Reuse and Recycling of Architectural Glazing

Summary: Glass is touted as a 100% recyclable material, but good luck recycling your average window glass. On the other side, crushed glass and antique glass are hard to obtain commercially. Through different projects, we show practical aspects of reusing and recycling architectural glass. This time, we tackled the typical wooden windows found in a trash pile, accompanied with practical aspects and specific details of how to retrieve reusable materials safely and efficiently. We found no reliable sources of this information anywhere else.

A frequent sight of abandoned old windows and glass doors leaning against trash containers, or on a side of a road. Old windows are hard to recycle, as neither their glass nor their wooden nor plastic framing are accepted by recycling centers. They require laborious disassembly to separate their respective components. All these disincentives work together to have the average fenestration dumped in mostly unecological and wasteful ways.

Introduction: In this paper, we tell a story that begins after a homeowner replaced old wooden windows, with modern PVC/IGU windows, chiefly due to their worn look and the need for repainting and other seasonal maintenance, such as fitting foam gaskets to prevent drafts. Such a maintenance became cost prohibitive due to shortage of skilled labor and uneconomical in comparison to a straight replacement with shop-fabricated, unitized standard fenestration. Performance of the old in-swinging windows was in many ways superior to the new ones, by virtue of being compartment windows separated by an air cavity several inches deep, that typically offered noise and heat resistance unmatched by cheap modern windows, but they had worse air tightness, and worse water-tightness due to the dimensional instability inherent in natural, unprocessed wood, and poorer tolerances of hand-made assemblies. However, we won't talk about the new windows, instead we focus on the old ones that were sitting on a driveway, ready to be placed in a dumpster at the time the story begins.

Safety First

Hazards. There are many things that could go wrong, more than this paper could possibly handle, so let's focus on the least obvious:

1) Lead poisoning. Ingestion and inhalation of lead makes people dumb, but just the fear of lead seems to wash brains even worse. The average Internet article would send a reader to EPA regulations, typically requiring certified professionals, and therefore making any such effort completely uneconomical. You may first want to acquire the necessary expertise yourself, to understand and quantify the risk first, before you

decide whether and to what degree you could put yourself or anybody else in the risk way. Here are only a few practical bits of information, that you won't find in most textbooks, and we offer them as a practical reference, as follows:

Two windows had reddish glazing putty (that color could only be observed when disturbed, because the putty was painted white): and the reddish color is typically an indication of a lead putty. The lead putty was normally used in steel windows, but in this case perhaps a glazer run out of the normal putty while reglazing these wooden windows decades ago. Also, the steel hardware had a reddish primer on it, it's a lead-based primer, and I am old enough to remember when I sprayed gallons of it on miscellaneous steel projects myself. (That's perhaps why I am not the sharpest kid on the block.) The coats of white paint could also contain lead, but there is not an easy way to find out, so we must assume that's the case. Therefore, cutting and planning of wood is best performed either windward, wearing an air-supplied hood, with dust collection system attached to power tools, or with combination of some of those safety means. (Staying windward generally beats most other protection, so if I can do it outdoor with enough air movement, I would just wear an ordinary paint mask.) Indoors, it's the air-supply system, same as with sand-blasting.

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The setup I was wearing turned out to be insufficient: there needs to be a full face shield and an air-supplied respirator.

2) Broken glass. Breakage releases a lot of energy. It therefore sends small sharp particles, that could travel several feet. E.g. If you stand in front of a concrete mixer full of glass in process of crushing, you will feel a constant barrage of these particles on your face. Wear a full-face shield.
3) Sparks, etc. Sparks sent by e.g. an angle grinder not only could permanently spoil soft and hard surfaces including ceramic tiles and glass, and they can also get in your eyes. In spite of safety glasses, some particles made it to my eyes, which would normally necessitate a trip to an overworked local emergency room, potentially full of Covid-infected patients. I had such particles removed from my eyes several times in the past, so I know the routine. A full-face shield should be used instead of safety glasses.

