

Energiesprong: A Dutch Approach to Deep Energy Retrofits and Its Applicability to the New York Market

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Energiesprong

A Dutch Approach to Deep Energy Retrofits and Its Applicability to the New York Market

Final Report

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Acronyms and Abbreviations

ft	feet
kWh	kilowatt hours
NYS	New York State
NYSERDA	New York State Energy Research and Development Authority

Definitions

Energiesprong	The coordinating not-for-profit, originally funded by the Dutch government. The name Energiesprong derives from the Dutch words “energie” (energy) and “sprong” (leap).
NOM-Keur	Energiesprong’s net zero energy certification.
NOM	Net zero in Dutch (in Dutch, referred to as zero-on-the-meter, or “Nul op de Meter,” with the acronym “NOM”)
Keur	Certification in Dutch

Executive Summary

An assessment of a program to lower energy use in affordable housing in the Netherlands was performed. This remarkable program appears to have moved well beyond the demonstration phase, and into a large-scale production effort. More than 1,500 homes have received deep energy retrofits through this program, which is initially targeting 20,000 homes with a longer-term goal of 100,000 homes. In addition, 2,000 new buildings that fall within the program parameters have been completed. Net energy use is successfully being eliminated by reducing energy use, converting all energy uses to electricity (eliminating fossil fuels), and producing this electricity on-site with solar energy. The program appears to be financially self-sustaining, with the investments financed through energy savings. The Dutch government played a critical role in supporting the program by coordinating efforts to set standards, harmonize the overall approach, implement supportive legislation, and stimulate the market.

The approach appears to be transferable to the New York State market. In some ways, it may be even easier to implement in New York, as some of its laws are less restrictive. For example, in the Netherlands, each resident has the right to refuse the energy retrofit. The local conditions differ in other ways, such as in the low cost of natural gas, which will make such a program more challenging in New York.

Recommendations for adopting or modifying the Dutch program for implementation in New York State include the following:

- Consider more work in the areas of lighting, appliances, and energy-efficient resident behavior.
- Set clear goals for energy reduction that are deep, consistent, and defensible. The success of the Dutch program appears to be at least partially due to the clarity and depth of their net zero goal.
- Standardize the scope of work (to reap the benefits of economies of scale, messaging, and more) while allowing for some flexibility in implementation. Again, the Dutch program appears to have benefited from a combination of flexibility, in areas such as building appearance and “add-on features,” while delivering a standard set of energy improvements.
- Seek to unleash entrepreneurial spirit, excitement, and “can-do” attitude, as the Dutch have done.

1 Introduction and Background

In 2010, the Dutch government awarded a group called Energiesprong a 40 million Euro (approximately \$50 million, at \$1.24 per Euro) contract to develop deep energy retrofits for residential and commercial buildings.

The residential effort proceeded more rapidly and so became a separate program. The residential program turned its focus to net zero energy renovations. In June 2013, a group of affordable housing corporations (Portaal, Lefier, Woonwaard, City Lander, Tiwos, and Housing Limburg) and construction companies (Volker Wessels, BAM, Ballast Nedam, and Dura Vermeer) reached an agreement to renovate 11,000 homes to net zero. An additional 24 housing agencies have committed an additional 100,000 homes.

In short, the goal has been to renovate 11,000 homes, as the first phase of then renovating over 100,000 homes, primarily dwellings from the 1950s to the 1970s. The broad approach has been to industrialize the process to deliver both low cost and high quality.

In the summer of 2016, a team from Taitem Engineering visited the Netherlands to see renovations up close and to interview a variety of stakeholders, including representatives from Energiesprong, builders, representatives of the social housing agencies (the building owners), and residents.

By December 31, 2015, approximately 600 homes had been renovated (Jaarrapportage Energiesprong 2015). By July 2016, approximately 900 homes had been renovated, successfully demonstrating net zero performance. The concept is being brought to other countries, with 80 units reportedly in the pipeline in the U.K. at the end of 2016, and startup in Germany in February 2017. As of early 2018, 10 initial homes were renovated in France, and an agreement between eight housing providers and major industry players has been developed for 3,600 net zero and net zero-ready homes.

1.1 Marketing

This report begins with a summary of the program's marketing/messaging, because this will track how well the program is achieving its publicly stated goals.

- Net zero renovation
- Long-term performance guarantee
- Savings pay for the work; no increase in costs to the resident
- Rapid renovation (example of a one-day renovation is touted; typically one week is promised)
- Buildings can stay occupied during renovation
- Most of the work is on the outside of the building

2 The Building Stock

The work in the Netherlands is primarily being done in two-story row housing, although a four-story complex has been renovated. Additionally, a six-story new building has been built using the methods developed in this program. This type of housing is widespread, the result of the post-World War II building boom. It is owned by “social housing agencies,” which are similar in many ways to public housing authorities in the U.S. They are not-for-profit and operate independently, but they are regulated.

The housing is typically in rectangular blocks, a form of row housing. There is a small front yard, with a front entrance facing the street that leads directly outdoors (no common corridor). The buildings are two-story, each unit having a downstairs with a kitchen located behind the entrance and the living room, with dining area, typically running the full depth of the house. The upstairs is mostly bedroom areas. Attics are used as a third floor for a dormer bedroom, storage, or housing mechanical systems (boiler and water heater), which are removed during the renovation. Attics are generally not vented.

Roofing is almost always slate tile over wood framing, usually a simple gable. Foundations are concrete and are uninsulated, and crawlspaces are common. The crawlspaces are shallow (less than a foot high). They are accessed from inside each house and are typically vented. Walls are usually brick, in two wythes, separated by an air gap, and typically not insulated. Interior floors and ceilings are often concrete, and interior walls are masonry with plaster finishes.

The building stock is somewhat standard in shape and layout, but there are differences between complexes, and even between buildings within a complex. For example, some buildings have dormer rooms in the attic, protruding from the roof line. There were various types of balconies, some protruding from the building and others recessed into the building as a type of unenclosed porch. Some buildings have first floor awnings, while others have decorative elements such as vertical brick “fins.”

Even though residents do not own the buildings, they often live in the buildings for decades or even generations. There are reports of residents modifying the buildings, possibly without approval, such as interior remodeling, adding stand-alone sheds on the property, and even building full additions in the back of the buildings.

For plumbing, the water service enters from a crawlspace below the front entrance hall, accessible with an access panel, hidden below a mat, as seen in Figure 1. As buildings go all-electric, water meters are being relocated into a closet in the entry, where gas meters have been removed. The entry closet also contains the existing electric meter and breaker panels.

Figure 1. Floor panel access to crawlspace



A single toilet serves each house, located in the downstairs hall, typically without a sink, as seen in Figure 2. An upstairs bathroom provides a shower (usually no bath), but no toilet. Clothes washers may be located in the upstairs bathroom or downstairs in the kitchen.

Figure 2. Downstairs bathroom

Only the toilet is in the downstairs bathroom, there is no sink.



Heating is provided by gas-fired boilers with hydronic (hot water) distribution systems. Existing domestic hot water systems are served by the space heating boilers, in a system referred to in Europe as “combi” (combination) boilers. These are typically located in the attic, along with hydronic specialties such as the expansion tank. This approach is the most common, but there are variations, such as a gas-fired vented room heater in a living room.

Lighting includes ceiling-mounted fixtures in the living room, kitchen, bathroom and toilet, bedrooms, and a variety of supplemental plug-in lighting. For appliances, cook stoves are typically gas-fired, and most homes have a clothes washer. Clothes dryers and dishwashers were found in some of the homes.

