Wee Energy House; Environmentally responsive Architecture for Rural Northern Ireland

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ABSTRACT: The Irish cottage was the autonomous house for rural Northern Ireland between the 17th and 19th Centuries. Its form enhanced the beautiful Irish landscape and provided a holistic response to the occupants' requirements. The goal of this study was to design a contemporary alternative which would meet the expected comfort levels of the 21st Century, but with lower energy consumption than current standard housing. The design develops through studies of the vernacular, deriving a series of design guidelines from the environmental attributes of traditional architecture. A further technical investigation of design for this climate with the materials available in the 21st century derives an alternative series of design guidelines. The culmination of the study is the assimilation of the results of both investigations in a design which incorporates traditional and contemporary design and construction. The design developed following a rationale to reduce energy consumption and heat loss, maximise passive solar gains and generate energy.

Keywords: energy, comfort, vernacular, traditional

1. INTRODUCTION

Northern Ireland is part of the United Kingdom, governed by Great Britain. It is a small country consisting of six of the nine counties of the historic Irish province of Ulster. Ireland has a long history of tenant farming and an assessment of the current status of housing in Northern Ireland, shows that more than a third of the population live rurally, and this continues to increase. [1]

In-efficient use of housing stock is causing a steady increase in domestic energy consumption levels of the country. The clients are now the only permanent residents in their large, rural, family home, and so they would like a house which meets their new life style requirements. They have requested a design which respects, but does not mimic, local architecture. Instead draws from the past yet represents the future.

2. CLIMATE

Northern Ireland's latitude is 54º39'. The air temperature can reach low as -4ºC and as high as 24ºC, however the average remains between 3ºC and 14ºC. The daily fluctuations are a maximum of 5ºC in winter and 10ºC in summer. There is minimal inertia and a relatively stable level of comfort already exists. [2]

The annual average relative humidity is 90%. Ireland is one of the windiest parts of Europe with the prevailing wind from the south west following the Gulf Stream off the Atlantic Ocean. [3] As the site lies in a valley which runs along a north-south axis, the valley channels the wind directly from the south. Local knowledge supports this and confirms that the less frequent north-easterly winds which come in from Northern Europe are actually the coldest. [4]

In this climate solar radiation has significant seasonal variations. Lowest irradiance is in December, with averages up to 100W/m² and a maximum of 260 W/m² the highest is in May with an average of 420 W/m² and a maximum of 880 W/m². The low sun angle in winter permits direct solar radiation deep into buildings and may be a potential heat source. The heating season is long; but the temperature to be made up is relatively small. There is no significant cooling season as overheating in summer can be accommodated with natural ventilation.

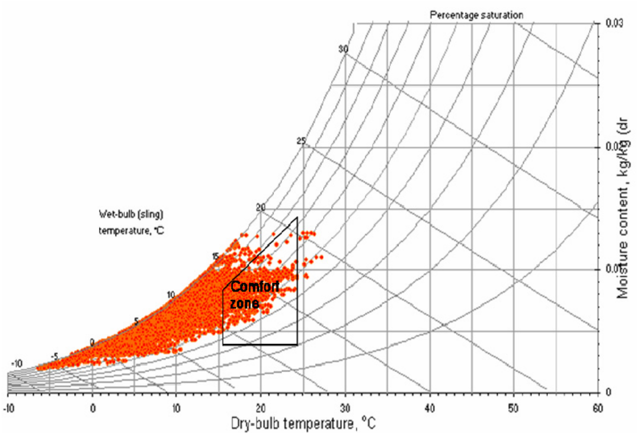

Figure 1: Pschryometric Chart. Source; Meteonorm version 5.0 in Climpro.

3. LESSONS FROM THE VERNACULAR

This section of the study aims to understand the environmental response of the cottages to the countryside and climate.

3.1 Site

Traditionally buildings were usually orientated to minimise the exposure to wind, rather than to encourage solar gains. When choosing the site to build, a sheltered site was preferable to reduce the exposure of the dwelling, but it was also important to build on the least productive piece of land. Often the two came together by building near the base of a sloped site where the gradient of the hill created a shelter belt and the sloped incline was not a productive piece of land.