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This photo represents bad practices: wear gloves, and install the safety cover and handle on the grinder.

4) Glass comes with sharp edges. What is not so obvious is that you WILL get lacerations, safety gloves or not, in the short moment when you did not wear the gloves, according to Murphy's laws. Accept it, and make sure your first-aid kit contains some easily accessible antiseptic like iodine or perhydrol, precut band-aids, etc. Glass is also slippery, so your gloves should offer a good grip, and the ones with soft rubber surfacing are best for glass.
5) Use. Internet is full of well-intentioned stories about reuse, upcycling, etc., but some of these cases illustrate potential breaches of elementary safety rules, e.g. where annealed window glass is used in bathrooms, baby projects, fences, shower enclosures, etc. Here is an example: *https://www.diyncrafts.com/23989/repurpose/40-simple-yet-sensational-repurposing-projects-old-windows* signed by Vanessa Beaty stated: "*What about using some old windows for your shower door? I love this idea so much. It's very unique and pretty easy to put together*." The same article earlier recommended

Shower curtains can be so boring and normal shower doors don't hold much excitement either. What about using some old windows for your shower door? I love this idea so much. It's very unique and pretty easy to put together.

using old windows for bathroom cabinets, fences, etc. Unless the old windows were made of safety glass (very unlikely), or you make them safer by laminating them, DON't do it.

How gorgeous is this fence made from old windows? This is such an easy way to use up those windows and dress up your outdoor living spaces at the same time.

The fence is made from old windows and an old stair baluster, both of which you can find at thrifts stores for just a few dollars each.

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Also, the same holds true for the overhead glazing, as we explained later in this paper.

Here's another wonderful way to use those old windows in the bathroom. I adore the farmhouse look of this bathroom cabinet, and you can build it easily in a day's time. It has such a great antique look to it and it will hold all those bathroom essentials that you just don't have room for in other cabinets.

Bathrooms Remodel

Rustic small bathroom. Old window frames as an alternative to a traditional glass shower door.

Saved by Jody Lutz

Bathrooms Remodel | Creative Decor | Shower Doors | Repurposed

More information...

6) Rotten Wood. Sill components were in some instances found rotten, as mentioned previously. As with any old wood, a rotten wood may be attacked by wood-destroying pests, and bringing such material in vicinity of healthy wooden structures, such as floors and roofs of the average house or workshop may result in pest infestation of these wood structures, which would be very expensive to exterminate, typically requiring a whole-house tenting. Therefore, it should go either directly to incinerator, or to a waste field.

Disclaimer: Don't do it at home. You are at your own risk, we can assume no liability.

Side Notes on Reuse.

Internet is full of stories about reuse of fenestration, e.g. Habitat For Humanity accepting them as a tax-deductible donation to be used in new homes, Building Materials Reuse Association, etc. However, it's important to keep it real: 1) Only door and window sashes normally remain, as opposed to their perimeter frames (Perimeter frames are normally badly mauled during prying-off and removal, and therefore seldom reusable), making it difficult or impossible to economically reuse them. 2) Building codes always come with more stringent performance requirements. Therefore, disposed old windows, even if only a couple years old, seldom meet the new codes' requirements, and hence their straight reuse, even refurbished would be extremely challenging, if not outright illegal on most projects. Also, what are the odds of matching the size? This is why new, unused windows sell at such a huge discount at Craigslist, and custom sizes are available for close to nothing at the back of an average home improvement store.

Upcycling, etc. Internet is full of pictures of small windows used as picture frames, mirror frames, or corkboards, artwork projects, etc. in e.g. cafeteria setting, and stories of their vintage charm, etc. However, it's also important to keep it real: old windows are normally thrown away because the manpower to maintain them simply isn't economically available anymore. Having these windows maintained after upcycling hits the same breaks: there simply isn't enough workforce to depaint, repaint, reglaze them when broken, etc. Therefore, these stories illustrate very isolated instances. Also, we flagged many such stories with other significant issues, as pointed out in our discussion on safety below.