In summary, the target building type is the rectangular row house, typically consisting of six to eight homes. These homes, referred to as terraced houses, have an upstairs/downstairs apartment, a small yard in front, and a patio or terrace in the rear. This existing building stock is fairly uniform, with the following common features: two-story, gable roofs, rectangular shape, side-by-side apartments, front and rear entry doors, individual meters for both gas and electricity which are located in an entrance closet, and shallow crawlspaces.

This uniformity lends itself to a common basic approach for retrofits. Yet, despite this uniformity, the number of custom modifications required with retrofits are numerous due to differences between complexes (for example, dormers and awnings).

3 Technical Approach of the Net Zero Renovations

As an overview, the retrofits install an entirely new insulated cladding to the exterior of the buildings, along with a new insulated roof over the existing roof. Existing roof tiles are removed to reduce weight on the buildings, allowing the existing structure and foundation to bear the weight of the new cladding and roof overlay.

The new cladding and roof are carefully air-sealed with gasketing, and new gasketed windows and doors replace the old ones. The infiltration rates of the renovated buildings are extremely low, measured as low as 0.34 cubic dm/s/sq. m. at 10 Pa (0.15 CFM/SF @ 50 Pa), and typically in the range of 0.4–0.6 cubic dm/s/sq. m. at 10 Pa (0.18-0.26 CFM/SF @ 50 Pa). These infiltration rates are not quite as tight as Passive House (approximately 0.11 CFM/SF @ 50 Pa), but they are tighter than the new 2016 New York State code requirement, which is approximately 0.56 CFM/SF @ 50 Pa. To deliver sufficient ventilation, a balanced heat recovery ventilation system is installed. One design uses room-by-room ventilation instead of a central heat recovery ventilation system.

The gas-fired existing heating systems are replaced with air-to-water heat pumps, which also supply domestic hot water. Interestingly, existing radiators are typically kept as part of the new air-to-water heat pump system, shown in Figure 3. The insulation and air-sealing measures reduce the building's heat loss sufficiently such that existing radiators can deliver the required heat using the smaller water temperature rise generated by the heat pump instead of the comparatively greater water temperature increase delivered by the pre-retrofit boiler systems.

Figure 3. Radiator left inside the building



A solar photovoltaic (PV) system is installed, usually covering the south-facing roof, or sometimes installed on roofs facing other cardinal directions, shown in Figure 4. In some cases, there were solar panels on north-facing roofs. Recognizing that yield can be reduced by 30% or more when panels do not face due south and observing that panels are almost always covering entire roof surfaces, the approach appears to be to maximize installed capacity without trying to optimize production.

Figure 4. Solar photovoltaic installation



An exterior mechanical room is installed to simplify installation and service of equipment. This includes the heat pump, heat recovery ventilator, water heater, and solar inverter/controls. The heat pump components in this shed include the air-to-water heat exchanger and pump that delivers water to the heated house as well as the outdoor fan and heat exchanger, shown in Figure 5. Exterior access means contractors can service equipment without disturbing residents, which is viewed as a plus for both residents and contractors.

Figure 5. The outdoor fan and heat exchanger



Lights and appliances are generally not replaced; however, in some cases incentives were provided for residents to do so. The one exception is gas-fired cookstoves; these must be replaced because gas is entirely disconnected from the buildings. They are replaced as part of the projects with high-efficiency induction electric cookstoves, shown in Figure 6. Because induction stoves can only use magnetic cookware, such as cast iron or magnetic stainless steel, new cookware is provided to the residents, shown in Figure 7.

Figure 6. Induction stove



Figure 7. Newly provided cookware



3.1 Step-by-Step Implementation Procedure

Before construction, the existing buildings are measured in three-dimensions with a laser measuring system. This measurement stores thousands of points and can identify if a building is not square and what adjustments might need to be made in the new pre-fabricated panels for the roof and walls. These measurements form the basis of the design.

Following the design, the wall and roof sections are then prefabricated off-site. According to reports, fabrication is happening on the floor of the contractors' workshops. The ultimate vision is for fabrication to happen on an industrial scale, but the scale has not yet reached the point where this is happening. The mechanical room additions are also prefabricated, off-site.

Construction begins with removing exterior wall elements, such as downspouts, house numbers, wall-mounted lighting, mailboxes, awnings, and more. The contractors then trench around each building to insulate the sub-surface foundation. Structural fasteners are mounted on existing walls (Figures 8 and 9), which will be used to support the new wall sections.

Figure 8. Structural fasteners



Figure 9. Structural fasteners attached to the wall



Figure 10. New wall cladding sections are brought on-site by truck



Figure 11. New wall cladding sections being installed with full scaffolding



Figure 12. Facing is typically a synthetic material



Figure 13. Synthetic facing



Figure 14. Alternative siding includes particle-wood with a protective facing



Figure 15. Alternative siding



Existing windows and doors are then removed. Prefabricated window and door extensions are installed, to account for the deeper overall wall depth (existing wall plus new wall). The new windows and doors are then installed. Tilt-and-turn windows are standard in Europe, in contrast to the casement, sliding, and double-hung windows that are more standard in the USA. Tilt-and-turn doors are also used. This hints at a possible opportunity to develop high-performance windows and doors in New York State. The tilt feature allows added natural ventilation, to supplement the base ventilation provided by the recovery ventilation system.

The windows are extremely high-performance gasketed triple-glazed assemblies, as seen in Figure 16.

Figure 16. High-performance windows



Figure 17. The doors are high-performance gasketed and insulated doors



Figure 18. Doors and windows frequently can tilt in to provide added ventilation.



Exterior roof elements are removed, including chimneys and roof tiles. The roof sections, also brought on-site by truck, are lifted into place by crane, shown in Figure 19. The roof sections typically already have rails in place to receive the solar modules. The solar modules can then be lifted and placed on the roof.

Figure 19. Roof sections are lifted by a crane



The work then moves indoors. Although most of the work is done outdoors, which is one of the promises of the program, there is still some important work that needs to happen indoors. For example, the gas meter is removed, as the buildings are essentially being fully electrified. Removing the gas meter results in substantial savings due to the elimination of the gas meter charge. The crawlspace is then insulated with loose expanded polystyrene chips (“flakes”), as seen in Figure 20.

Figure 20. Crawlspace insulated with polystyrene chips



If the new ventilation system has any interior ductwork, this needs to be routed around the house. Some of this ductwork was routed through the attic, some in soffits, and some exposed, for example vertically through stairways, as seen in Figure 21.

Figure 21. Exposed ductwork



Some of the designs do not require interior ductwork. For example, one approach uses room-by-room through-wall ventilation exhaust fans, but this does not provide for heat recovery. Another approach reportedly routes ductwork through the new exterior wall and roof cavities. In many cases, kitchens and bathrooms receive upgrades, such as new floor and wall finishes, shown in Figure 22. These perks are offered as part of the energy project, even though they do not save energy.

Figure 22. Bathroom upgrades are offered as part of the project



Gas stoves are replaced with induction electric stoves (Figure 23), and new cookware (pots, pans, etc.) that will work with them is provided.

Figure 23. Newly installed induction stove



Finally, exterior work is completed, including restoration of the site and surface elements (gutters, downspouts, house numbers, mailboxes, etc.) reinstalled or replaced with new, shown in Figure 24.

