Energy Efficiency and the Swedish Catalog House

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ABSTRACT

This is a qualitative study of the energy efficiency innovations about the Swedish catalog house industry, based on historical research and fieldwork in Sweden. It presents several key differences between Swedish residential construction and the methods used in America. It finds that Swedish practices are mature, with major innovations having been introduced decades ago with incremental improvements occurring continuously since. The most significant energy-efficiency measures were achieved after 1973.

INTRODUCTION

In Sweden, over 80% of single-family homes are ordered from a catalog and built in factories; Sweden is known as "an innovator" in prefabrication (Terner Center, 2017). Swedish houses are fabricated as elements—wall and floor panels, roof trusses and panels—flat-packed for efficient transportation and rapid onsite construction. The Swedish catalog house (*kataloghus*) industry is important to study because its outcomes are so impressive: when complete these houses are superior by practically any measure, including structural resilience, energy use, and comfort. You can order a Swedish Catalog House today, choosing from a wide variety of types and styles, and it will be delivered in about six months and assembled onsite in one day. It will likely have R-36 walls, R-60 in the roof, and R-30 or more under the slab-on-grade (U=0.027, 0.016, 0.033 respectively). It will be all-electric and relatively little heating energy.

In 1999 Sweden established national environmental goals (*miljömål*), including to reduce energy use in the building sector by 20% by 2020 and 50% by 2050 (Miljöbalken 1998, no. 808). Therefore it is reasonable to expect that Swedish homebuilders will continue to innovate and improve in energy performance, and that these practices are worthy of broader attention.

The "Swedish achievement" seems almost miraculous to some Americans, but in fact it has been well-known for decades. Lee Schipper, author of *Coming in from the Cold: Energy-Wise Housing in Sweden* (1985) testified to Congress about Swedish houses in 1984, praising the "…rather stunning performance of the Swedish housing industry." He continued: "In 1981, homes in Sweden had on average twice the effective levels of wall insulation as homes in Minnesota!" (Review of Federal Policies 1984). Numerous popular publications and television programs followed (Savage 1987, for example). The Swedish catalog house today represents the product of a mature industry whose practices have been shaped by

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decades of research, technical innovation, and sensitivity to market forces.

THE CATALOG HOUSE INDUSTRY

Sweden has approximately 70 factory homebuilders. The market is highly-competitive and consumer-focused, where buyers can easily find detailed information about each company's products and processes. The industry is also mostly homogenous in terms of construction methods; while you will find minor differences in technique from one factory to another, no companies have significant patented technologies or proprietary information.

Swedish factory homebuilders generally have more 'white-collar' workers than 'blue-collar'. This reflects the great efficiencies achieved by factory production methods. For example, nobody spends time on a Swedish jobsite stapling housewrap to sheathing while the wall is vertical and the wind is blowing; it is done much more efficiently indoors, horizontally on a waist-high table. Architects and drafters generally work 'in-house' for the homebuilders, and a great deal of time is spent in design because (for example) each piece of lumber is drawn and dimensioned for the cutting station or the machine. Also much more effort is required in sales and marketing due to the competitive marketplace. So, for example, Eksjöhus—a larger company, producing about a house per day—has about a third of its employees in architecture and drafting, a third in sales and marketing, and a third in construction. While it is impossible to generalize about American homebuilders, it is safe to say that very few are organized in this way and that the proportion of effort signifies a meaningful difference between the Swedish and American homebuilding industries. (While it is not strictly pertinent to the subject of this paper, it can also be noted that the 'blue-collar' workers in Swedish house companies are characterized by gender and age diversity. Women and older workers can persist because of the safe and low-impact working conditions. Lifting, climbing and reaching are uncommon.)

Figure 1 Typical 1.5-story Swedish catalog house (author).

