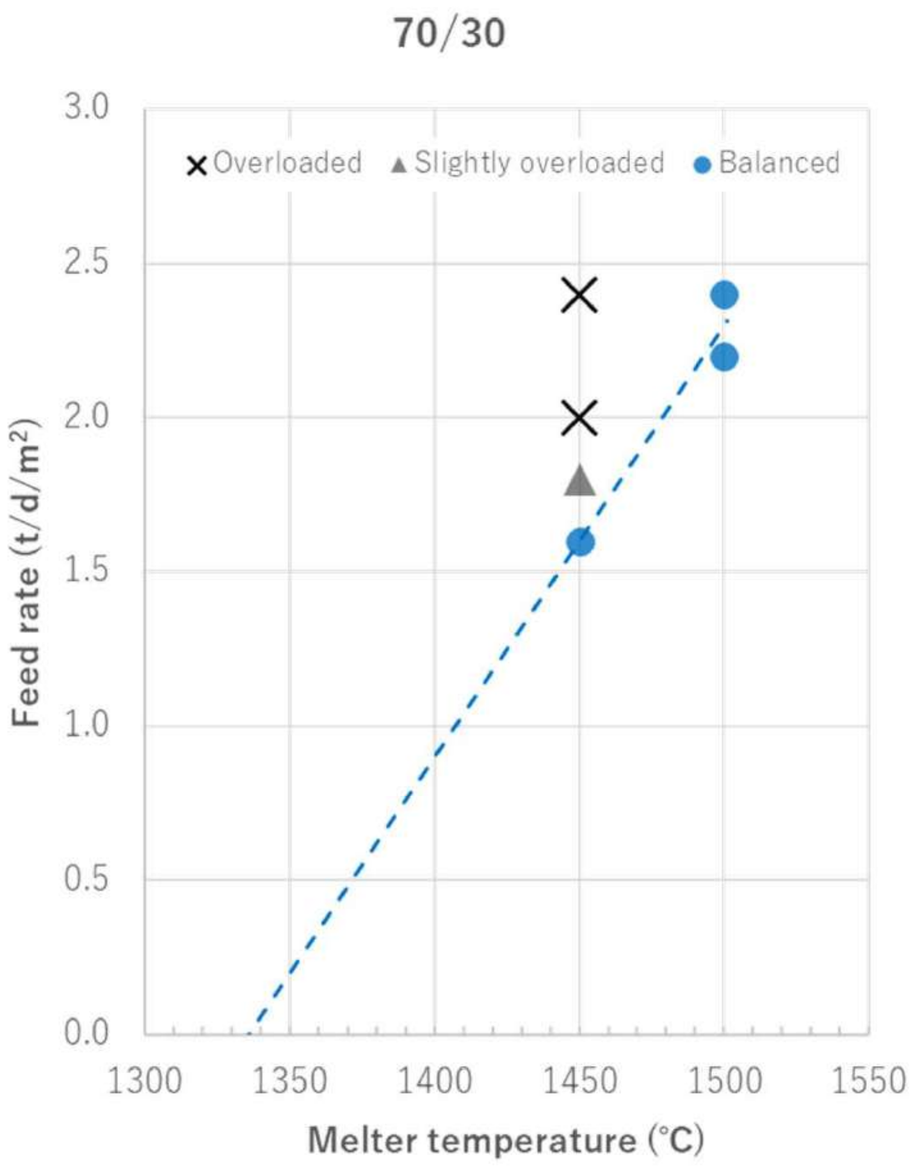




1350℃
98% calcined
10℃/min
Temperature: 1101
1350℃
900℃
100% calcined
10℃/min

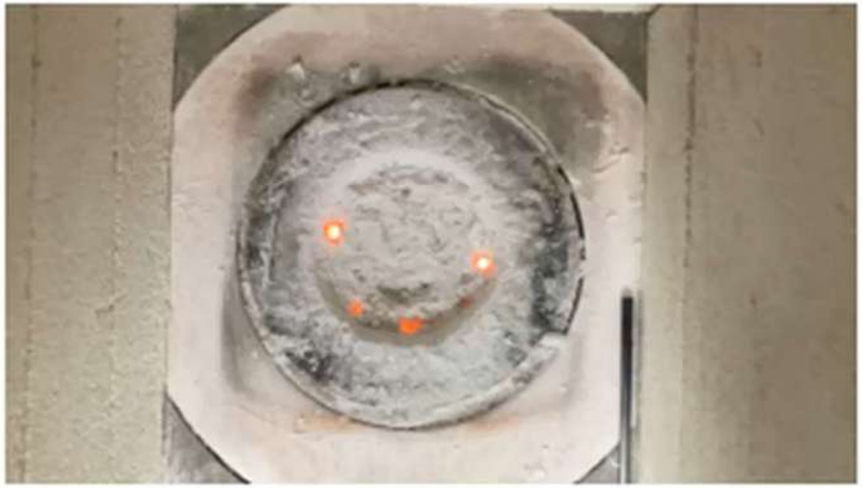
Specific pull rate cold-top melting of soda-lime glass