Figure 24. Completed exterior work



4 Resident Relationship Management

A repeated theme in the majority of interviews was the importance of managing relationships with residents. These are complex, major construction projects with significant impacts on the residents, involving change, noise, disrupted routines, and more. It appears when project goals (installation in under a week, all work done outdoors, residents can remain in apartments without disruption) were presented, they became expectations. So, when these goals were not all perfectly met, some residents were disappointed. Many installations took more than a week and all involved some minor work indoors, which some residents found to be fairly disruptive. Therefore, a major takeaway was the importance of not over-promising on issues such as schedule and scope of work. Likewise, it was found that residents who were shown color schemes for finishes frequently came to expect results, so changes were difficult for them. Other resident issues include equipment training, understanding utility bills, and conserving energy via their own behavior, from choosing light bulbs to turning off lights. There is ongoing work for best practices regarding interaction with residents.

5 Unusual Issues

Unusual issues arise in the projects. Asbestos is reportedly present in some of the existing construction and needs to be removed. Also, Dutch law requires accommodation for birds and bats that may have made nests in existing construction, so provisions have been made for nests in the new construction (Figures 25 and 26).

Figure 25. Bird nest accommodation



Figure 26. Bat nesting accommodation



5.1 Variations

Despite the uniformity in existing construction and of the renovation solution (insulation plus heat pumps plus solar PV), a variety of geography-specific, customer-specific, and contractor-specific variations were seen.

One contractor uses a roof-mounted heat exchanger for the heat pump. This appears to be passive, allowing air to flow without a fan from a grille at the peak of the roof to a grille above the gutters, shown in Figure 27. The same contractor uses room-by-room ventilation through the wall, shown in Figure 28. So, without having to house the heat pump, outdoor heat exchanger, or the ventilation system within the shed, a far shallower mechanical addition is required. In fact, it appears more like a chase than an addition (Figure 29), and serves the purpose of a chase, allowing piping and electrical components to rise two stories, including the attic and roof.

Figure 27. Roof-mounted heat pump heat exchanger: air grilles are above gutters and at roof peak



Figure 28. Room by room ventilation



Figure 29. Exterior mechanical enclosure/chase



In the northern part of the country, there have been earthquakes, attributed to hydrofractured gas extraction drilling. As part of a settlement with gas drilling companies, the energy renovation projects have incorporated structural reinforcement, in order to earthquake-proof the buildings. This has involved significant strapping of the building exteriors. These projects have reportedly cost over \$200,000 per house, largely paid for by the gas drilling companies.

At one site, we saw that a first-floor addition had been added to the back of some of the homes. This is an “age-in-place” accommodation that provides an accessible bedroom and bathroom on the first floor (Figures 30 and 31).

Figure 30. Additional bathroom



Figure 31. First floor “age-in-place” addition



At the same complex that has the age-in-place additions, there has been a more extensive implementation of automation, including a computerized energy consumption dashboard used by the residents (Figures 32 and 33). The dashboard not only allows the resident to see information about their energy usage, but also limited control of their energy system, such as adjusting temperature setpoints. There was mention that the dashboard raised residents’ awareness of their energy usage, in a positive way, although formal studies have not yet been undertaken to assess possible benefits of this awareness in terms of energy savings.

Figure 32. Energy consumption dashboard



Figure 33. Another view of the energy consumption dashboard



There was also mention of a guarantee that the retrofit solution is burglar proof. These added features, from the age-in-place addition to automation to the burglar-proof certification, provide contractors with ways to offer additional services and value-added solutions to differentiate themselves from other contractors.

5.2 Medium-Rise Buildings

The approach for a four-story complex is very similar to the two-story buildings: a roof and wall exterior cladding/insulation retrofit, individual heat pumps for each apartment, exterior mechanical rooms, heat recovery ventilation, and solar PV. See photos A22 – A29 in Appendix A. Additionally, a six-story new-construction building is reportedly complete.

6 Program

6.1 Process

The program appears to proceed as follows. Energiesprong first chooses a handful of builders, then vets and approves them. Next, Energiesprong engages with a social housing agency, what would be considered a public housing authority in the U.S., basically an owner of affordable housing buildings. A builder is chosen from among the list of pre-approved builders. A series of meetings is held to define the program for the social housing agency and residents are introduced to the program. Then the builder makes a proposal to the agency. Finally, the agency attempts to sign up the residents, who can refuse the renovation. Compliant with government regulations developed for this program, any specific building that has at least 70% of its residents in favor of the renovation can proceed.

There are three important contractual relationships:

1. Social housing agency and the residents, through a modified lease. The resident agrees to allow the renovations to be made and pay an additional fixed monthly energy service charge, in exchange for reduced energy costs.
2. Social housing agency and the builder. The builder agrees to make the renovations and provides a long-term performance guarantee. The duration of the guarantee varies by contractor and was heard to range from 25 years to more than 40 years. The terms are reported to typically include all maintenance of the energy systems.
3. Social housing agency and the lender. The lender refinances the buildings, providing capital to pay for the renovations.

The loan is used to pay the contractor for the renovations. Essentially, the residents' new energy service charge is used to pay off the social housing agency's loan with the lender. The entire renovation is reportedly paid for by the service charges in most cases. In some cases, special funding is applied to the projects. For example, in the earthquake zone, third-party funding from the settlement of earthquake lawsuits was used for some of the project funding. The resident also continues to pay the utility for electricity, which should have been reduced to zero. If the resident uses unexpectedly high amounts of electricity, for example due to their behavior (plug loads, leaving windows open, etc.), the resident remains responsible for paying this non-zero electricity usage. If the reason for high electricity use is equipment problems, the resident is reimbursed by the housing agency, which in turn is repaid by the contractor, who maintains long-term responsibility for system performance.

Interestingly, Energiesprong is not a party to any of these contracts. It is the catalyst to bring the parties together. Energiesprong's roles include market stimulation, relationship management, advocacy, training, innovation, standards development, and goal setting.

6.2 Financing

There are two main lenders used in the Netherlands for the zero-energy retrofits. Interest rates are reported to be in the low 1% range. Terms of the financing are long-term characteristics of mortgages rather than shorter-term loans for energy improvements common in New York State. The housing portfolio itself serves as collateral for the loans.

6.3 Regulatory

Energiesprong lobbied and succeeded in getting a law passed to allow the building owners (social housing agencies) to add an energy fee on top of controlled rent. To do this, 70% of the homes in a building need to sign up for the program.

7 Assessment

7.1 Installed Cost (per House)

First prototypes are reported to have cost 130,000 Euros, or approximately \$143,000 at the time of the visit in 2016. One Euro has been worth \$1.10 fairly consistently over the past few years, although recently has risen above \$1.20.

It was reported that the current cost was 65,000 Euros, without bath/kitchen/extras. This appears consistent with one particular contract that was for 82,000 Euros and included extras such as bathroom and kitchen renovations.

Cost reduction is a major focus of current efforts; Energiesprong's goal is to bring the cost down to 40,000 Euros. The path to reduced cost is seen as including further integration. For example, if the heat pump is fully integrated into the mechanical shed, then the heat pump does not need its own weatherproof housing. Another path to cost-reduction is through scale and the purchasing leverage that might be derived through scale. Hence, efforts to expand the effort to other countries.

Takeaways regarding installed costs include the fact that the costs vary widely, by contractor and over time. Installed costs are recognized to be high and attempts are under way to further reduce these costs.

7.2 Energy Prices

Electricity prices in the Netherlands are currently in the \$0.17- \$0.23/kWh range. This cost range is similar to the current range of prices in the New York City area and higher than Upstate.