THE TYPICAL CATALOG HOUSE

Architectural Design

In terms of architectural design, some of the salient features of the Swedish catalog house are simple forms, modest size, and stylistic variety. The most basic designs are simple boxes with four corners and a gable roof, very efficient both in terms of construction and thermal performance. More commonly one room is added to this form, resulting in a T-shaped plan with six corners (see figure 1). Anything more complex is eschewed as irrational because each corner and seam represents additional expense and potential heat loss. For some cultural context, Anna Lantz, chief architect of Trivselhus, finds inspiration in early-20th-century architect Josef Frank. She proudly described Frank's houses in Falsterbo, compared to the International Style, as: "More spartan. More reduced. Maybe more Swedish" (Trivselhus AB 2008). In other words, simple forms are identified as virtuous in Swedish architectural culture.

The average size of the Swedish home is 144 m² (1550 ft²); this is about 93 m²/1000 ft² less than the US average (La Vardera 2011b). A popular type in Sweden is the 1.5-story house, where the upstairs rooms (usually the children's realm), are 'in the attic' with knee walls and partially-sloped ceilings. This type of house is eminently logical in terms of optimizing the amount of living space with the least construction materials. Because the upper-level rooms are small in terms of volume, they can be heated efficiently.

Stylistic variety is immediately apparent from a quick perusal of house catalogs or a visit to a model-home village (*husutställning*), where various companies display their works side-by-side. This is a critical concept that Swedish architects take for granted: architectural style is independent from the internal nature of the structure and the fact of its prefabrication. (In American architectural culture, prefabrication is often seen as aesthetically-limited, and likewise American consumers tend to view manufactured housing negatively. There are no such stigmas in Sweden.) Many Swedish homes are in a traditional style, resembling the iconic 'little red cottage' with white trim and sometimes white 'gingerbread' details. Many others are in styles imported from America; the Cape Cod is a common type. And quite a few are in a modern style descended from the 1930 Stockholm Exhibition as well as from Mid-Century modernism.

Foundations

Swedish houses are commonly built using a raft slab system (*platta på mark*), a superinsulated slab-on-grade in which expanded polystyrene (EPS) forms are placed above the ground on a layer of compacted gravel. Basements or crawlspaces are rare. The slab includes hydronic radiant heating with PEX tubing (first commercialized in Sweden in the 1970s). Under the slab, three layers of 100mm (4") foam (300mm or 12" total) is typical, with a vapor-proof layer and capillary breaks. This totals about R-49 (U= 0.02). The perimeter is also formed by foam, whose outside vertical face is coated with a fiber reinforced concrete finish that prevents damage. On top of the slab, wood sill plates are installed; they are set back slightly from the perimeter, ready to receive a wall element built with a 'split sill' and a void channel in the center. The result is a kind of tongue-and-groove sill joint, which makes setting the walls very efficient and precise (Hedges and La Vardera 2013).

The *platta på mark* method has many advantages: excavation costs are avoided, and foundations may be placed in any season of the year, thus there is a great savings in time, effort, and expense. Because the house types are standardized and each element is designed in detail, items like rebar for the slab can be prefabricated. All quantities are well-known and therefore costs are highly predictable. Additionally the energy-efficiency of the *platta på mark* system is excellent. The method is quite mature by now; such houses were advertised as "basement-free" houses (*källarlöst hus*) by Aneby-Hus in 1972 (Jönköpings Läns Museum).

Wall Construction

Contemporary. Wall construction varies little among Swedish house factories; thus it is possible to characterize the 'typical Swedish wall'. Wood studs are normally dimensioned at 170mm (approx. 6-3/4") or 200mm (7-7/8") and spaced 450mm (17-3/4"). The cavities are filled with mineral wool insulation, measuring about R-30–32 (U=0.033). A vapor barrier is attached to the interior face-of-stud and a drainage plane/air barrier to the exterior. Each face then has 45 or 50mm furring (approx. 1-3/4") with about R-9 (U=0.11), so there are no thermal bridges (see Figure 2). The interior furring also serves as a wiring chase, and thus the system preserves the integrity of the vapor barrier. The interior is finished with a layer of OSB then gypsum board. Outside, the wall often has a second-layer of furring so that the cladding is back-drained and ventilated. In total the typical wall is over a foot thick and measures about R-50 (U=0.02). Joints between panels are made with an expandable gasket (*expanderande fogband*) and membrane layers are given sufficient surplus to be lapped and sealed.