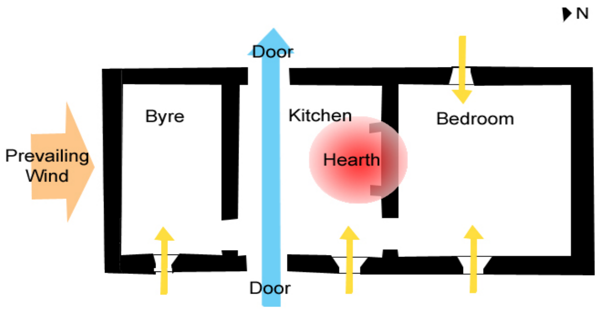

Figure 2: Typical cottage floor plan showing environmental attributes.

3.2 Form

A narrow plan evolved due to a lack of timber to span a larger roof plan. The environmental benefits of this narrow plan include cross ventilation and dual aspects. The dual entry allows for separate access for the inhabitants and the livestock and for cross ventilation. The most typical plan developed with a hearth in the kitchen at the centre, buffered by the bedroom one side and side byre, which housed the animals. The internal organisation placed the inhabitants at the warmest point, between the hearth and the livestock, and in the cooler bedroom. The roof is steeply sloped, designed for rain run off in a climate of high precipitation but where snow rarely lies.

Aperture was always on the long walls catching sun in the morning from the east and in the evening from the west. Small windows reduced heat loss and the walls around the window were tapered so maximum daylight entered through minimum glazed area. The gable walls incorporated the chimney stack, with the chimney spout at the ridge, protruding through the roof. The dwellings always extended in length not breadth, through a series of parallel gable walls. [5]

A farm cottage may require several ‘out houses’ for the livestock. These were laid out in clusters, often in a courtyard formation, to provide a sheltered outdoor space creating a micro-climate.

3.3 Materiality

The building techniques developed with whatever materials the locality provided. The walls of the Irish cottage where traditionally stone which provided both the envelope and structure. Stone was cheap and abundant. Walls were constructed either with mortar, or dry walling techniques depending on the available local resources. This was a good source of thermal mass to radiate heat produced by both solar radiation and internal heat gains. In areas which lacked stone, houses were built from peat or mud. Timber was scarce everywhere following the widespread destruction of the forests of Ireland in the 16th and 17th centuries which led to a lack of timber availability. [6]

Mud houses were biodegradable because when they are no longer in use they would melt back down to the earth. Thatch and mud houses were very comfortable. This building technique was highly insulative but with low absorption of solar gains; therefore providing a warm winter shelter which was cool during the summer. Thatch roofs were complied of a layer of wattle, supporting the top layer of peat from the bog and a layer of thatch to reduce water penetration in the damp climate. In later years corrugated iron sheeting and slate roofs became increasing popular as an alternative to thatch.

Figure 3: Restored Cottage, Co. Donegal, Ireland.

3.4 Thermal Performance

There were various styles and sizes of hearths and chimneys used in cottage design though they were often restricted in size by the ‘hearth tax’ charged to the residents. Range stoves were a later development which rural homes installed in place of the open fire. They provided cooking facilities, hot water and heating for the house. They are still popular in rural Irish houses today. Many are designed to for oil fuel but they were originally designed to use solid fuel such as peat or wood.

3.5 Design Guidelines

These buildings evolved in response to their locale and their function on the land.

There are several common features in these buildings. They have a rectangular plan, extending in length, not depth. They are only one room deep allowing dual aspect day-lighting and cross ventilation. The construction is thick, strong walls solidly built of mass mineral material supporting a steeply sloped roof. The height is limited to one storey, and designed for protection from the elements, rather than solar gains and the windows and doors are never placed on the gable walls. Finally an open hearth at floor level in the centre of the plan provides the auxiliary heat source for the house and heat loss is reduced by buffering either side of this space with a byre and a bedroom.

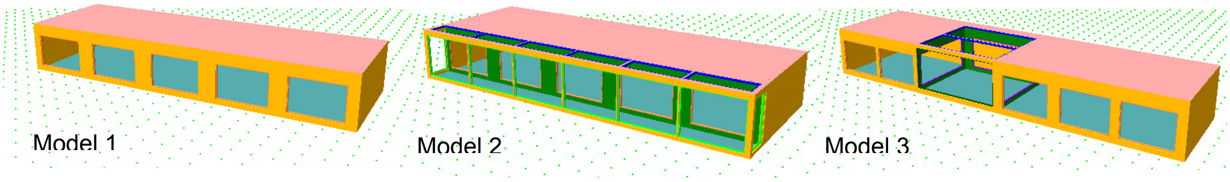

Figure 4: TAS models used to simulate the performance of a sunspace in the design.