Your Dreams, Our Challenge

Batch is fed by hand



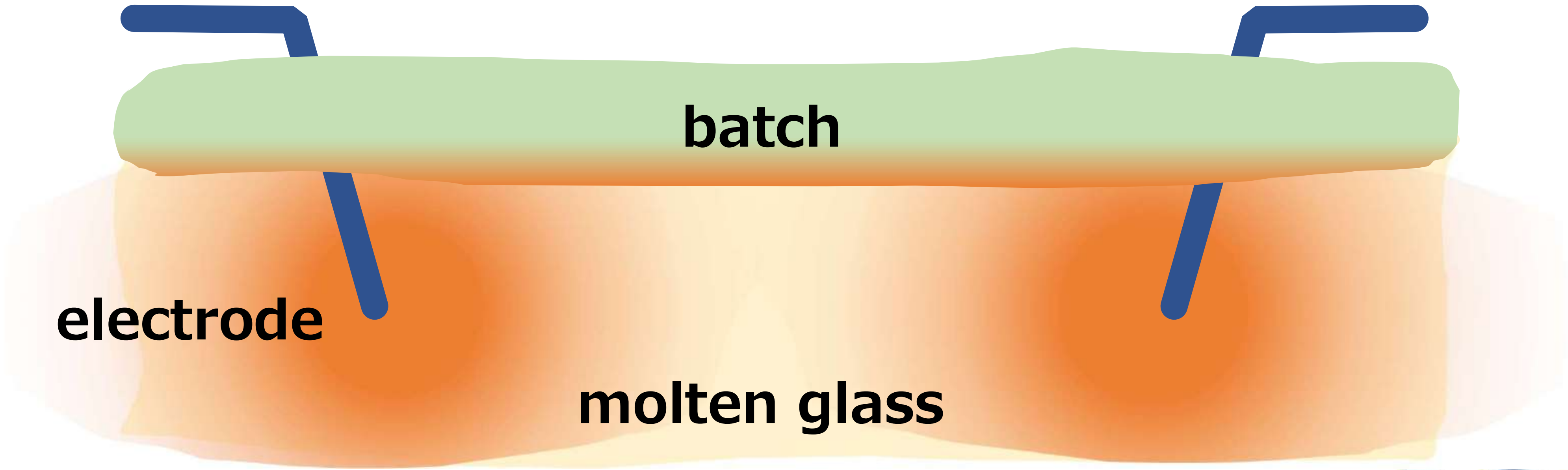
Pull rate is controlled
by nozzle diameter choice and nozzle temperature

Pros & Cons of Cold-top melting

☺Relatively lower fining load thanks to less evaporation of fining agent.

☹Low melting capacity per unit area due to lack of topside heating

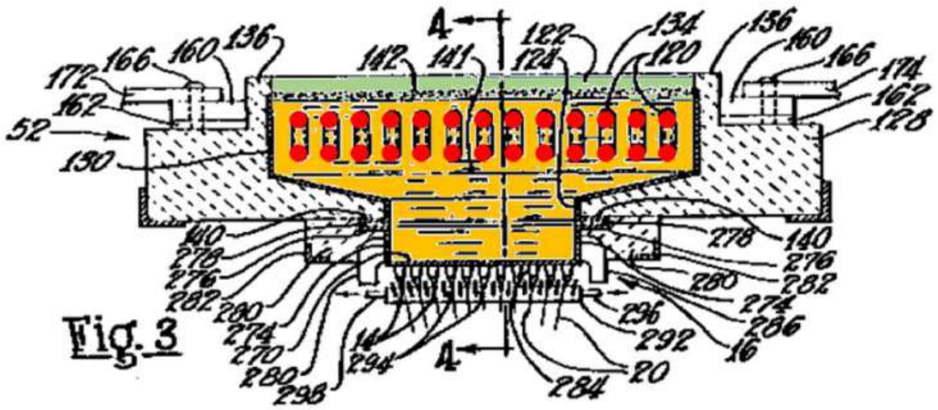
☹Furnace design that suits the electrical resistance of each glass composition is required.