Natural gas prices in the Netherlands are currently over \$2/therm. This is two to three times as expensive as in New York State. The far higher gas prices in the Netherlands mean that renovations will achieve faster returns on investment than we would see in New York State on comparable projects. In Upstate, if the same approach of eliminating fossil fuels and electrifying buildings is used, lower electricity prices will partially offset the opportunity cost of switching away from cheap gas by making electrically driven heat pumps more attractive.

7.3 Energy Performance

The concept is clearly delivering on its promise of net zero performance. Monitored results for multiple houses consistently show that annual on-site generated solar energy exceeds annual in-house energy use (“Results from first “Net zero Energy” projects in the Netherlands Monitoring @ EnergieSprong”, Niels Sijpbeer, January 2016). In other words, the renovated projects are net zero. Monitored household use in three homes varied between 2,000 and 3,000 kWh/year, less than the predicted use of between 2,200 and 3,400 kWh/year. Generated solar power was reported at 3,500 kWh/year.

A simple energy model of a typical Energiesprong retrofit showed that just from the design (highly insulated wall and roof, low air leakage, use of heat pumps, etc.) the buildings are likely to be net zero. Resident behavior is always an unknown, but the model confirms the basic design of the retrofit is sound and supports the elimination of energy use on a net-annual basis.

7.4 Resident Complaints

Noise of mechanical systems was mentioned as a minor issue:

- When mechanical systems are in back yard next to outdoor table
- When ventilation systems are room-by-room

Duration of construction was mentioned a few times to be longer than expected. Changes from what was promised (e.g., colors of finishes), was mentioned as having annoyed some residents.

7.5 Noise

The noise of the heat pump systems inside the homes is likely to be as low, or lower, than the prior boiler system. It is unlikely that heat pump noise inside the exterior mechanical rooms reaches into the interiors of the homes, and we did not hear any such noise. Any prior combustion noise from the boilers, typically located in the attic, has been eliminated, so there may even be less interior noise.

The added insulation, air-sealing, and features such as triple pane windows all mean that exterior noise, such as cars, construction (that is, construction not related to the renovation), or other machinery is far less likely to be heard inside the homes. In other words, the homes are very quiet on the interior, with

significant reduction in noise that is transported by infiltration, relative to the pre-retrofit homes. This is what was observed when visiting the homes. The only adverse noise reports received pertained to the heat pumps located in mechanical rooms on the rear of the buildings, next to patios and associated tables and chairs.

There was concern that the deeper wall dimension and associated window extensions might reduce natural light in the apartments. Residents were asked if they found this to be true, and it appeared there was no concern with loss of natural light. Residents also consistently reported liking the deeper shelf space created by the window extensions on the interior of the windows. This space is used for plants, other decorative displays, and as a general shelf. Appendix A shows examples of what the windows look like in the thicker walls.

7.6 Rents

The complexes are reportedly rent-controlled, and so the rents cannot be changed. However, a fixed energy fee is paid by the residents in addition to the rent to repay the loans obtained to pay for the renovations. The renovation is funded entirely by this energy service charge.

7.7 Operation and Maintenance Costs

Operation and maintenance costs were not investigated, but it is speculated that routine maintenance (annual maintenance) of the new electric heating systems costs less than that of the pre-retrofit boiler systems. A fossil-fuel combustion boiler requires annual maintenance to ensure combustion is clean, such that carbon monoxide is not being formed. Additionally, boilers can foul up and require extensive cleaning, especially on oil-fired systems, and often require monthly anti-corrosion chemical treatments, yet another cost. A heat pump might warrant inspection every other year, primarily to make sure that the outdoor heat exchanger has not accumulated dust, leaves, or other contaminants.

Some forms of non-routine service would be less for the new system. For example, the new all-electric system would never require investigation of gas leaks, and the costly and aggravating service shutdowns that often accompany utility gas leak investigations.

In the long-term, the new system may require more non-routine service, such as repairs for the compressor or outdoor fan. A comparison of significant components (moving parts and controls) between the two systems is shown in the following table. There are three significant components for the boiler system, and four significant components for the heat pump system.

Table 1. Comparison between boiler and heat pump systems (moving parts and controls)

System	Boiler	Heat Pump
Pump	X	X
Burner	X	
Controls	X	X
Compressor		X
Outdoor fan		X

7.8 Durability

Not enough time has elapsed to evaluate long-term durability. Based on U.S. estimates, boilers have an expected useful life of 25 years. Data is not available on air-to-water heat pumps in the U.S. However, water-to-air heat pumps have an expected useful life of 25 years, and air-to-water heat pumps are expected to have a similar useful life because they have the same components. The conclusion is that long-term durability of heat pumps and boiler systems are similar.

7.9 How have goals been met?

The beginning of the report listed some of the primary messaging of the Transition Zero program. All the program goals appear to have been either fully or largely met

1. Net zero renovation. Goal: Met.
2. Long term performance guarantee. Goal: Met.
3. Savings pay for the work; no increase in costs to the resident. Goal: Met.
4. Rapid renovation (example of a one-day renovation is touted; typically, one week is promised). Goal: Largely met. Renovations do not appear to be consistently less than one week, but appear to nevertheless be remarkably fast, typically one to four weeks.
5. Buildings can stay occupied during renovation. Goal: Largely met. Some reports of residents who felt inconvenienced or who chose to move out during renovation.
6. Most of the work is on the outside of the building. Goal: Met.

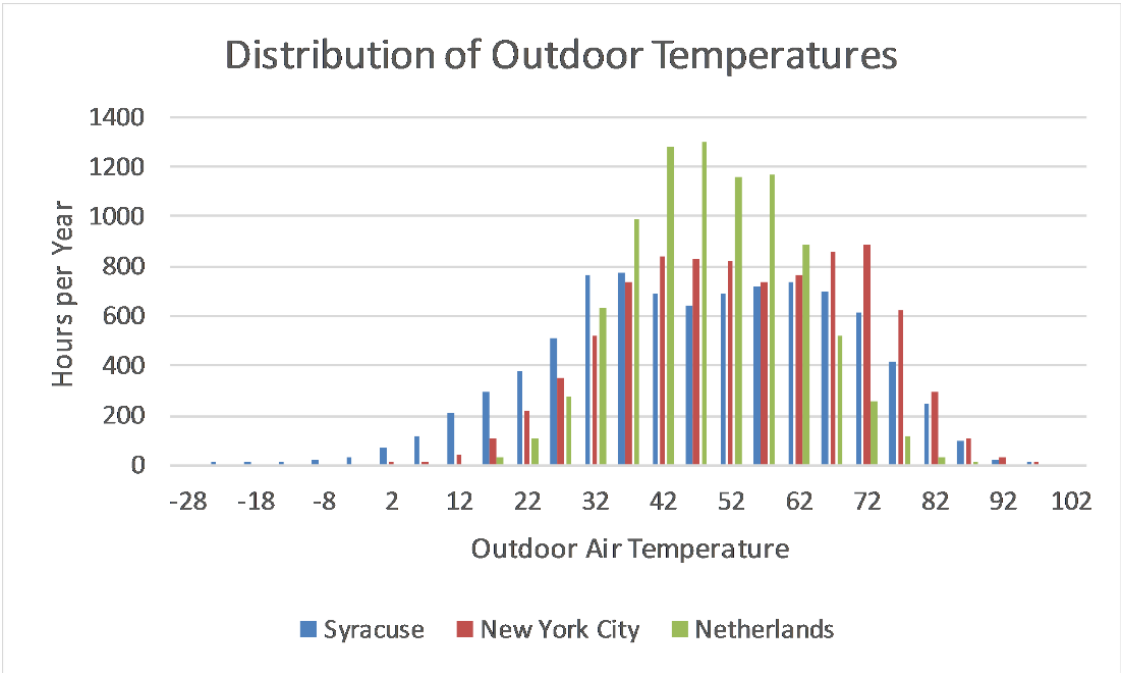
8 Transferability

8.1 Climate

The Netherlands is a small country with a fairly narrow variation in climate. Its heating degree days are in the 5000-6000 range, whereas New York State has both colder and warmer climates, ranging from 4500 heating degree days (Downstate) to 7000 heating degree days (in colder areas of the State). Overall, the climates are not so different, if it is considered that the Netherlands has a 5,500-heating degree day midpoint, and New York State has a 5750-heating degree day midpoint. Factors such as energy rates will have a far bigger impact than will climate.