4. Design Strategies and Tools

4.1 Design Considerations

Space heating accounts for 62% of the annual energy consumption of an average house in the UK and water heating accounts for 22%. [7] The intention is to reduce the space heating requirement of the scheme and so greatly reduce the overall energy consumption.

4.2 Eliminating the need for Space Heating

A series of tests were performed on a box model in the Energy Index spreadsheet [8] to establish how best to reduce the need for space heating in this climate. The model was single storey, detached house with a floor area 120m² and height of 3m. Four models were tested with variable window to floor ratios and with the glazed area on the south façade to maximise solar gains. Model A was based on standard practice, with double glazing and curtains and a U-value of 2.63 W/m²K. Model B was tested with a double glazing low-emissivity system with night shutters applied from 1900-7000 and a U-value of 1.3 W/m²K. Model C was tested with the same glazing system and improved walls, roof and floor U-value of 1.0 W/m²K. Finally model D maintained this standard but introduced mechanical ventilation to further reduce the space heating requirement.(Fig.5).

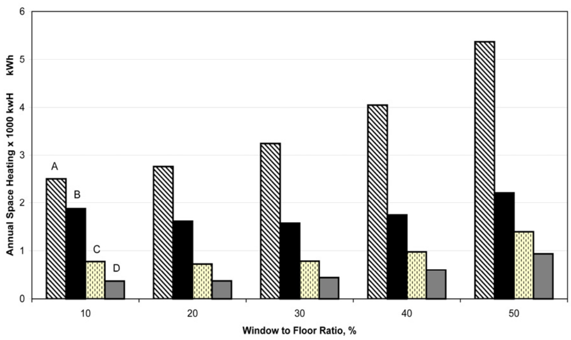

Figure 5: Effect of window to floor ratio on the annual space heating requirement.

The results show that the optimum window to floor ratio is between 10%-30% on model D. The double glazed window with curtains (model A), which is commonly preferred in Northern Ireland, increases the annual space heating load proportionately as the area of glazing increases. Although the space heating requirement of the model has been reduced by mechanical ventilation, it has not been eliminated and an auxiliary heat source will have to be specified.

4.3 Thermal potential of a Sunspace

The design brief includes a sunspace. This provides the opportunity to exploit ambient heat in the environment, by collecting and concentrating solar gains in the space and then releasing the pre-warmed air through the rest of the house. Creating this thermal buffer also reduces the heat loss from a highly glazed design. It is a logical expectation that the sunspace will overheat in summer therefore shading and ventilation would be employed to counteract this. Reducing the area of glazing would also reduce overheating.

Studies carried out on Thermal Analysis Simulation, New Generation [9] compare outdoor temperature, indoor performance on model 1 with no sun-space, model 2 with an external sunspace and model 3 with an internal sunspace. Each model has the same floor area, window area and construction properties. The sunspaces have a floor area of 24 m², which is not included in the model floor area of 120 m² and aperture of 9m² between the conservatory and house 30% of which is open to couple the spaces from 0700-1900. Internal Shadows were also applied.

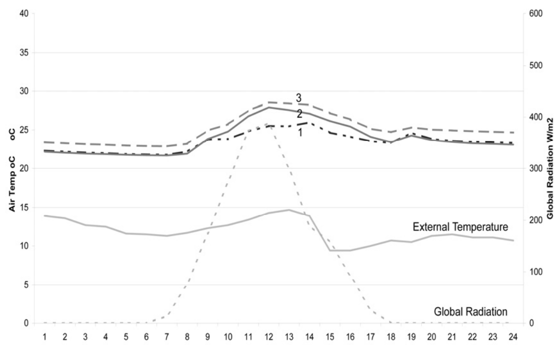

Figure 6: Thermal performance of the models on a Sunny Mid Autumn day.