Storm Windows. Working in Building-Enclosure related trade, I always advised homeowners to reuse old windows to make storm windows within the same openings. The benefits come with better noise resistance, water, and heat resistance. I saw and measured multiple instances of old windows retrofitted with the same-size windows (typically disposed by their neighbors in multifamily residential buildings) as storm windows, with stunning performance results. In most cases an old re-used sash was simply fixed outboard of the existing window, to be only periodically removed for cleaning. Similar effects were accomplished by enclosing balconies

Greenhouses. The most typical reuse of old fenestration in northern climates is to build makeshift greenhouses. These require a large number of equally sized, large sashes, that are normally seen only at larger commercial projects (which would seldom store them in a trash pile accessible to general public), and specific socioeconomic setting, e.g. poorer rural and suburban people travelling through affluent urban districts disposing them, so they could be picked up in time. These limitations cause most architectural glass left unused.

Why. With all this buzz online, nowhere we found any actual instructions on how to do it: most descriptions kept it safely vague, while those that dug into details were either wrong or unrealistic, and most were simply full of drivel. (It does not help that ecology has been used as a safe haven for the most incompetent individuals for at least the last two decades.) This is our attempt to show a repeatable, reliable process, that could be scaled, and yielded a good outcome. Please do keep in mind that the economy simply isn't there: generally, the cost of hauling this trash, labor, storage, etc. exceeded many times all alternative ways of acquiring these materials. It explains why such processes are neither researched nor applied widely. However, if you happen to actually need glass, firewood, hardware, scrap metal, fertilizer, carbon, and some strips of good-quality old-growth wood, having ample storage space and some downtime, this is the way you may want to approach it.

Condition: The vast majority of fenestration that we saw disposed had nothing really wrong about them: they could be either brand new windows that were fabricated to incorrect dimensions, incorrect type of glass, mismatched framing colors, or pulled out of openings due to some remodeling.

It was also the case here: very few units were found to have any damage: a rotten sill (easily replaceable), few had significant dimensional instability inherent in the natural wood: twisted out of plane, and most called for a new coat of paint, requiring a laborious de-painting procedure first. Several glass panes had old cracks (typically at corners, where it tends to bother people less), and some were outright broken during removal. The homeowner was embarrassed to give these to us, but we cleaned the whole yard, because the cracked glass was still good enough to be recut to smaller size, and the completely broken windows we picked as a favor to the homeowner, to not leave them with the trouble of having to dismantle and dispose of the last few of them.

Old wooden frames were disposed earlier, so we were given a pile of glazed sashes. Brass knobs were removed by the homeowner earlier for scrap, but there were still many steel hardware components sticking out of sashes, such as steel stops and knob's stems that made stacking them and packing quite challenging. Most sashes were similar size, but those that were much smaller were hard to fit in the stack. When we tightened straps on the load, we could hear some glass breaking due to the stress imposed by those protruding components. After unloading, even more glass was discovered broken.

The Project. We picked two truckloads of these old wooden windows, packed them on pallets, reused and recycled them, with almost zero waste. By showing how it was done, and the benefits of the reuse, we hope we would encourage more people to either follow this path, improve on it, or at least be able to assess the ramifications.

How to Remove Glass from Sashes. Do NOT attempt to remove the old putty and pry the glass out, because it will typically break. We cut one corner of each sash, opened it, stretched and widened the other three corners, and pulled the glass pane out, almost parallel to its plane. We used an angle grinder to cut through the steel corner key, and a reciprocating saw to cut through the mortised wood connection. These steps are illustrated on photos.