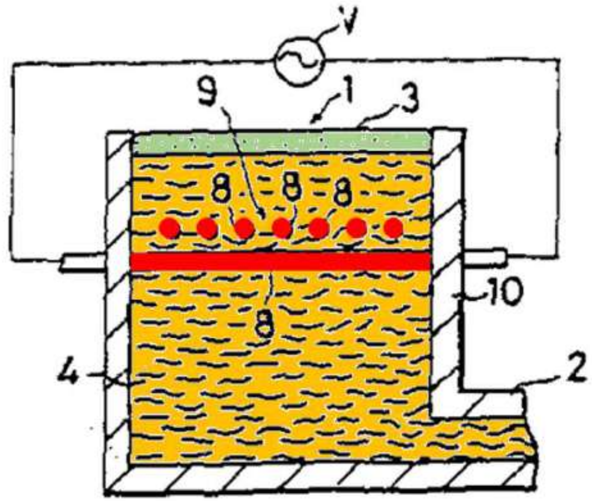
Your Dreams, Our Challenge

Alternative electrical heating ideas

- Patents describing immersed heating element made of solid metal or tubular metal in molten glass were exist.

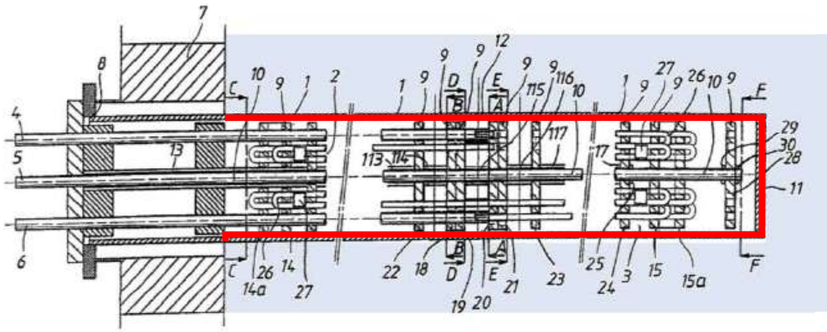


Owens-Corning (1975)



NSG (1987)

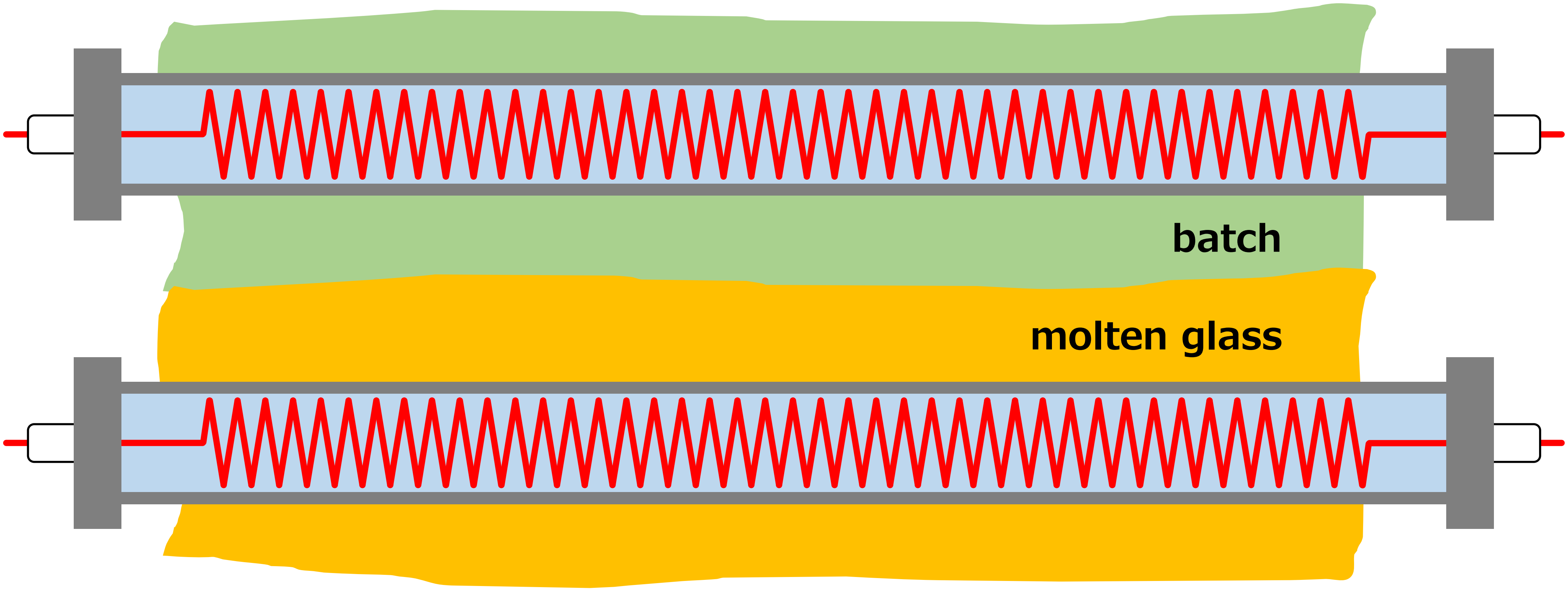
- Radiant heaters for atmospheric heating protected by a metal jacket are commercially available.