The simulations were tested without a source of auxiliary heat, to predict the internal temperatures of the spaces, influenced only by climate and internal gains. The tests were most successful in spring and autumn. A maximum difference of 7˚C can be clearly seen between the results of the model with an internal sunspace and the model without a sunspace. It is therefore assumed that the additional heat gain is due to the effect of coupling the space with the sunspace. The predicted interior temperature of model 3 is constantly 3˚C higher than that of model 2. This is due to the larger exposed surface area of the external sunspace and therefore greater exposure to the elements, including the prevailing wind. (Fig.6)

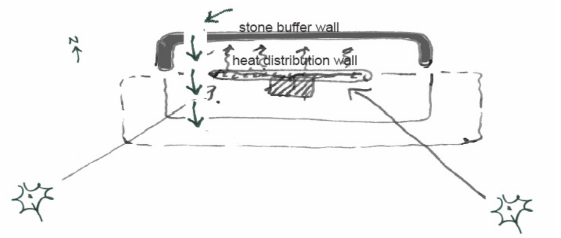

Figure 7: Concept sketch of building

5. APPLICATION IN CONTEMPORARY DESIGN

5.1 Design Brief

As their family are leaving home to pursue careers so the clients' have requested a new home which meets their new lifestyle requirements. They now have more time to enjoy as a couple and their social and work patterns are changing. They require a home with space for their hobbies and have requested a library and an artist's studio. They no longer require the large number of bedrooms they have presently, but request additional sleeping quarters for family visits. It is important the design considers possible changing future needs and is low maintenance.

5.2 Concept Design

The form is derived from a synthesis of response to the location, climate and the vernacular. A reclaimed stone 'buffer' wall on the northern boundary protects the house from the cold north wind, reflecting the dense construction of the traditional cottage with minimal aperture. This 'buffer' wall is continued inside the plan. Here the wall is entirely an internal thermal mass acting as a spine for the plan, separating and connecting individual spaces, but also collecting, storing and distributing the heat gains of the internal environment to all spaces in the house. On the south side the building opens up to the sun in a contemporary passive solar design.

The organisation of this scheme is designed for the daily occupancy of the house to follow the sun path. While the sunspace should face south, the studio requires north light and the kitchen is the warm centre of the house, derived from the vernacular.

5.3 Form

The intention is for the form to emphasise the contrast between the traditional, dense protective building technique in the north zone, and the open highly glazed south elevation of the passive solar zone. The north zone of the scheme has a massive external stone wall constructed from the reclaimed stone of existing buildings. This is internally insulated for fast thermal response. The south zone is constructed to maximise its passive solar gains and is insulated externally and with exposed thermal mass in the floor and walls.

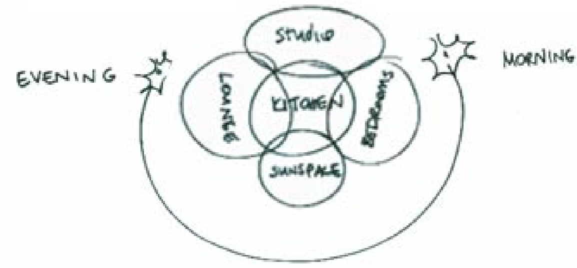

Figure 8: Concept for internal organisation

5.4 Orientation

The prevailing wind is a warm mild wind which enters the site from the south. In summer this wind will aid natural ventilation when the aperture, on the south façade, is opened. Glazing is primarily on the south elevation to maximise passive solar gains.

Apertures to the north, east and west of the house provide diffuse light, morning sun and views of the sunset respectively. Access is from the north east of the site; therefore, the entrance is on the north elevation to be clearly visible upon arrival. This provides the opportunity to break the dense construction, emphasizing the depth of the stone wall.

5.5 Architectural Quality

The elongated, single unit deep plan of the vernacular is represented in one half of the scheme. To replicate this exactly and meet the requirements of the brief would have created an extremely long, narrow form. Rather, the building is two units deep, yet the overall form retains the proportions of the vernacular, albeit on a slightly larger scale.

The sunspace provides an aspect through the house to the landscape. The studio and library have access to an evening terrace with a south westerly aspect. The library, hallway and living area all have direct access to the sunspace. The sunspace façade is a folding system which allows it to become an open south facing terrace in summer months. The living area prioritises the south aspect. The sleeping quarters have developed as a north bedroom for summer occupation and a south bedroom for winter occupation, with an adjoining dressing area allowing easy access from either room. Both bedrooms also open onto a morning terrace with a south easterly aspect.