However, it should be noted that whereas the accumulated heating degree days are similar for the Netherlands and New York State, the distribution of outdoor temperature is quite different between the two geographies. The Netherlands is warmer in winter than New York, with outdoor air temperature distribution narrower. In other words, there are fewer very cold hours and fewer very warm hours. See Figure 34. Note how many more hours per year the temperature is between 35°F and 60°F in the Netherlands, compared to either of two representative locations in New York, Syracuse and New York City. There are very few hours above 80°F or below 20°F in the Netherlands.

Figure 34. Distribution of Outdoor Temperatures



There are several implications of the different distributions of outdoor temperatures:

- The Netherlands can get by without air conditioning. This means heat pumps can be air-to-water, instead of air-to-air. This also constitutes an extra opportunity to save both energy and cost on cooling in New York State.
- Any air-source heat pumps (whether air-to-air or air-to-water) will work more efficiently in the Netherlands, due to the mild outdoor air temperatures. Air-source heat pumps are far more efficient at milder (warmer) outdoor temperatures.
- The size of the heat pumps can be smaller in the Netherlands, due to the significantly higher winter design temperatures.

8.2 Structure

The capacity of the building to bear the weight of the added exterior cladding and the solar modules is key. In the Netherlands, this weight is transferred to the existing walls, which in turn transfers the weight to the existing foundation system.

Part of the added structural load in the Netherlands is offset by the removal of existing slate roof tiles. This structural load reduction is not as frequently possible in New York, because existing low-rise construction typically uses lighter asphalt tile, or a fully-adhered roof, common on flat roofs in New York State. Slate tile is generally 8-15 pounds per square foot (psf), four or more times heavier than asphalt tile (2-3.5 psf) or adhered roof (approximately 2 psf).

Wind loads appear to be about 10-30% less in the Netherlands than in New York State, depending on the region; snow loads also appear to be less. A literature search shows that roofs in the Netherlands are designed for 15 psf. The minimum snow/live load in U.S. codes is 20 psf, and the design load for snow in Upstate New York is typically 32 psf.

Low-rise construction in New York State is often wood-frame, especially Upstate, whereas the construction in the Netherlands was all masonry, specifically brick.

In short, due to higher wind and snow loads, lighter roofs (compared to slate roof tile that can be removed to offset the added weight of new cladding and solar modules), and lighter frame construction (at least for low-rise buildings), the conditions in New York are structurally more challenging all-around. A study is recommended to assess the ability of typical multifamily buildings in New York State to bear the weight of new exterior cladding and solar modules.

8.3 Building Code

New York State has a new stringent energy code as of October 3, 2016. If the Dutch deep energy retrofit were adopted as is, it would likely be subject to this new energy code, due to the extensive scope of the renovation. However, meeting the new energy code with a similar retrofit should not be a problem, given the significant addition of insulation, the provision for continuous ventilation, and the tight air-sealing.

8.4 Product Availability

If New York State were interested in adopting the air-to-water heat pump approach used in the Netherlands, there may be an issue of product availability. Air-to-water heat pumps are far more available in Europe and Canada, than in the U.S., where major heat pump manufacturers (Mitsubishi, Daikin, Fujitsu, LG, etc.) do not currently offer air-to-water heat pumps in residential single-phase and 60-hertz electrical. This contrasts with their broad air-to-air heat pump offerings in the U.S. Availability will likely change in the next few years, as major manufacturers have informally mentioned the possibility of air-to-water heat pump products options in the U.S.; however, currently, product availability is an obstacle at this time.. A summary of air-to-water heat pumps supplied by a few small manufacturers available in the U.S. is shown in Appendix D. Very few have been installed and their capacity range is limited.

What are the implications of poor air-to-water heat pump availability? It is important to recognize that the vast majority of New York State's multifamily buildings use either steam heat or hydronic heat (i.e., radiators), as opposed to other heating systems such as forced-air systems, electric baseboard, etc. It is believed that more than 80% of the State's multifamily building stock is steam or water heated. To take advantage of these existing radiators, and their associated distribution systems (piping, etc.), as they did in the Netherlands, there needs to be better availability of air-to-water heat pumps.

However, an important difference from the Netherlands is that apartments in New York State are generally air-conditioned, whereas theirs are not. None of the apartments in the Netherlands discussed in this report are air-conditioned. Air-to-water heat pumps typically do not provide cooling; therefore, air-to-air heat pumps in New York State may be a better option. This will allow replacement of low-efficiency cooling, such as room air conditioners, which are prevalent in New York, while also providing the space heating function. The tradeoff would be losing the opportunity of cost-effective reuse of existing radiators. If and when air-to-water heat pumps become more available, the option will be whether to use them with existing radiators and forgo cooling, or instead, use air-to-air heat pumps that provide both heating and cooling.

Another important difference between the Netherlands and New York State is the majority of multifamily buildings are steam-heated. Because steam heat is so inefficient, there is a higher energy savings potential to convert to heat pumps.

8.5 Comments and Analysis

As mentioned earlier in this report, the Dutch building stock undergoing these deep energy retrofits appears to be fairly uniform (rectangular, two-story, etc.), but still presents challenges for cost-effective implementation at scale as no two building complexes are identical. It is possible that a fairly homogeneous building stock has either purposefully or programmatically been selected for the early renovations, and that moving forward, the Dutch will find a more diverse building stock, which will drive costs even higher. There were examples of these throughout the country. A single example shows the kinds of challenges that will arise; roof lines that are not uniform, dormers, skylights, bay windows, and wall protrusions, shown in Figure 35. Other examples observed include hipped roofs, protruding balconies, and exterior steps.

Figure 35. Example of a more challenging building in the Netherlands



Defining the scope of work of a deep energy retrofit program is important. There are significant decisions to be made around balancing flexibility with standardization of the scope of work. There are benefits to allowing flexibility in the scope of work; potentially improved competition, innovation, and cost-competitiveness. There are also benefits to standardizing the scope of work; economies of scale, shared best practices, and consistency of messaging and marketing. In the Dutch program, flexibility

appears to have been provided around material selection, fabrication techniques, finishes/appearance, details of the warranty (the exact length did not seem to be uniformly defined), and “extras” such as allowing the contractors to offer features such as the age-in-place addition, automation, earthquake proofing, and anti-burglar certification. By contrast, what is inflexible and standardized is the net zero performance goal. This resulted in the need for on-site solar photovoltaic, which then resulted in the need for full electrification, meaning heat pumps for heating and hot water, and electrification of all appliances (most importantly, the cookstove). The net zero goal also requires a well-sealed building envelope, which requires ventilation. The net zero goal also includes a complete insulation package and replacement windows and doors. It is a little puzzling that high-efficiency lighting was not included in the package, although in some cases, the residents are encouraged to install high-efficiency lamps. The final package is remarkably standard: Solar PV, heat pumps for space and water heating, ventilation, insulation and air-sealing, and replacement doors and windows. This supported the positives of standardization: economies of scale, shared best practices, and consistency of messaging and marketing.