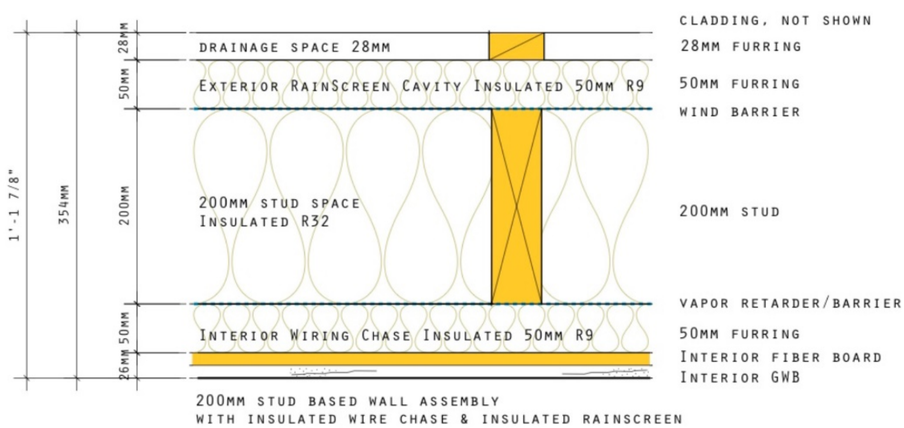

Figure 2 Typical wall section of Swedish factory house (La Vardera).

Historical. Swedish house factories have been prefabricating wall panels and delivering them in flat-pack shipments since the 1920s. In the 20s–40s, these walls were produced by layering planks of wood in alternating directions (Björk et.al. 2013, Hedges 2018), a technique not dissimilar from today's Cross-Laminated Timber (CLT). These were delivered in smaller panels (*småbloc*), which could be flat-packed for delivery and then lifted and set by hand. Sweden adopted the American method of wood framing in the 1950s, after a contingent of Swedish architects and engineers toured the US in 1948. These were called *regelhuset* (literally, stud houses) in the 1950s. Initially the stud cavities were insulated with sawdust, soon with mineral wool. And with the invention of the truck-mounted crane (*HIAB*), factories could make larger wall-sized panels (*storbloc*). Historically, then, today's characteristic 'Swedish wall' is a product of American framing methods and Swedish innovations in insulation and site logistics.

For a time in the 1970s–80s, several Swedish house factories used Masonite i-beams as studs (Savage 1987). The typical Swedish wall as practiced today and described above was documented in Adamson et. al 1987. A 1985 house catalog from Borohus showed walls having a k-value of 0.17 (R-33.4) and the ceiling having a k-value of 0.09 (R-63). A 1990 house catalog from Sävsjö Trähus AB showed nearly identical values (Jönköpings Läns Museum). Similarly, housing researcher Paul Kando conducted an extensive survey of Swedish factory homebuilders in the mid-1980s and found: "New Swedish houses are heavily insulated. Typical thicknesses of batt insulation are 10" in walls (R-35) and 21" in ceilings (R-70, U=0.014). Three inches of foam insulation (R-21, U=0.5) is usual in floors" (Kando 1988).

Windows

Contemporary. Triple-pane windows are ubiquitous in Sweden. Most have aluminum-clad wood frames. Typical U-values range from 1.2 to 0.8 (R-4.7 to R-7). The Swedish Energy Agency tells consumers: "When building a new house, you should specify windows with a U-value of 1.0" (R-5.7) (Energimyndigheten 2015).