5.6 Glazing System

Shutters reduce heat loss, raise the night time U-value of the glazing system and hence the

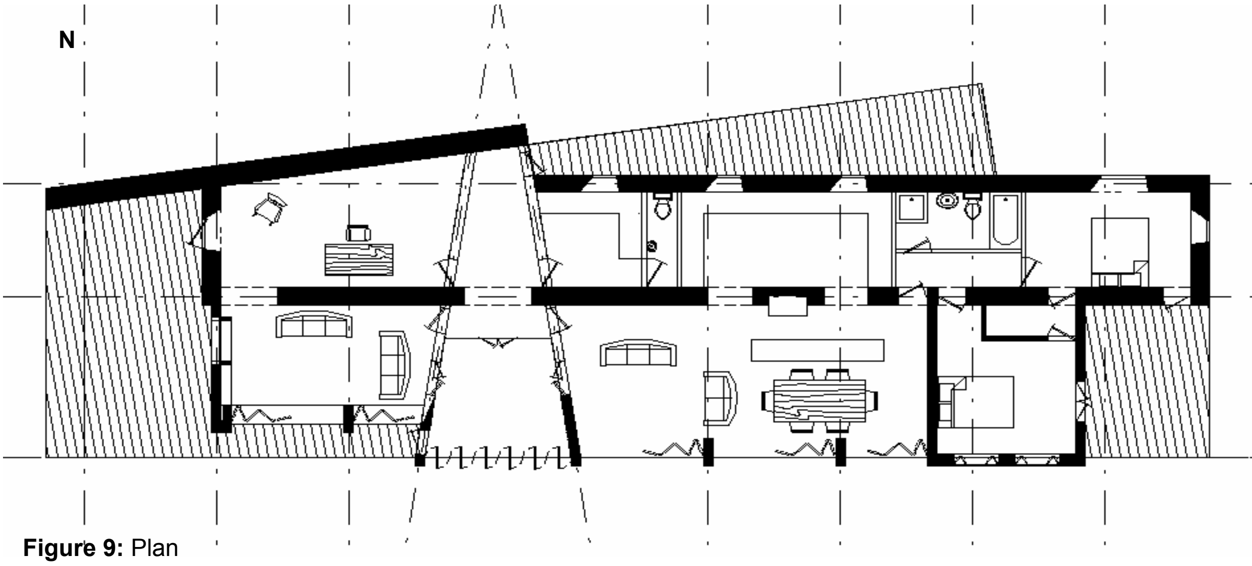

Figure 9: Plan

Figure 10: South West perspective

Figure 11: North West perspective

mean glazing U-value, without reducing solar gains in daylight hours. In this scheme the shutters are fitted internally for easy access in winter evenings. Inside they are less prone to weathering, and therefore require less maintenance. The shutters can be left open in summer months when night cooling of the space would provide a better environment for the following day.

The smaller windows in the stone buffer wall replicate the characteristics of the vernacular window, the inner walls are tapered to maximise daylight penetration while minimising heat loss. A large roof overhang on the south elevation will protect the façade from weathering by reducing exposure to the sun, rain and snow. The depth of overhang prevents passive solar gains in summer, without reducing passive solar gains in winter. The glazing system specified is low emissivity double glazing with a U-value of 1.8 W/m²K reduced to 0.8 W/m²K with night shutters. Assuming the shutters are closed from 1900 – 0700, the mean U-value of the glazing is 1.3 W/m²K.

5.7 Ventilation

Providing ample aperture at both high and low levels encourages natural ventilation. The air warmed in the sunspace is used for ventilation and reduces the need for space heating in the dwelling. A façade designed to open completely converts the sunspace into a roofed courtyard in summer. (Fig.12)

5.8 Alternative Roofing System

The detailing of the junction between the roof and the gable wall is derived from the vernacular. The south pitch has a series of 1m² modules, including south facing glazing panels, solar collectors and photovoltaic panels. These modules actively and passively generate energy for the house and are incorporated into the design as a considered element in the form.