8.6 Financing

The Dutch low-interest financing of 1% may be hard to beat. However, the availability of low-income housing tax credits (LIHTC) will help to offset higher financing interest rates in New York State. Some buildings in New York can also benefit from historic preservation tax incentives. Whatever financing is sought, it likely needs to be long-term financing in order to make the substantial scopes of work needed for deep energy retrofits affordable.

In order to deliver positive cash flow, business models will need to actively pursue all possible cost savings, not only from reduced load and lowered energy consumption (and potentially lower electric demand charges), but also from smarter system design and operation (e.g., pre-heating DHW with space heat rejected during cooling season), water savings (in steam-heated buildings especially), streamlining of maintenance procedures, and reduced risk.

8.7 Other Transferability Issues

Some aspects of the Dutch approach will be easier to implement in New York State than they have been in the Netherlands. There are no laws in New York protecting nesting sites for birds and bats in residential buildings, for example. Additionally, there is no regulation stipulating that retrofits are contingent on buy-in from a building’s residents, so there is no percentage of resident approval required before a retrofit can proceed (unlike in the Netherlands where 70% is stipulated). This results in the

additional benefit of not having to work around homes whose residents do not approve of the work. Note how in Figure 36 the end unit (on the left) chose not to be renovated. When some units are not renovated, more attention needs to be directed to the junction between renovated and not-renovated units, as seen in Figure 37. Such challenges in New York State are not anticipated.

Three specific examples of transferability for different types of New York State buildings are provided in Appendix C.

Figure 36. Residents did not approve the work in the end unit (left)



Figure 37 The junction between units that opted-in and opted-out



8.8 Conclusions about Transferability

The climate is roughly similar and heating-dominated, although the mild Netherlands climate (fewer hours in the temperature extremes) mean air-source heat pumps likely operate more efficiently there. The overall approach (insulation plus air-sealing plus heat pumps plus ventilation plus solar PV) will make sense for the New York climate, and in fact is already being adopted for high-performance new construction in the State. The dominance of steam-heating systems in New York multifamily building stock means energy savings from the retrofit will likely be higher, on average.

Appendix A. Site-Specific Photos and Observations

A.1 July 1, 2016

Site: Heerhugowaard
City: Heerhugowaard
Contractor: BAM
Social housing agency: Woonwaard
Hosts: Marnette Vroegop and Niels Sijpheer

Figure A1. Building not yet renovated



Figure A2. Renovated building



Figure A3. Mechanical rooms are in the rear



Figure A4. Computer dashboard provided to the residents

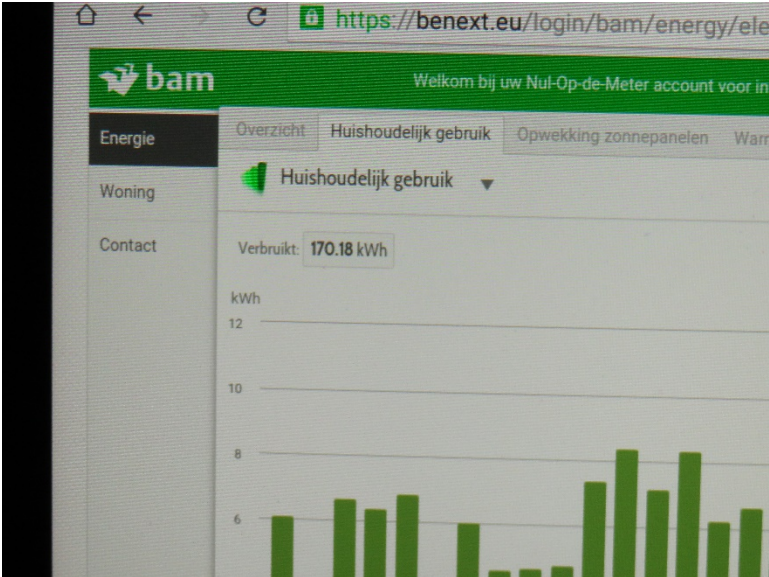


Figure A5. Computer dashboard

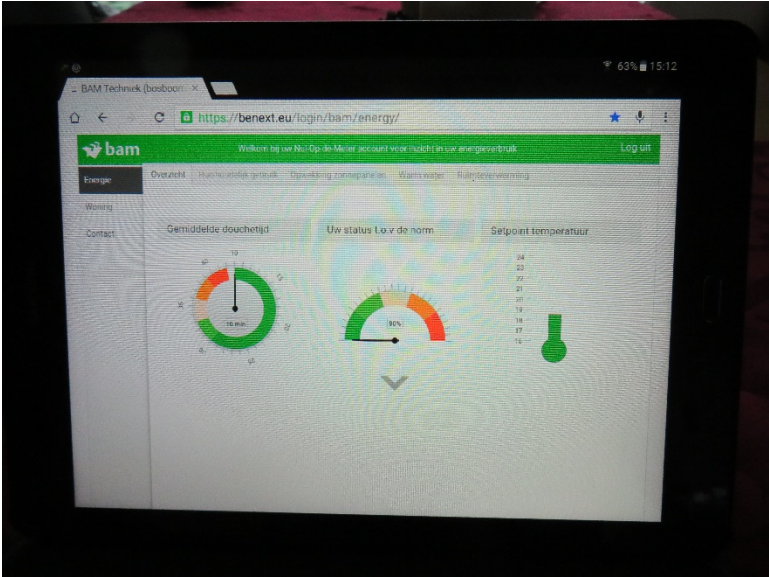


Figure A6. Radiator, below window extension used as a shelf



Figure A7. Exterior patio – new rear window and door



Figure A8. Filter in heat recovery ventilator



Figure A9 Front entrance/façade – solar modules on the roof



A.2 July 4, 2016

Site: Soesterberg

City: Arnhem

Contractor: Dura Vermeer

Social housing agency: Arnhem (Portaal?)

Hosts: Twan van Neunen

Figure A10. Pre-retrofit façade undergoing preparation for renovation



Figure A11. Mechanical rooms are in the front of the buildings



Figure A12. Open mechanical room

Lower right: Heat pump outdoor heat exchanger. Upper right fastened to interior of door: Solar inverter. Upper right inside the shed: Heat recovery ventilator. Top: Ventilation ductwork. Left (white): Water heater.



Figure A13. Excavation to add foundation insulation



Figure A14. Existing façade and scaffolding for renovation



Figure A15. A closer look at the existing façade and scaffolding for renovation



Figure A16. New exterior wall assembly seen over the existing wall



A.3 July 5, 2016

Site: Loppersum/Appingedam

City: Loppersum/Appingedam

Contractor: Three contractors—BAM, Balast, and Dura Vermeer.