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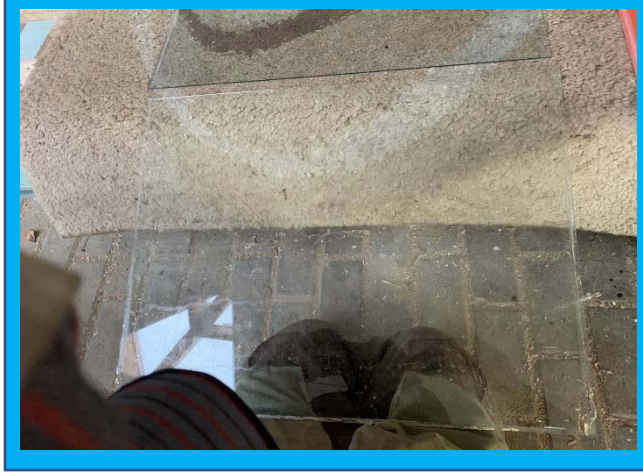
This process resulted in three items: a pile of empty wooden sashes, a container full od broken glass, and the reclaimed glass panes.

Glass Use. The most compelling reason for reuse is the actual need for the glass. At the time we started this project, we needed a large quantity of approx. 3ft (0.9m) wide clear flat glass panes glass to improve acoustic and thermal properties of residential skylights. Such a glass would cost us over $1,000 if purchased new. The windows that we got allowed us to cut approx. 2ft x 3ft (0.6m x 0.9m) rectangle out of each sash. The glass was annealed, and turned out to be very thin, with strips of tough, well adhered putty at edges, requiring significant labor to make it suitable for overhead use. Smaller pieces were stored for future glazing of cabinet doors.

Cutting a glass is a process that requires a right tool and some experience. A good cutter is crucial, and even more important is its continuous lubrication. We put a thick old carpet on a large wooden pallet, and used this setup as a table for glass cutting. We used a $36 Toyo Pistol Grip Glass Cutter, that comes with its own oil feed; however, the one we purchased on Amazon came clogged and did not feed oil from its container, so we just kept dipping it in a dish full of hydraulic oil. Experience comes from exercise, and having a large number of free glass panes encouraged learning. Even after having cut many glass panes in the past, I still had to re-learn the process, as I simply no longer remembered it, but the re-learning curve was short.

If the glass is not stamped as a safety glass, there is a good chance that it could be re-cut to whatever size you need, except for small downward adjustments (narrow strips of glass are very difficult to cut and break off cleanly). Safety glass could be either heat-treated or laminated or both, or it could be yet another animal (e.g. wired glass). If it's heat treated, it would break during any attempt to cut it, with a large field of debris. If it's only laminated, (you should be able to tell by its irregular edges), you could cut it, if you manage to score it precisely along a single line on both sides, and remove the unwanted side of glass without breaking the needed side.



We put a thick old carpet on a large wooden pallet, and used this setup as a table for glass cutting. Glass was marked to size with a waterproof marker, and then scored with the glass cutter along a straight edge ruler. Then, it was slid to the edge of the pallet and slightly bent downward, to break along the scored line.

This often resulted in either cracking of the needed part, or a crack extending into the unneeded part, that in turn required chipping it away. The most important part was to keep the cutter well lubricated.

Storage: All brittle material is best stored and transported vertically, but we discovered that it's not necessarily so in case of diverse window sashes with protruding hardware. The crucial issue is prevention of differential movement and point stress transfer; and therefore, the pallets must be well strapped. Also, the homeowner initially suggested to separate glass from sashes prior to the transport. Although it may sound like a good idea: to transport a tight packet of glass separately, as opposed of a huge pile of windows, it would be unpractical to clean the glass of the old putty to allow the desired parallel stacking, and diverse glass sizes would require dedicated glass racks with spacers. We broke as much hardware as we could prior to the loading, to eliminate protrusions prior to transport, and stacked pallets horizontally, after learning the hard way that vertical stacking allowed for too much load shifting. Once the glass is cut into uniform sizes and cleaned, it's best shrink-wrapped and bubble wrapped in vertically-stored, tight packets.