Sandvik (2006)

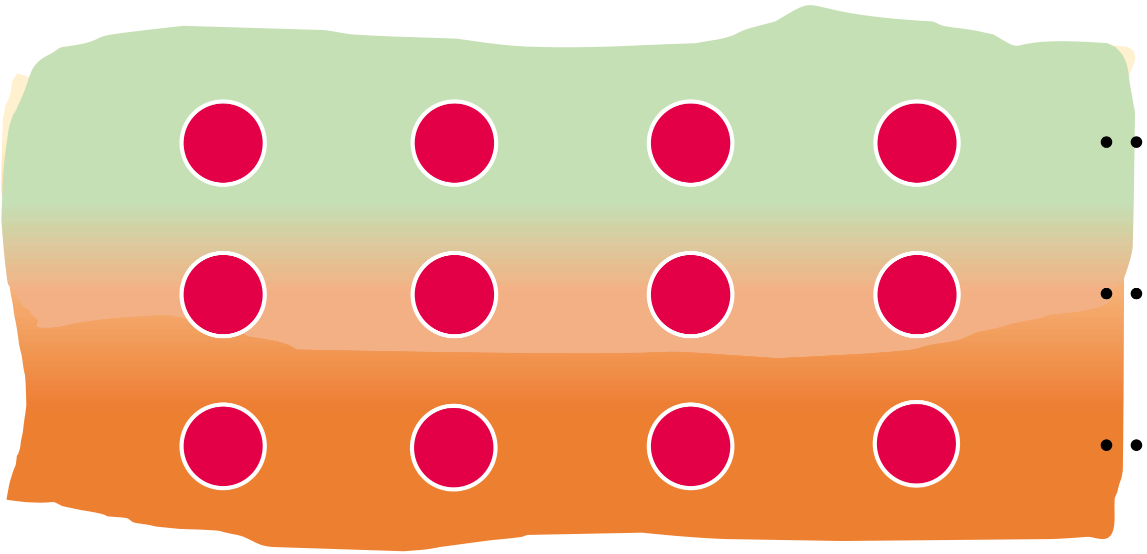
www.kanthal.com

A new heat source for glass melting



Immersed Radiant Heater

Ideal glass melting idea using IRH



・・・ **heating batch**

・・・ **batch to melt conversion**

・・・ **heating molten glass**

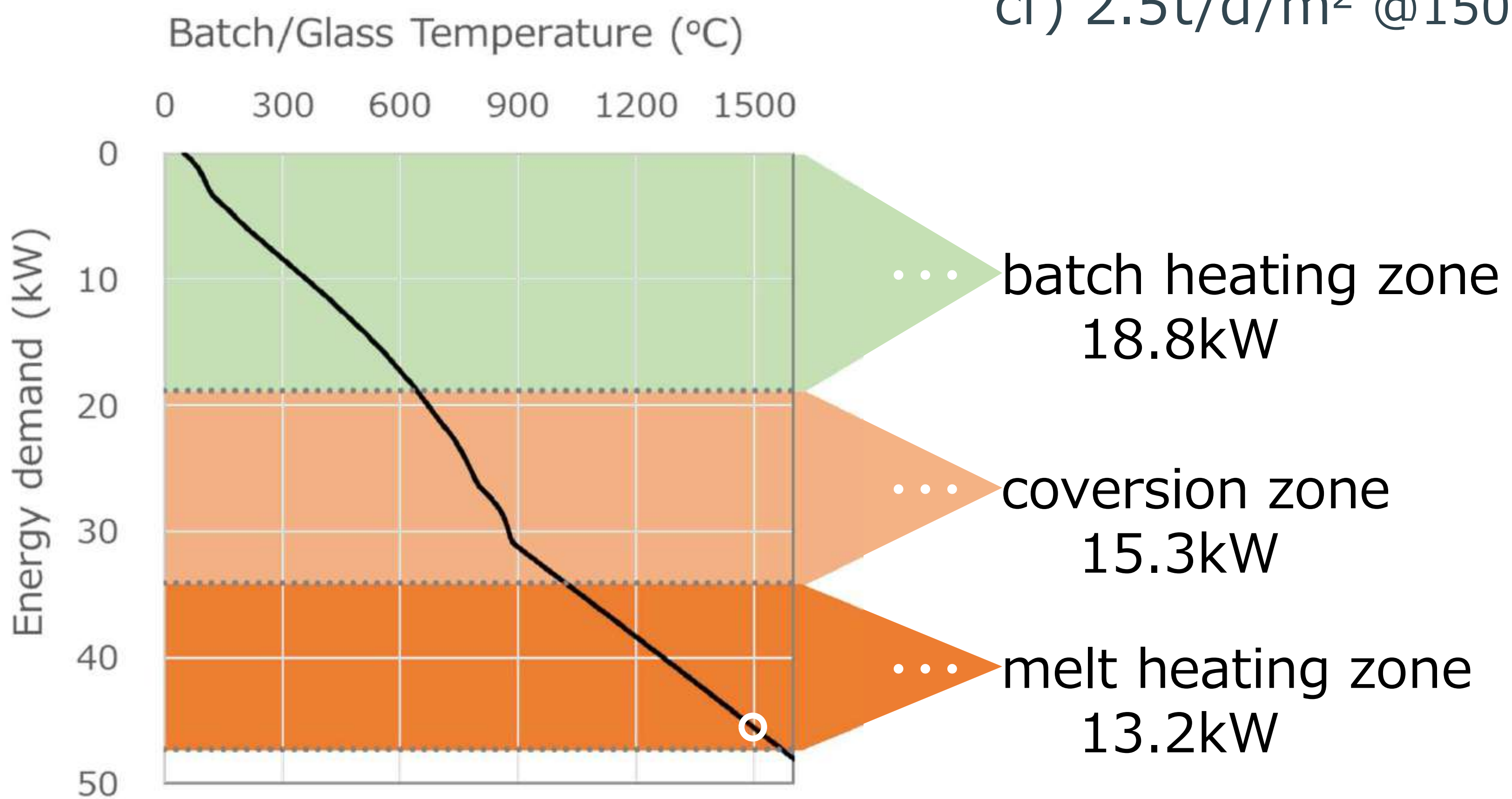
Heat on demand

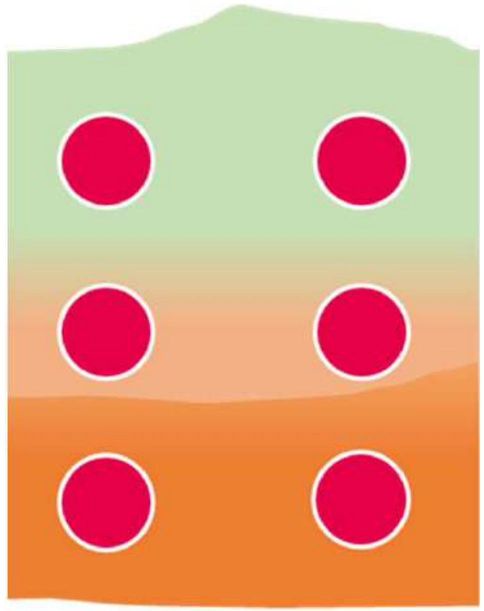
Your Dreams, Our Challenge

Melting capacity (t/d/m^2) and efficiency

- Soda lime glass: **7.5**t/d/m^2, $T_{maximum}$=1500℃

cf) 2.5t/d/m^2 @1500℃ cold-top melting





1.5t/d @0.2m^2

46kW ÷ **47.3kW** = **97%**

Theoretical energy demand / **Total energy input** / **Energy efficiency**

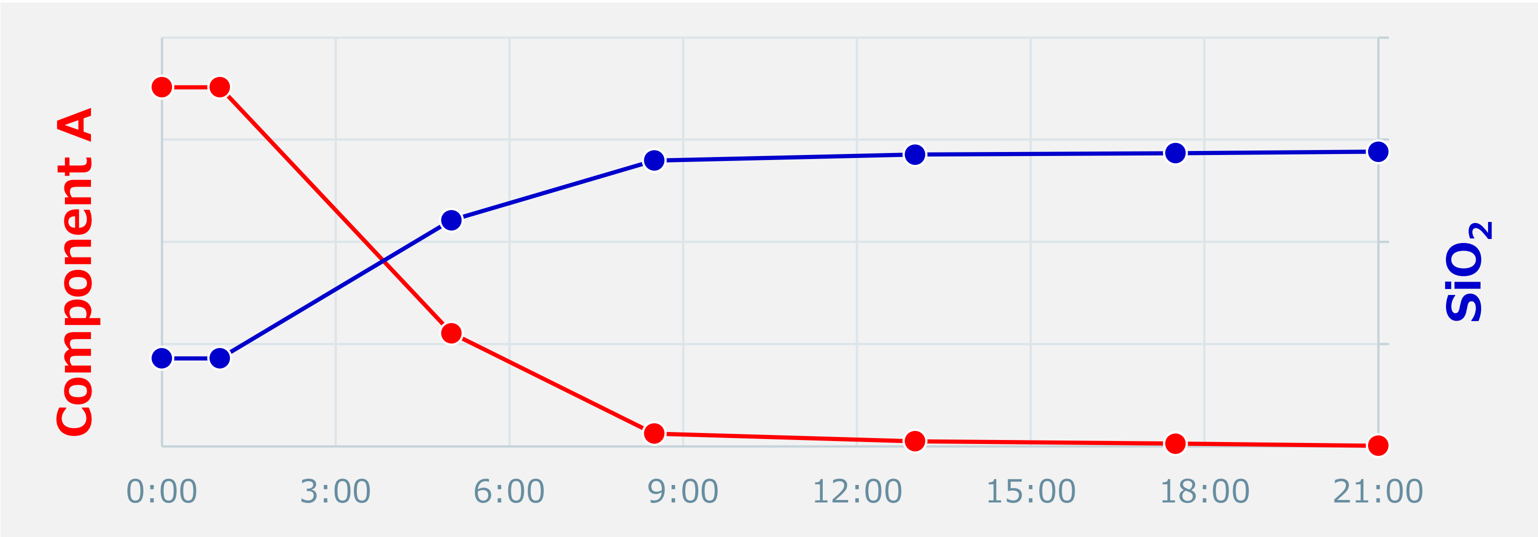
AGC

Your Dreams, Our Challenge

Availability for multi-product melting

