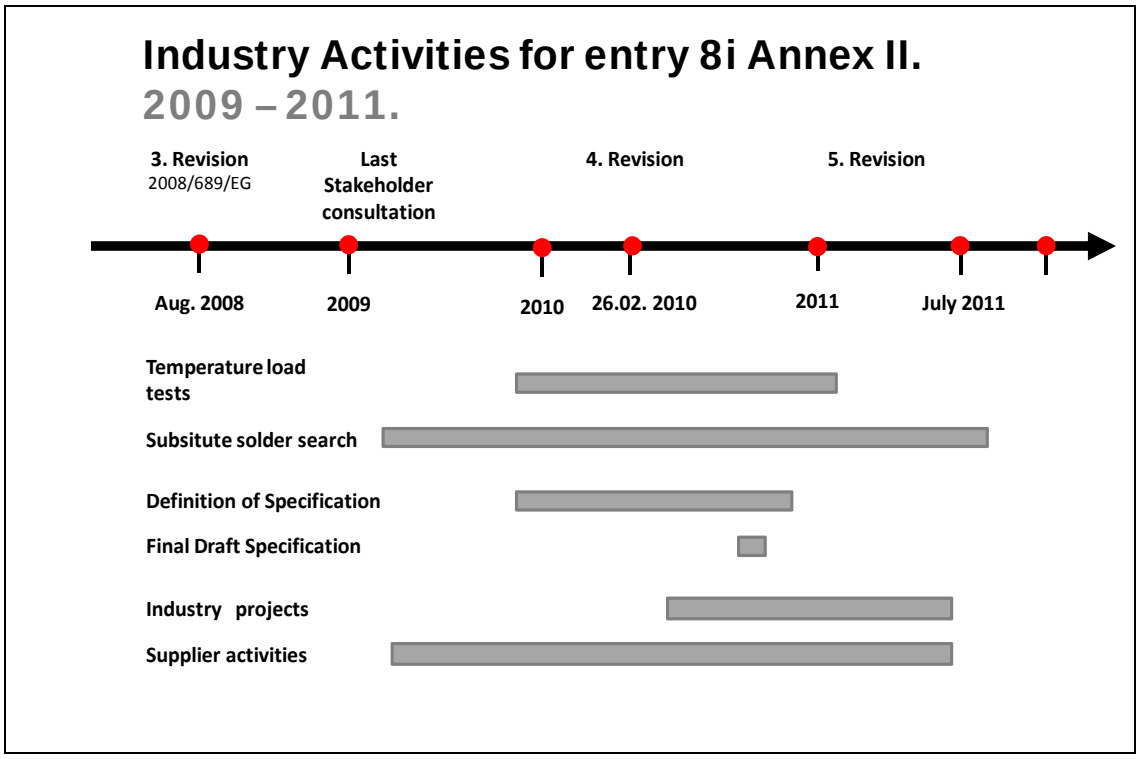
<u>Enclosure 2</u>: Industry activities 2009 – 2011

Even if the intensity of R&D work to find substitutes for lead in solder for soldering on glass was influenced by the bad economic situation from 2008 -2010 there were still several respectable intensive development activities conducted. The following figure 2.1 gives a survey.



<u>figure 2.1:</u> survey on industry activities 2009 -2011

The temperature load tests as well as the work on a draft specification are subject of *<u>enclosure 1</u> (Temperature load measurements)*.

The next section of this document refers to substitute search.

Industry activity report 2009 – 2011

Pb Free Solders For Automotive Glass Products

Overview of alternatives to eliminate Pb from soldered connectors to silver printed products

This document is an updated version of the summary document that was prepared in February 2009 and submitted as part of the CLEPA response to the request for technical information to support the review of Exemption 8b in Annex II of Directive 2000/53/EC (ELV Directive).

The new information also summarises more recent test work with more solder compositions and alternatives to solder.

Possible Pb free Alternative Solders	**Comments**
91Sn-9Zn (198.5 °C eutectic) 89Sn-8Zn-3Bi (189 – 199 °C)	No silver content causes silver leaching and gives poor adhesion and unreliable joint. Zinc alloys suffer rapid oxidation and are subject to corrosion problems. Very active fluxes needed which can lead to joint corrosion problems in service.
70Sn-20Bi-10In (143-193 °C)	No silver content causes silver leaching and gives poor adhesion and unreliable joint. Indium is not readily available so long term use is uncertain. Indium can cause a low temperature phase (Sn-In eutectic at 117ºC) which can cause cracks in the joints.
77.2Sn-20.0In-2.8Ag (175-187 °C)	Indium is not readily available so long term use is uncertain. Indium can cause a low temperature phase (Sn-In eutectic at 117ºC) which can cause cracks in the joints. Fails thermal cycle test requirements and causes cracks in the glass.
96.5Sn-3.5Ag (221 °C eutectic) 96Sn-4Ag (221-229 ˚C) 98Sn-2Ag (~221-225 ˚C)	Fails thermal cycle test requirements and causes cracks in the glass.