Broken Glass. Approximately 1 out of 5 windows broke during transport, and 1 out of 5 broke during removal from their sashes, while 2 out of 5 broke during cutting, so in the end we were left with only 1 out of 5. This number was further diminished when some newly re-cut panes broke during later storage and transport. Some glass was discovered glazed in sashes with imperfections such as e.g. edge chips (as seen on the photo on the left side), that significantly increased risk of breakage. The broken glass was placed in a concrete mixer and tumbled with a large stone, until a rough, crushed glass aggregate was obtained: this aggregate is valuable. We add it to a concrete mix in order to make it rodent-proof (rats often chew through a normal concrete). The large-size crushed aggregate is unavailable commercially, as far as we know. (In the past, we had to haul truckloads of beverage bottles disposed by a nearby restaurant and crush it, in order to obtain this aggregate.) Crushed glass takes much less space in storage, so it's best to do it asap.

Old, Rolled Glass. The windows were seven decades old, produced, glazed, and installed in 1940's, prior to the invention of the float glass production process by Mr. Pilkington. Also, most reglazing was done before the era when the float glass became widely available. Therefore, the glass that we salvaged was produced by rolling a molten glass mass, and it could be recognized by characteristic wavy reflections and visual deflections, that are less regular than the roller wave sometimes caused by the process of the modern heat treatment. The float glass technology has been so superior that it wiped out the old technology, making it challenging to obtain the antique glass commercially nowadays, with only a handful of companies that custom-produce it specifically as a restoration window glass, at a premium. Therefore, an old, salvaged glass like could be very useful and economical for reglazing of historic fenestration. E.g. Wikipedia article about the float glass: *https://en.wikipedia.org/wiki/Float_glass* shows a picture of an old window that was partially reglazed with modern float glass, and simply looks stupid. But if you are in historic restoration trade, you do not need to read this.

Old window containing a single sheet of float glass in the upper left section, Jena, Germany. The remaining sections are possibly not float glass as indicated by the distorted reflections of a tree.

IGUs. Our project did not involve insulated glass units, but in most cases of modern glazing, you would deal with IGUs. If they are bad (e.g. de-hermetized as evidenced by fogging, broken, etc.), you may want to salvage any remaining good

plies of glass. It's done by cutting the spacer separating these plies at the perimeter, and then scraping the remains of it from the perimeter of the needed glass pane.

Tempered Glass. Many projects, e.g. sliding terrace doors from multifamily residential buildings in S. Florida yield almost exclusively tempered glass as opposed to annealed. Such a glass is much tougher and could be used as countertops, shower enclosure, or even laminated to create walkways, guards, stairs, etc. It typically has polished edges, and therefore does not require any framing, making it a really cool material for reuse. All that is needed is a standard s.s. hardware and a good structural sealant. The primary limitation is its size: it cannot be modified, because any attempt at re-cutting, drilling, etc will result in breakage.

Old Windows Craft. Disassembly of old wooden windows exposed and illustrated their makeup and techniques used by old craftsmen in building them. Double-mortise corners reinforced and stiffened with steel corner keys, elaborate three-point locking hardware, all hand-made with precision matched only by today's unitized fabrication, they all impressed us.

Old Wood. It's a pleasure to work with an old growth pine wood, and the first indication is its strong resin fragrance, the second is the uncanny resistance to elements and pests, and third is its high density. On the picture to the right, you can see a cut through the sash that was exposed to elements for seven decades, yet remained healthy and strong.