Social housing agency: Wierden en Borgen

Hosts: Erik Jan van den Broek

Figure A17. Building not yet renovated



Figure A18. Solar modules



Figure A19. Building without renovation



Figure A20. Renovated building with shallow mechanical chase and individual exhaust fans



Figure A21. Renovated building (second contractor) with mechanical addition in the rear



Site: "4 story" site
City: Groningen
Contractor: Dura Vermeer
Social housing agency: Lefier
Hosts: Visited without hosts

Figure A22. Building not yet renovated



Figure A23. Recessed patio in building not yet renovated



Figure A24. Renovated building



Figure A25. Exterior mechanical shed attached to renovated building



Figure A26. Exterior mechanical shed attached to renovated building



Figure A27. Façade and solar modules on roof on a renovated building



Figure A28. Ventilation ductwork in renovated building



Figure A29. Ventilation ductwork in renovated building



Site: Gorredijk (pilot house with ground floor addition for medical “age-in-place” care)
City: Gorredijk
Contractor: Van Wijnen
Social housing agency: Not identified
Hosts: Hilbrand Katsma (builder)

Figure A30. Exterior mechanical shed in the front yard



Figure A31. New mailbox integrated into the new mechanical shed



Figure A32. Photo showing both a renovated house and a not-yet-renovated house, side-by-side



Figure A33. New windows, with extension showing depth of wall.



Figure A34. New windows, with extension showing depth of wall



Figure A35. Attic in renovated building showing evidence of air sealing, but insulation is all exterior, above the roof-line



Figure A36: Attic in renovated building showing evidence of air sealing, but the insulation is all exterior, above the roof-line



Figure A 37: Gable end of renovated building, with age-in-place addition shown at right



A.4 July 6, 2016

Site: Soesterberg

City: Soesterberg

Contractor: BAM

Social housing agency: Portaal

Hosts: Visited without hosts

Figure A38. Building not yet renovated



Figure A39. Renovated building



Figure A40. Solar modules on roof



Figure A41. Renovated façade



Figure A42. Dormer in renovated building



Figure A43. Mechanical sheds in rear of renovated building



Figure A44. Renovated building



Figure A45. Crawlspace vent in not-yet-renovated building



Site: Oud-Vossemeer

City: Oud-Vossemeer

Contractor: VolkerWessels

Social housing agency: Stadlander

Hosts: Sjoerd Klijn Velderman (Stroomversnelling staff person, who previously worked for BAM, I believe)

Figure A46. Building not yet renovated



Figure A47. Renovated building



Figure A48. House not renovated adjacent to three renovated houses, in the same building



Figure A49. Closeup/detail of not-renovated house adjacent to renovated house



Figure A50. New ventilation fan used on a room-by-room basis



Figure A51. New ventilation fan used on a room-by-room basis



Figure A52. New ventilation fan used on a room-by-room basis



Figure A53. New window and extension



Appendix B. Grading

In order to provide an overview of the Dutch accomplishments with their deep energy retrofit program, grades were assigned to different aspects of the program. These grades are somewhat subjective, and the broad basis for the grades are provided in the notes column.

Construction cost	C	Recognized as a challenge. Many extras are being provided (kitchen/toilet/bath renovations, new landscaping in front), and the envelope is intrinsically complex. Also, distribution of the ventilation ductwork is intrinsically complex. Many custom accommodations are required. Also, there are hints that soft costs have not fully been covered, and also that there has been some “loss leader” investment by builders, so actual costs may be higher than seen so far. Despite a large effort to reduce cost, which is ongoing, the challenge to do so significantly is high.
Tenant satisfaction	B+	Appears generally good. Some noise issues (though not in all installations, and so likely resolvable). Some timing issues. Some changes to scope reportedly bothered tenants. Experience is driving this grade higher, and this should become an A soon.
Benefits to tenants	A+	New clean façade, new windows and doors, kitchen and toilet/bathroom renovations in some cases.
Noise control	B	See Tenant Satisfaction, above.
	Grade	Notes
Energy conservation	A+	Net zero has been delivered in at least one complex, and possibly more. The approach is robust and should reliably deliver significant energy savings.
Aesthetics	A-	Clean new façade is a positive. Loss of old façade is a negative in some cases. See Photo: Woomward - BAM - 7-1-2016\IMG_2758
Heating	A+	Re-use of existing distribution is a plus – reduces cost and minimizes work in apartments. Conversion to electric heat pumps helps the net zero effort.
Ventilation	A+	Balanced heat recovery.
Insulation	A	Innovative. However, does not appear to be significantly more than code requirement.
Air sealing	A	Tight, and tested. However, does not appear to be Passivhaus level.

Education and behavior	A	Tenant focus is excellent. One-on-one work with stakeholders appears excellent. Not 100% sure of higher-level development and dissemination of best practices. Constant focus on moving on to “the next big thing” might be reducing focus on best practice development.
Market transformation	A	Outstanding market transformation for large builders and the specific sector (affordable housing).
Spillover	B	There are discussions of the concept being adopted in the UK, France, and the US. Early work is being done on other building sectors. At least one builder is already applying the techniques to new construction.
Stromversnelli ng	A+	Remarkable achievements, moving a well-defined concept well beyond prototype phase.
Expected persistence of energy savings	A+	Long-term guarantee is excellent.
Durability	A	May become an A+. Façade durability still to be determined. Also, new sheet metal enclosures for mechanicals need to be proven to stand up to weather (long-term) and to weight of components.
Maintenance / serviceability	A	Exterior mechanicals make for excellent access. Drive to miniaturization may compromise serviceability, otherwise this would be an A+.
Holistic	A	Envelope (insulation, windows, doors, air-sealing), heating, hot water, and ventilation are excellent. This would be an A+ if lights and appliances were included.

Appendix C. Transferability to NYS Buildings

C.1 Two-story building

The technology appears readily transferable to a typical two-story building, common in Upstate and similar to the building stock in the Netherlands. Major differences are the wood-frame construction, sometimes insulated, compared to the uninsulated brick buildings in the Netherlands. There is also greater variation in New York building stock. For example, the building in the comparison is heated with forced air furnaces, the hip roofs will be slightly less receptive to solar energy, and there is a basement that will need a different treatment than the typical Dutch crawl space. But overall, the transferability of the approach is high for this building stock.

	Energiesprong Buildings	New York State Example	Notes/Applicability
Stories	2	2	
Location	Netherlands	Syracuse	
Number of buildings	Varies, 5-10 typical	3	
Number of apartments	Varies - typically 6-8 per building	5	
Wall construction	Brick, uninsulated	Wood-frame, 2x4, uninsulated	
Wall R-value	R-3 estimated	R-3.6 estimated	Slightly higher R-value in NY, so less savings.
Roof type (flat, pitched, etc.)	Pitched, gable	Pitched/hip	Hip roof allows for less solar.
Roof/ceiling R-value	Wood frame uninsulated, R-2 estimated	1" fiberglass, R-4.5 estimated	Slightly higher R-value in NY, so less savings.
Roof cover	Slate tile	Asphalt shingle	
Domestic hot water	Natural gas "combi"	Natural gas storage	Higher savings potential in NY
Ventilation	None, or exhaust only	Kitchen exhaust	
Stove (gas or electric)	Natural gas	Natural gas (one electric)	
Clothes dryer type (gas or electric)	Varies	Natural gas	
Site description - space available for shed?	Yes	Yes	
Solar - south exposure?	Yes	Yes	
Solar - shaded?	Usually not	No	
Roof obstructions for solar (vents, etc.)	Varies - some chimneys, vents, skylights, etc.	None	
Heating type	Boiler (hydronic)	Furnace (forced air) - one basement apartment has electric resistance heat	
Heating fuel	Natural gas	Natural gas	
Efficiency	80% estimated	78% estimated	
Cooling type	None	None	
Metering type (master, individual, etc.)	Individual gas and electric	Individual gas and electric	
Foundation	Crawl space	Basement	
Windows	Mix of single-pane and double-pane	Single-pane wood, metal storms but storms all left open	
Laundry	Varies, some in-unit, some not	Gas dryer, top loader washing machine	