- Soda lime glass: **7.5**t/d/m², $T_{maximum}$=1500℃
- High alumina glass: **5.0**t/d/m², $T_{maximum}$=1550℃

☺The difference in electrical resistance between the glass currently being melted and the glass to be melted next need not to be cared.



☺The time required to change the glass composition is 1/30 shorter than in the case of typical combustion furnace.

Summary

- We created a unique heat source for glass melting named the 'Immersed Radiant Heater' and tested the various ideas.
- IRH can heat the molten glass irrespective of its electric resistivity and heat the glass batch directly inside as well.
- Melting capacity of the furnace equipped IRHs in 3 stages was 3 times higher than typical cold-top furnace.
- Ultimately minimized volume of molten glass in the furnace gave us the following remarks:
  - 97% of energy efficiency for batch to melt conversion.
  - Only half day of the transition time for glass change.

Invention of technologies that give competitiveness to the small-scale production of specialty glasses.

Innovative technology that makes the mass production process of commoditized glass carbon neutral.

Although these may seem to be at opposite ends of the spectrum, the scientific understanding required is common to both types of development.

Thank you for your attention.

Acknowledgment

CN topics

AGC) M. Shirai, H. Imai and T. Kamihori

Briquetting & IRH

AGC) Y. Doi, A. Niwa, S. Hyodo, T. Enomoto, T. Yamazaki

Apollo Furnaces) L. Keen and R. Pauli

AGC

Your Dreams, Our Challenge