A remarkable difference between Swedish and American framing methods is that the Swedish wall starts with the window. In the Swedish house factory, a robust butyl gasket is applied to the window frame, then it is laid flat on a hydraulic compression table, where the framing members will be pressed tightly against the window frame and then nailed together. The resulting airtight 'sub-element' is ready to be placed in the wall; flashing will also be installed in the factory. The window is designed with hardware so that it can be adjusted to be square and plumb with the turn of a screw at any later time, if needed. By contrast, the typical American method involves building a wall with a hole in it. The window is placed later, vertically, in the field. It is attached with nailing flanges, and any adjustments to make the window square and plumb must be done with shims. Gaps between the window frame and the structural frame—thermal problems—are ensured; these must be filled with foam and caulk (Hedges and La Vardera 2013).

Historical. In 1985 Schipper et. al. found triple-pane windows had recently become standard in Sweden, and they measured R-3 (U=0.33) at that time. The study found: "Doors, too, are of exceptional quality." Insulated windows were first commercialized in the US in the 1940s, and Libbey-Owens-Ford offered "Triple Thermopane" (Denzer 2013) but triple-pane windows did not become standard in the US marketplace. This is another example where the Swedish homebuilding industry adopted an American innovation and made it standard practice, while the same innovation failed in the American marketplace.

Floor and Roof Construction

Contemporary. In American platform framing, floors are typically supported by walls, and it is well known that the perimeter of the floor—the rim joist—is thermally vulnerable because it is difficult to insulate and air-seal. Swedish methods are substantially different. Intermediate floors (*mellanbjälklag*) are placed inboard of the wall, supported by a ledger beam attached to the inside face of the wall structure, in the space of the interior wiring chase. This allows the wall insulation to run continuously outside of the floor framing, while the membrane extends up to the second floor deck and the integrity of the air tight envelope is maintained. The upper-level wall is placed on top of the lower-level wall, with the same tongue-and-groove 'split sill' detail described earlier, plus it is gasketed (Hedges and La Vardera 2013). Where American homes have two horizontal joints and dozens of joist-ends dying into rim joists—major points of vulnerability—Swedish homes have one joint and no rim joists. Intermediate floors in Sweden are often prefabricated in *kassetten,* and they are often insulated with mineral wool for acoustics.

Swedish house factories typically make their own roof trusses (*takstolar*). By inspection these are more robust than their American counterparts, because the individual members are 170 or 200mm (6-3/4" or 7-7/8"), like studs. Some companies use a laser-projection device to assist layout of the pieces and nailing plates. Virtually all Swedish roof trusses are designed so that the full depth of insulation can run above the full width of the exterior wall (called an 'energy-heel' truss in the US). Ceilings are 'furred-down' for wiring space inside the vapor barrier, just as walls are 'furred-in'.

Practically all Swedish houses with sloped roofs use concrete roof tiles, which are raised on wood furring strips so that they are back-ventilated and avoid any potential ice dams. This works irrespective of whether there is an unconditioned attic or an insulated pitched roof (as in 1.5-story houses). Some US builders use this technique and call it a 'cold roof' system.

Historical. The floor and roof construction methods described above, including the 'inboard' method of supporting floors, were prevalent in Sweden by the late 1970s (Carlsson et. al. 1980). Since these methods have changed little since then, an American architect concluded: "As a solution the Swedish Platform Frame has already been vetted by 40 years of home construction" (La Vardera 2010).

Systems

Contemporary. Most Swedish houses have water-based electric heating, heat-recovery ventilation (HRV), and no cooling. The exhaust air heat pump (*frånluftsvärmepump*), commercialized in Sweden in the 1980s, is the main source of heating in single-family houses, though geothermal heat pumps are also common. About 20% of single-family houses are served by district heating, usually biomass. These are the same types of systems used in the US and elsewhere; again, there is very little experimental or proprietary in the Swedish factory house.

Historical. Swedish houses in the 1940s–60s were commonly heated with oil boilers and radiators. With the OPEC oil embargo of 1973, oil prices rose sharply. Sweden was 100% dependent on imported oil. The share of electrically-heated homes was 15% in 1972, and this jumped to 70% in a decade (Schipper 1984). In other words, the Swedish catalog house was electrified two generations ago. HRVs were developed and commercialized in the 1970s because "value of the heat in the exhaust air increased severalfold" after the 1973 oil embargo (Schipper et. al. 1985).