C.2 Four-story building

The technology appears readily transferable to a typical four-story brick building, in many ways similar to the building stock in the Netherlands. Similarities include the brick construction and lack of insulation. Differences with the Dutch building stock include steam heat, which is so common in New York State (well over 50% of multifamily buildings). Like the two-story New York building in the previous example, there are also more variations in the New York building stock as shown in the building in the example below. For example, this New York building has hip roofs with dormers that will be slightly less receptive to solar energy, and there is a basement that will need a different treatment than the typical Dutch crawl space. But overall, the transferability of the approach is high for this building stock. Due to the existing inefficient steam heat, the energy savings potential is likely higher than the Dutch building stock. In New York State, especially Upstate, many multifamily building complexes have more site available where geothermal heat pumps can be installed, further reducing the energy required for heating.

	Energiesprong Buildings	New York State Example	Notes/Applicability
Stories	2	4	
Location	Netherlands	Mt. Vernon	
Number of buildings	Varies, 5-10 typical	4	
Number of apartments	Varies - typically 6-8 per building	76	
Wall construction	Brick, uninsulated	Brick, uninsulated	
Wall R-value	R-3 estimated	R-3 estimated	
Roof type (flat, pitched, etc.)	Pitched, gable	Pitched, hip	
Roof/ceiling R-value	Wood frame uninsulated, R-2 estimated	"Minimal", R-8 estimated	
Roof cover	Slate tile	Asphalt	
Domestic hot water	Natural gas "combi"	Tankless coil on steam boiler	Should be outstanding energy savings
Ventilation	None, or exhaust only	None	
Stove (gas or electric)	Natural gas	Natural gas	
Clothes dryer type (gas or electric)	Varies	Natural gas	
Site description - space available for shed?	Yes	Likely yes - courtyard in middle of the complex	
Solar - south exposure?	Yes	Yes	
Solar - shaded?	Usually not	Some shading by trees	
Roof obstructions for solar (vents, etc.)	Varies - some chimneys, vents, skylights, etc.	Yes - dormers	This may be a challenge to get substantial solar
Heating type	Boiler (hydronic)	Boiler (steam)	Should be outstanding energy savings, also water savings
Heating fuel	Natural gas	Natural gas	
Efficiency	80% estimated	70% estimated	
Cooling type	None	Window room air conditioners	
Metering type (master, individual, etc.)	Individual gas and electric	Individual gas and electric, but common area metering for common electric and heating	Apartment gas is only used for cooking.
Foundation	Crawl space	Basement	
Windows	Mix of single-pane and double-pane	Double hung double-pane aluminum, installed 1995	
Laundry	Varies, some in-unit, some not	Common laundry	

C.3 Seven-story building

This randomly selected seven-story building in New York City happens to be a newer building (1992), and is insulated, with less potential energy savings. Similarities to the Dutch building stock include the masonry construction and gas-fired hydronic heat. Differences include wall and roof insulation, and the flat roof. Overall, the transferability of the approach for this type of more modern building is moderate. Energy savings will be low. Perhaps a building like this could be considered for conversion to heat pumps and solar energy to reduce carbon emissions, but the savings would likely not be a driver for the required investment.

	Energiesprong Buildings	New York State Example	Notes/Applicability
Stories	2	7	
Location	Netherlands	Queens	
Number of buildings	Varies, 5-10 typical	1	
Number of apartments	Varies - typically 6-8 per building	100	Built in 1992.
Wall construction	Brick, uninsulated	Block wall, face brick, cavity insulation	Existing insulation will reduce potential energy savings
Wall R-value	R-2 estimated	R-10 estimated	
Roof type (flat, pitched, etc.)	Pitched, gable	Flat, concrete deck, 2" insulation	Existing insulation will reduce potential energy savings
Roof/ceiling R-value	Wood frame uninsulated, R-2 estimated	R-10 estimated	
Roof cover	Slate tile	Built-up, covered with gravel	
Domestic hot water	Natural gas "combi"	Natural gas boilers	
Ventilation	None	Exhaust only (kitchen and bath)	
Stove (gas or electric)	Natural gas	Natural gas	
Clothes dryer type (gas or electric)	Varies	Natural gas	
Site description - space available for shed?	Yes	Yes, likely. Roof is also available.	
Solar - south exposure?	Yes	Yes	
Solar - shaded?	Usually not	No	
Roof obstructions for solar (vents, etc.)	Varies - some chimneys, vents, skylights, etc.	Minor - vents, stair penthouse.	
Heating type	Boiler (hydronic)	Boiler (hydronic)	
Heating fuel	Natural gas	Natural gas	
Efficiency	80% estimated	80% estimated	
Cooling type	None		
Metering type (master, individual, etc.)	Individual gas and electric	Individual electric, master metered gas	
Foundation	Crawl space	Slab	
Windows	Mix of single-pane and double-pane	Double-pane	
Laundry	Varies, some in-unit, some not	Central	

Appendix D. Available Residential Air-to-Water Heat Pumps

Make and Model				Features	Performance Metrics			
Manuf.	Model	# of installs	Cost (Indoor+ Outdoor)	Available in single phase	Capacity	Capacity at 0F	Efficiency	Min. OA Temp.
Nordic	ACE/ATW (split System)	Roughly 100	ATW 75 is \$6,868	Yes	2-6 tons	under 30,000 Btuh, loop temp slightly over 100F	3.7 COP @ 45F, 1.3 COP @ -20F	-20F
Electro Industries (NorAire)	NorAire	Not many	Looking at total: ~\$10,000 for fully installed system	Yes	3,4,5 ton	50-60,000 Btuh (with electric supplemental heat)	Depends on OA temp - rating for Minneapolis MN (-12F design day) 1.73 COP	-20F
Aermec	ANK	In the houndreds	Pending - vendor email	Yes	2.5-4 tons	From tables: at -20C (-4F) capacity of largest is ~18,900 Btuh (at 50C supply temp)	Varies- nice chart in the manual 1.25 to 3.7+ COP at 55-60 C output temp	-4F
Sanden	SanCO2	A couple houndred	Total estimated cost including installation: ~\$5,250	Yes	Small - 15,400 Btuh	capacity, 4.5 kW (flat capacity to -15F, at -20F ~12,000 Btuh)	4.5 COP COP at -20F ~1.7-1.8, Max COP 5.2	-15F
Chiltrix	Cx30	In US ~200 installations	Pricing for CX-30 \$3,400	Yes (will run 208-240)	Heating capacity is given at 95F outlet temps and drops from 30.5k at OAT of 43F to 20k at OAT of +17F.	From literature it appears that capacity at 113F supply water drops from 45,516 at 77F OAT, to 12,147 at -4F OAT.	1.66 COP @ -4F, 2.5-4.1 COP @ 50F (86F-131F LWT)	-20C (-4F)
Solstice (spacePac)	Solstice Extreme (LAHP48 series)	In the 1,200 range	The Solstice Extreme retails for \$7,100.	Yes	48,000 Btuh	Capacity - Just under 40,000 Btuh at 5F OAT, 120F supply water	up to 4 COP	as low as 0F (with 120F suply temp)

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