Some hardware was installed in a way that prevented disassembly, and since removal of hardware would be the most laborious process, we decided to skip it altogether. We just cut the corners, hinges, and latch areas away, and fed this scrap to furnace heating our workshop area. The hardware was later picked with a magnet from the resulting ash. We removed glazing pins with pliers, and the straight sections of wood were planned to remove the old paint, re-cut and used as strips to reinforce the concealed connections of melamine boards in cabinetry woodwork. Make no mistake: there is no way to avoid spoiling blades, as there is always some concealed nail here and there. We had to re-sharpen our blades frequently.

Zero Waste. Also, we used the ashes as a plant fertilizer, there was several wheelbarrow loads full of ash: it's rich in potassium and other important metals. We even reused the carbon that we found in the ashes for our filtering needs.

The photo on the left shows an example of a nailed insert, hidden behind layers of paint, impossible to detect prior to cutting and planning. Every now and then, a shower of sparks was coming from blades, that we had to sharpen and re-sharpen again. A blade-sharpening tool is shown below. High cost of servicing tools is yet another reason why such fenestration would normally land in a land field.

Removal of steel glazing pins, concealed under glazing putty, prior to chopping and planning. These pins mechanically hold the glass in place while the glazing putty hardens and serve as redundancy clamp later. Seven decades later, glazing putty was clinging most to those spots, hiding the steel pins.

Wood-cutting station. A chop saw is used with a shop vac (through a dust separator) to cut off the straight sections of wood that could be later reused for cabinetry from corners and sections with hardware.

Planned wood sections, prepared for longitudinal cutting and further planning. They exhibit their attractive texture and release strong fragrance of resin.

Hardware. Besides wood, firewood, and glass, there is some hardware that remains. It's best retrieved after the wood was burned. Wrap a large magnet in a bag and run it several times through the ashes, once they cooled down. There will be some reusable components, such as corner keys, that could be used for e.g. cabinet making. All hinges are female, (because male parts of hinges were disposed by the homeowner together with the broken frames), but they can be reused if you fit matching diameter rods in half of them. Latching bolts are made of long square rods that could be used as a stock for future projects.

Intended Overhead Use. This is where the glass is intended, showing the temporary fit as the bottom layer of large skylights. However, the annealed glass will need to be secured for such a use, because it's not only prone to breakage, but also it would fall in large triangular pieces, and therefore would constitute a significant safety hazard. It could be secured by lamination (e.g. EVA film, or liquid), application of a safety film, extended and held by laminated edge strips, safety nets, or heat treatment (hard to accomplish for an average DIY). In our case, we plan to structurally adhere narrow glass safety ribs that would also serve as stiffeners. We will present this as soon as it's completed.

Final Words. We re-used and recycled old windows with zero waste, and showed you an example how this process works, with its pros and cons. The DIY approach we described in this paper seems to be beyond reach of the average homeowner. On the other hand, commercial reuse and recycling would be uneconomical due to the dispersed source, challenging transport and storage, and high labor intensity. If you are looking for a way to ecologically dispose of your old fenestration, we don't have good news for you. You may be able to twist your glazing contractor's hand to haul away and dispose them, but that's just another way of dumping them in a land field, and you would be charged the disposal cost. Another way would be to post it on Craigslist under "Free" section, but

there are seldom any takers. Anyway, we are hopeful that this detailed description would clarify the required steps, and equipment, and allow better control of the process for someone who would take it further and improve it to the point of making it economically viable.

Literature and Other Sources.

Besides many casual references online, we found some common industry association's links, such as Glass.com and many charities, such as e.g. Building Materials Reuse Association. However, most of them didn't bring anything worth mentioning. We also attempted to reach out to the charities that are involved in the construction material reuse and recycling; however, most were outdated/unresponsive, having e.g. their phone lines disconnected and uninformative websites. Also, our searches for building materials reuse centers and salvage directories were quite disappointing.