Energy Use

Codes. The Swedish Building Code—*Boverkets byggregler (BBR)*—establishes standards for residential energy performance (*energiprestanda*). Prior to July 2018 the code defined four climate zone with corresponding numerical targets. BBR 25 introduced new method: a national standard of 90 kWh/m² (28.5 kBtu/ft²) annually, with "geographic adjustment factors" ranging from 0.8 in mild areas (such as Malmö) to 1.9 in the coldest climate (Kiruna). Additionally, the energy performance may be multiplied by a factor of 1.6 if the source is electricity, which is the case for most new Swedish homes. The code also prescribes Specific Fan Power (SFP) values.

In 2021 it is planned to reduce the standard to 80 kWh/m² (25.4 kBtu/ft²) but increase the primary energy factor to 2.5 for electricity—clearly a major incentive for electric heating and hot water systems. (For all other sources besides electricity, the factor is, and will be, 1.0.)

Swedish homes do not achieve energy efficiency at the sacrifice of comfort. The BBR assumes that the indoor temperature is 21°C (70°F) for housing. Decades ago an American researcher observed Swedish houses were "heated to extraordinarily high indoor temperatures by current American standards. 72–75°F is quite common" (Dean 1984).

Modeling. Since 2006, Swedish builders must perform an energy calculation to show that the house design meets the code requirements. Residential energy modeling tools in Sweden are relatively mature. A common software program is VIP Energy, which is a descendant of VIP+, originally developed by Skanska in 1990, and ENORM 1000, which was introduced in 1988 (Burke, et. al. 2017).

Performance. Since Swedish house companies have control of all aspects of design and construction, including mechanical systems, many of them advertise and publish the anticipated energy use of their products while others publish results. (The Swedish consumer is highly educated.) Table 1 gives some sample values collected from various online sources, with conversion to English units and comparator North American cities for context.

Table 1. Advertised Energy Use of Sample Swedish catalog houses, For Heating and Hot Water

House	Location	kWh/m²/yr	kBtu/ft²/yr	Comparator
Älvsbyhus: Liv 1.5	Malmö	27.56	8.74	Minneapolis
Älvsbyhus: Liv 1.5	Stockholm	31.57	10.01	Montreal
Älvsbyhus: Liv 1.5	Luleå	48.73	15.45	Edmonton
Eksjöhus: PrioTvå	Malmö	25	7.92	Minneapolis
Eksjöhus: PrioTvå	Uppsala	31	9.83	Duluth
Eksjöhus: PrioTvå	Avesta	33	10.46	Fargo

Eksjöhus: PrioTvå	Östersund	37	11.73	Calgary
Eksjöhus: Vision	Malmö	29	9.19	Minneapolis
Eksjöhus: Vision	Uppsala	36	11.41	Duluth
Eksjöhus: Vision	Östersund	45	14.26	Calgary
Hjältevadshus: Hus Spira	Gothenburg	29.17	9.25	Buffalo
LB-Hus: Villa Vakteln	[former Zone 3]	33.99	10.78	Green Bay
Villa Varm: Villa Sörfors	Umeå	30.97	9.82	Winnipeg
SmålandsVillan: Villa Ljungby	Malmö	29.6	9.38	Minneapolis
SmålandsVillan: Villa Ljungby	Uppsala	40.8	12.93	Duluth
SmålandsVillan: Villa Ljungby	Sundsvall	53.5	16.96	Saskatoon
SmålandsVillan: Villa Ljungby	Luleå	64.1	20.32	Edmonton

In 2014 the average Swedish home (all ages, all regions) used 15,900 kWh (54,250 kBtu) annually for heating and hot water, which translated to 106 kWh/m^2 (33.6 kBtu/ft^2) (Statens Energimyndighet 2015).