5.8.1 Autonomous architecture

The houses of rural Northern Ireland are not connected to mains sewage systems or fuel source. They may connect to the mains water supply and national grid. Fuel for heating systems must be stored on site, currently oil is most popular. Many rural homes have wells and use this as their water supply. (Fig.13)

The Irish Meteorological Office has recorded the average daily wind speed in this area to be 5m/s. This will support a wind turbine of rotor diameter 2.5m and produce an estimated annual output of 1354kWh. [10]

Figure 12: Section through sunspace

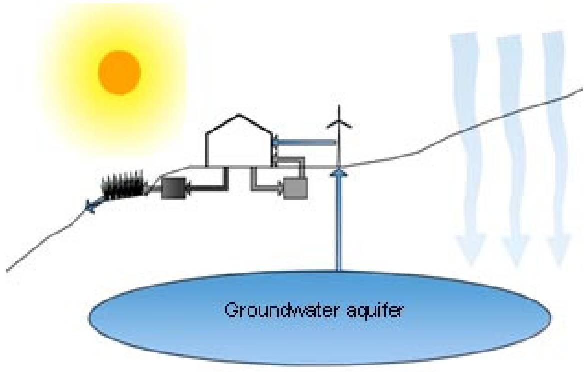

Figure 13: Section through sunspace

6. CONCLUSION

As the internal gains will not meet all the heating requirements the clients have specified a range stove to provide the cooking facilities for the house. These stoves provide a continuous source of background heat, auxiliary heating and hot water. The solid fuel stoves can run on wood, smokeless fuel or peat. The stove releases 0.5kW per hour continuously and increases to 1.0 kW per hour while in use for cooking. [11]

In winter this background heat often brings the internal environment of the living space up to the preferred thermal comfort levels, without additional heating. As the studio and library may not be occupied at all times, additional heating required for these spaces, may be generated only when required. The internal 'heat distribution' wall connects the living space to the winter, south facing bedroom and provides thermal mass to retain the heat of the house.

The clients have always lived in this cool temperate climate and are robust and well adjusted. Dataloggers were used to monitor their thermal comfort levels in their current residence. A week of testing concluded that their preferred whole house temperature is 18˚C. However this is expected to rise to 21˚C when they become elderly.

The thermal performance of the scheme was tested in Thermal Analysis Simulation, New Generation [10] to predict the energy requirements of the proposal with a mean whole house temperature of 18˚C.

The graph shows the annual energy consumption of the clients' current house compared to the new proposal with and without the range stove. The results show the range stove is not the most efficient heat source, as the energy of the continuous heat supply is greater than the actual required energy.

Lessons from the vernacular combined with contemporary design techniques have been the driving forces throughout the design process with the goal of incorporating appropriate form, organisation and materials to create a house that reflects the age we live in. The final scheme is simple, energy-efficient, contemporary architecture for rural Northern Ireland. It is designed to keep running costs and maintenance low with regard to the stringent planning regulations for the countryside.

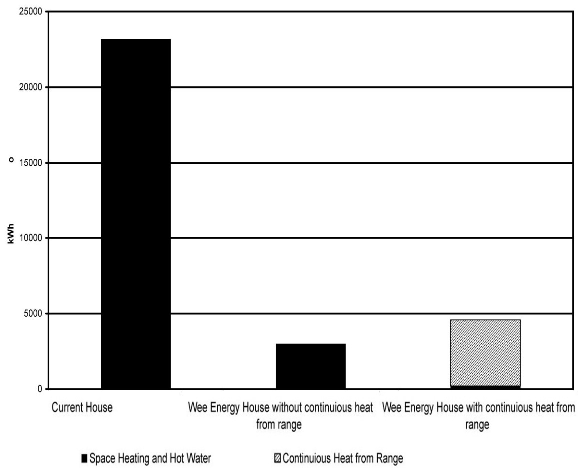

Figure 14: The predicted annual energy requirement for space heating.

The techniques of using south facing glazing for passive solar gains, the incorporation of a sunspace, coupled with high insulation and natural ventilation greatly enhance the thermal performance of the house without increasing the budget because the architecture becomes the technology in this design. The reduction of energy consumption will greatly reduce the CO^2 emissions of the house, and hence it's overall impact on the global environment. The water management system, reclamation of materials and minimisation of construction waste will reduce the buildings affect on the local environment. The advantages to this design include contemporary self-sufficient design, reduced energy requirements and a strong aesthetic link to the vernacular that enhances the countryside of Northern Ireland.

ACKNOWLEDGEMENTS

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