Below are those sources that we found noteworthy:

Chemical & Engineering News. Mitch Jacoby's "*Why Glass Recycling In The US Is Broken*" https://cen.acs.org/materials/inorganic-chemistry/glass-recycling-US-broken/97/i6

Adam Minter's "*Junkyard Planet: Travels in the Billion-Dollar Trash Trade*." https://www.amazon.com/Junkyard-Planet-Travels-Billion-Dollar-Trash/dp/1608197913

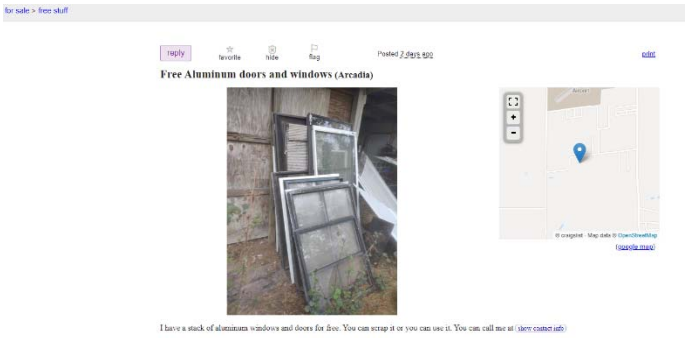
Adam Minter's "*Secondhand: Travels in the New Global Garage Sale*." https://www.amazon.com/Secondhand-Travels-Global-Garage-Sale/dp/1635570107/ref=pd_sbs_14_1/134-7616372-7097306?_encoding=UTF8&pd_rd_i=1635570107&pd_rd_r=61e06b18-bbaf-42c0-87c6-8311aa74db32&pd_rd_w=1iI66&pd_rd_wg=DQcCj&pf_rd_p=ed1e2146-ecfe-435e-b3b5-d79fa072fd58&pf_rd_r=3V47AM5E4BCZN2ASMFNK&psc=1&refRID=3V47AM5E4BCZN2ASMFNK

Edward Humes' "*Garbology: Our Dirty Love Affair with Trash*" https://www.amazon.com/Garbology-Dirty-Love-Affair-Trash/dp/1583335234/ref=pd_sbs_14_2/134-7616372-7097306?_encoding=UTF8&pd_rd_i=1583335234&pd_rd_r=61e06b18-bbaf-42c0-87c6-8311aa74db32&pd_rd_w=1iI66&pd_rd_wg=DQcCj&pf_rd_p=ed1e2146-ecfe-435e-b3b5-d79fa072fd58&pf_rd_r=3V47AM5E4BCZN2ASMFNK&psc=1&refRID=3V47AM5E4BCZN2ASMFNK

Research papers on glass aggregate in concrete: https://www.sciencedirect.com/topics/engineering/glass-aggregate

North America's Wood Reuse & Recycling Directory. A sample directory of companies accepting wood windows: https://reusewood.org/guide/topics/wood-windows It's a good Idea, except that only 10 companies were found in the directory, and the ones we tried to contact had their contact information outdated (disconnected phones, websites with 404 errors, etc.)

Craigslist.org seemed to be the best salvage exchange platform we found so far, except that it's not categorized in any way that would make such searches efficient. *SearchTempest* aggregates Craigslist results from larger areas, and as such was also found a valuable source, subject to the same limitations.



Myths. In one of our trips, a manager of an office tower, although obviously happy to unload tens of old windows sitting in her yard, shared her uneasiness. “You must know,” she said, “that this old glass is burned out by the sun, and therefore it’s not good at all, can break at any time, and cannot possibly be reused.” When we inquired about her source of this information, she told us that the seller of the new windows told her so… That’s how he closed the sale.

There are many myths of this kind, more than we can possibly tackle here. Many of them have a grain of truth to them, as typically things that “cannot” be done turn out to be only uneconomical.

Some of these myths relate to how glass is attached to the framing. Most people would swear by glazing putty or silicone. However, most typical glazing seen disposed these days in the US comes from 1950’s-2000’s period, and therefore was most typically glazed and sealed by either a dry-fit gaskets or double-sided adhesive tapes.