Historical. As mentioned above, the "Swedish achievement" (so-called in Schipper et. al. 1985) was well-known to Americans in the 1980s. When American researcher Lee Schipper testified to a Congressional committee, describing work assisted by Henry Kelly and Stephen Meyers, he put it succinctly: "What we found was that on a unit area basis a home there uses 30 to 50 percent less heat energy than one in this country." Were the Swedes forced to build energy efficient homes by government intervention, he asked. "… actually no … the industry was always far ahead of Government codes." Speaking directly about the American homebuilding industry, he concluded: "our examination of Swedish technology suggests that we are so far behind in the way we build homes for thermal comfort and that we are not moving. That is the really frightening thing" (Review of Federal Policies 1984). Further work to document and understand the history of the "Swedish achievement" and the parallel story in the US is warranted.

Airtightness

Codes. In the Swedish Building Code airtightness (*luftläckage*) requirements are not given, but buildings "should have good air tightness as possible" (Boverket 2018). The absence of a prescriptive standard may be explained by the high quality of standard practice; the typical new Swedish home is practically airtight as a matter of course. Any company producing homes with significant leakage would fail in the competitive marketplace.

Historical. Swedish researchers were at the forefront in developing methods to measure airtightness (Kronvall 1978, Blomsterberg and Harrje 1979), and it is likely that the first prototype for the blower door was developed in Sweden before being commercialized in the US (Sherman 1998). Airtightness standards for new homes were introduced in Sweden in 1980, with maximum values of 3 ACH at 50 Pa (Liddament 1986). By comparison, IECC 2009 gave an airtightness guideline of 7 ACH at 50 Pa. Building Science expert Joseph Lstiburek says Sweden's were the first airtightness codes, and that lower values established later in Canada and Germany were "arbitrary and capricious" as well as "not worth it" (Lstiburek 2011). Kando (1984) reported: "new houses are built virtually airtight-at 0.5 air changes per hour under pressurization. This is equivalent to less than 0.1 natural air changes per hour."

A notable 1986 study presented airtightness values for 500 Swedish homes built between 1900 and 1982. Homes built after 1970 were quite tight, as may be expected, with an average measurement of 0.17 ACH. But strikingly, houses built between 1940 and 1960 and never retrofitted were measured at 0.35 ACH. This was a methodological study and so the authors did not comment on the qualitative characteristics of the results (Boman and Lyberg 1986). These values compare favorably with US homes of the same period, which had measured values above 1 ACH (Sherman 1998). In other words, Swedish catalog houses were built with relatively tight construction methods long before the 1970s emphasis on energy efficiency and the introduction of airtightness codes.

Costs

Given the high structural robustness and excellent energy performance of Swedish homes, it is reasonable to raise the question of consumer affordability. Because the Swedish catalog house industry is highly-competitive and customer-oriented, cost information is relatively accessible. Some companies publish "turnkey price lists" (*nyckelfardigt hus prislista*) and in other cases consumers share quotes via online message boards. A sampling of typical costs is shown in Table 2. These are all-inclusive, except the cost of the land.

Table 2. Advertised Costs of Sample Swedish catalog houses

House	Characteristics	Floor Area		Turnkey (Retail) Cost		Cost per ft^2
SmålandsVillan: Villa Ljungby	1.5-level 2BR 1BA	142m^2	1528ft^2	1 766 000 kr	$184,464	$121/$ft^2$
Älvsbyhus: Henrik	1.5-level 2BR 1BA	129 m^2	1389 ft^2	1 800 800 kr	$185,640	$134/$ft^2$
Myresjöhus Smart 150	2-level 5BR 2BA	150 m^2	1615 ft^2	2 495 000 kr	$257,205	$159/$ft^2$
Eksjöhus Prio 143	1-level 4BR 2BA	143m^2	1539ft^2	2 530 000 kr	$260,813	$169/$ft^2$
Myresjöhus Kärngården	1.5-level 4BR 2BA	153 m^2	1647 ft^2	2 700 000 kr	$278,338	$169/$ft^2$
Intressanta Hus C3:132	1-level 3BR 2BA	132m^2	1421ft^2	3 300 000 kr	$340,191	$239/$ft^2$
Willa Nordic ONV A5L+	1-level 3BR 2BA	170m^2	1830ft^2	4 250 000 kr	$438,125	$239/$ft^2$