95.5Sn-3.8Ag-0.7Cu (217 °C eutectic) 96.5Sn-3Ag-0.5Cu (~220 ˚C)	Fails thermal cycle test requirements and causes cracks in the glass. Fails some humidity tests also.
40Sn-60Bi (~140˚C) 42Sn-57Bi-1Ag (139-140˚C) 43Sn-54.4Bi-2.5Ag-0.1Cu ~140˚C)	Fails thermal cycle test requirements and causes cracks in the glass.
24In-71.5Sn-0.5Cu-1.6 Bi-2.2Ag(?)	Fails thermal cycle test requirements and causes cracks in the glass. Fails some humidity tests.
65In-30Sn-4.5Ag-0.5Cu (109-124˚C)	Melting properties lower than high temperature requirements of vehicle manufacturers. Alloy is not solid at temperatures that have been measured in vehicles and is therefore not stable under those conditions. Fails some vehicle makers' high temperature test requirements. Fails some OEMs humidity tests.
New solder types and processes in investigation in 2011	New candidates for substitutes in development. Further test work necessary; potential for being a solution. Further test work is necessary to clarify applicability in vehicles (e.g. reliability) More details possible in confidential communication. But 3 to 5 years necessary for industrialization to mass production
Alternative to Soldering	**Comments**
Direct welding of the connector to the silver print (eg: by ultrasonics)	Silver print is rough and not conducive to good adhesion through direct welding techniques. Adhesion is low and joint reliability is poor. Also high stresses due to thermal expansion mismatches are likely to cause failure in service.
Direct welding of the connector to the silver print (eg: by thermo-compression)	Thermal expansion mismatch problems cause cracks in the glass.

Conductive adhesives	Lower connector adhesion strength and durability is poor leading to premature failure in service. Recent testing shows that conductive adhesives are not capable of carrying the required current for automotive glass printed products. Do not meet OEMs test specifications.
Solderless contacts (eg: springs)	Current carrying capacity insufficient for printed automotive glass product requirements. Creates unacceptably high temperatures (hotspots) on the glass. Also electrical arcing occurs.

version updated 25.08.2011

Conclusion: There is currently no "drop-in" replacement for lead containing solders for this application for mass production for every model. New substitute candidates need about 3 to 5 years for implementation for being used in new type approved cars.

The next page describes a short summary on the activities of the Flat Glass Manufactures Association of Japan (FGMAJ) within the last years.

Industry Activity Report from Flat Glass Manufactures Association of Japan (FGMAJ)**: 2011.8.10**

Report summary concerning lead free solder

Before 2000:

Use of lead-free solder was studied in response to trends to restrict use of lead. However, studies showed that lead-free solder was inferior to lead-based solder in almost all aspects, including performance, reliability, physical properties and price, etc. Nevertheless, anticipating wider use of lead-free solder, development for lead-free solder has been continued.

Since 2000 until today :

1) Considering accelerated trends toward lead-free solder, more efforts were devoted to related development.

We investigated various material compounds, considering also the results of studies before 2000. Consequently, the development focused on Sn-based compounds.

(Examples: Sn-Ag, Sn-Ag-Cu, Sn-Ag-Bi, Sn-Ag-Zn, etc.)

2) Although there were minor improvements, Sn-Ag-based solder has the following problems.

- No satisfactory performance can be obtained with the same process and conditions as those for the current lead-based solder.

  It would, therefore, be necessary to improve the process and install new equipment.

- The evaluation results fluctuate more significantly than with lead-based solder.

- Since cracks occur in the glass in thermal cycle tests, etc., there is a problem of reliability.

  No complete solutions have been found for these problems.

3) In-based solder has been studied for several years.

There are also problems with In-based solder mentioned below. These problems have not been solved.

- Indium is a costly and rare material. However, to obtain the performance equivalent to lead-based solder, the indium content should be several tens of per cent or more.

- Since the melting point is low, it would not be resistant to high temperatures.

No perfect solutions have been found at present for the problems mentioned in 2. and 3. above, and no potential solutions are currently known.