When US homebuilders see these sales prices they are generally surprised at the low numbers. There are, of course, many caveats. First, the quality of interior finishes, fixtures, and equipment makes a major contribution to construction costs both in the US and Sweden, and Swedish customers may opt to 'upgrade' and raise the list prices shown above. Second, this is not a rigorous economic analysis, so the conversion from Swedish kronors to US dollars does not include any corrective factors for variables such as purchasing power or even income. This is a subject for future scholarly work. From a qualitative point of view it can be noted that Swedes have slightly lower incomes and higher taxes than Americans, but no healthcare or higher education liabilities.

CONCLUSION

A study of Swedish house factories today yields the same conclusions that American researchers found in the 1980s: "Swedish houses … are built to the world's highest standard. The average Swedish home has fewer defects in workmanship and is more free of drafts than its equivalent in North America or the rest of Europe. It is heated to a higher temperature, yet consumes considerably less energy for heating. Its superior performance is largely due to the technological sophistication of the Swedish product, not to significant compensatory differences in the size or comfort of homes, the behavior of occupants, or energy prices. The point is not that the best Swedish house is better than the best U.S. house, for example, but that the average new Swedish house is so much better than the average U.S. product" (Schipper et.al. 1985). A more contemporary conclusion is similar in spirit: "One could consider Sweden as a 'crystal ball', showing what American House Building might look like if we had spent the past 40 years committed to improving efficiency" (Hedges and La Vardera 2013). The root causes of this issue, and the potential solutions, are highly complex and beyond the scope of this study. A few US homebuilders such as Unity Homes and EcoCor are learning from Sweden and applying these methods directly. Certainly it can be concluded that American homebuilders and policymakers can benefit from further exposure to the "Swedish achievement."

ACKNOWLEDGMENTS

Scott Hedges assisted the author in this research in a number of ways, including arranging visits to numerous Swedish house factories in 2018 and 2019. Figure 2 was created by Gregory La Vardera Architect and distributed under the Creative Commons Attribution-NonCommercial-ShareAlike United States License (CC BY-NC-SA US).

REFERENCES

Adamson, B., Jonsson, B., Semeonova, E.I., and A.V. Sherbakov. 1987. Design of low energy houses with lightweight walls and roofs in severely cold climates. Swedish Council for Building Research.

Björk, C., Kallstenius, P. and L. Reppen. 2013. Så Byggdes Husen 1880-2000: Arkitektur, Konstruktion och Material i våra Flerbostadshus under 120 år. Svensk Byggtjänst.

Blomsterberg, A.K. and D.T. Harrje. 1979. Evaluating air infiltration energy losses. ASHRAE Journal 21(5): 25-32.

Boverket. 2018. Boverket's mandatory provisions and general recommendations, consolidated version. BBR 26, BFS 2018:4. Retrieved from https://www.boverket.se/globalassets/publikationer/dokument/2019/bbr-2011-6-tom-2018-4-english-2.pdf

Boman, C. A. and M. D. Lyberg. 1986. Analysis of Air Change Rates in Swedish Residential Buildings. Measured Air Leakage of Buildings. ASTM STP 904, H. R. Trechsel and P. L. Lagus, Eds., American Society for Testing and Materials, Philadelphia, 399-406.

Burke, S., Kronvall, J., Wiktorsson, M., and P. Sahlin. 2017. Method for Probabilistic Energy Calculations–Variable Parameters. Energy Procedia 132: 3-8.

Carlsson, B., Elmroth, A., and P. Å. Engvall. 1980. Airtightness and thermal insulation: Building design solutions. Swedish Council for Building Research.

Dean, E. 1984. The New Foreign Import: Manufactured Housing Systems. Journal of Architectural Education. 37(3/4): 12-19.

Denzer, A. 2013. The Solar House: Pioneering Sustainable Design. Rizzoli International Publications.

Energimyndigheten. 2015. Windows and doors. Retrieved from https://www.energimyndigheten.se/en/sustainability/households/other-energy-consumption-in-your-home/windows-and-doors/

Finrow, J.V., 1990. Composite Industrialized Energy Efficient Construction for Housing: Case Studies of Recent Danish and Swedish Housing Projects and Implications for US Multi-Family Housing.

Hedges, S. 2018. Elementhus: Sweden's ultra modern & totally forgotten, awesome, factory-built house. Retrieved from https://medium.com/@scotthedges/elementhus-swedens-ultra-modern-totally-forgotten-awesome-factory-built-house-899d0c96687d

Hedges S. and G. La Vardera. 2013. Innovation in Residential Construction Systems in Sweden. 1st Residential Building Design and Construction Conference. Pennsylvania Housing Research Center (PHRC).

Jönköpings Läns Museum. Kataloghus archival collection.

Kando, P., 1984. Made in Sweden: Better Houses Come Ashore. Solar Age, 9(3): 24-28.

Kando, P. 1988. When the best cost less: an economic comparison of the Swedish factory-crafted house construction system and conventional homebuilding. Washington, DC: Center for the House.

Kronvall, J., 1978. Testing of houses for air leakage using a pressure method. ASHRAE Transactions, 84(1), pp.72-9.

La Vardera, G. 2010. Swedish Platform Framing Info. Retrieved from http://blog.lamidesign.com/p/swedish-platform-framing-info.html

La Vardera, G. 2011a. Swedish Platform Framing in detail. Retrieved from http://blog.lamidesign.com/2011/06/untitled-1.html

La Vardera, G. 2011b. Energy Smart Housing Innovation, The Swedish Way. Retrieved from http://blog.lamidesign.com/2011/09/energy-smart-housing-innovation-swedish.html

Liddament, M. W. 1986. A Review of European Research into Airtightness and Air Infiltration Measurement Techniques. Measured Air Leakage of Buildings. American Society for Testing and Materials. 407-415.

Lstiburek, J. 2011. BSI-053: Just Right and Airtight. Building Science Corporation. Retrieved from https://www.buildingscience.com/documents/insights/bsi-053-just-right-and-airtight

Review of Federal Policies and Building Standards affecting Energy Conservation in Housing: Hearings before the Subcommittee on Housing and Community Development of the Committee on Banking, Finance, and Urban Affairs, House of Representatives, 98th Cong. 457 (1984) (Testimony of Lee Schipper). Retrieved from https://hdl.handle.net/2027/pur1.32754066853353?urlappend=%3Bseq=457

Savage, C. 1987. Swedish Prefab Houses. Fine Homebuilding 40: 50-54.

Schipper, L. 1984. Residential energy use and conservation in Sweden. Energy and Buildings, 6(1), 15-38.

Schipper, L., Meyers, S. and H. Kelly. 1985. Coming in from the Cold: Energy-Wise Housing in Sweden. Seven Locks Press.

Sherman, M. H. and D. Dickerhoff. 1998. Airtightness of U.S. Dwellings. ASHRAE Transactions 104(2):1359-1367.

Statens Energimyndighet. 2015. Energistatistik för småhus 2014. Retrieved from https://energimyndigheten.a-w2m.se/FolderContents.mvc/Download?ResourceId=104734

Terner Center for Housing Innovation. 2017. Housing in Sweden: An Overview. White paper. UC Berkeley. Retrieved from http://ternercenter.berkeley.edu/uploads/Swedish_Housing_System_Memo.pdf

Trivselhus AB. 2008. Cape Cod: Åtta New England-villor från Trivselhus. Retrieved from https://docplayer.se/35594932-Trivselhus-concept-series-atta-new-england-villor-fran-trivselhus.html