Design Guide:
Healthy Low Energy Home Laundering

Rosalie Menon and Colin Porteous

MEARU (Mackintosh Environmental Architecture Research Unit)
The Glasgow School of Art

Design Guide:
Healthy Low Energy Home Laundering

Rosalie Menon and Colin Porteous

MEARU (Mackintosh Environmental Architecture Research Unit)
The Glasgow School of Art

Published by MEARU (Mackintosh Environmental
Architecture Research Unit)
The Glasgow School of Art

ACKNOWLEDGEMENTS:
The design guide is based on the work of the multi-disciplinary research team for the 'Environmental Assessment of Domestic Laundering'
(Grant No. EP/G00028X/1). We gratefully acknowledge the financial contribution of the Engineering and Physical Sciences Research Council (EPSRC), thus enabling an in-depth study over three years, the findings of which carry considerable economic significance

Mackintosh Environmental Architecture Research Unit
(MEARU), Mackintosh School of Architecture,
The Glasgow School of Art
Principal investigator: Prof Colin Porteous; Co-investigators:
Dr Tim Sharpe, Rosalie Menon and Donald Shearer;
Senior Research Assistant: Dr Haruna Musa

Centre for Research on Indoor Climate & Health (RICH),
Glasgow Caledonian University
Co-investigators: Dr Paul Baker and Chris Sanders

Energy Systems Research Unit (ESRU), University of
Strathclyde
Co-investigators: Dr Paul Strachan and Dr Nick Kelly;
PhD student: Anastasios Markopoulos

The team also recognises the valuable contribution of housing associations and individual households in making this guide possible.

www.homelaundrystudy.net
ISBN number: 978-0-9571595-0-1

Guide design and production: Duich McKay, photography:
Colin Gray. Typeset in Avenir. Printed by Hay Nisbet Press

Contents

THE PROBLEM: PASSIVE DRYING LAUNDRY POSES A HEALTH RISK IN CURRENT HOUSING DESIGN

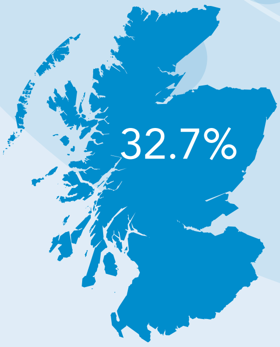
HEALTH RISKS

There are three main health risks associated with indoor drying, all relating to moisture.
This practice is also inconvenient and unsightly and affects a general sense of well-being.

MOISTURE AND EXCESS DUST MITES
= asthma risk (p15)

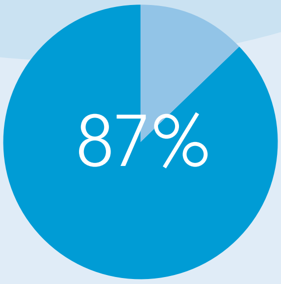
INDOOR DRYING = high mould spore count = asthma, eczema etc. risks (p16)

INDOOR DRYING + FABRIC SOFTENER
= hazardous carcinogenic chemical
= health risk heightened with moisture (p18)



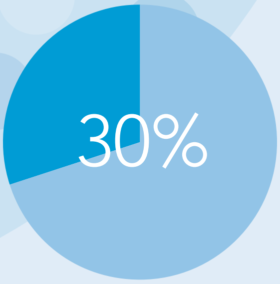
SCOTTISH CONTEXT

- High level of fuel poverty:
  – 32.7% Scotland
  – 20.1% England (p18)
- More indoor drying
- Less tumble dryer usage in Glasgow

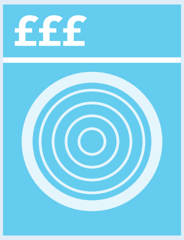


INDOOR DRYING HABITS

- 87% dry indoor during the heating season (p19)
- Open window + heat = fuel poverty
- Closed window + moisture = health risk



MOISTURE FROM DRYING
30% of moisture in homes is attributable to clothes drying on wash days (p11).

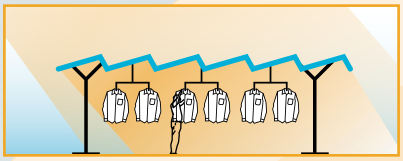


TUMBLE DRYING – HEALTHIER BUT ENERGY INTENSIVE
3.5 kWh per cycle typical

THE SOLUTION: DEDICATED DRYING SPACES

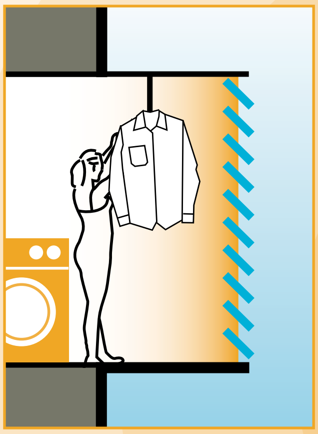
Current housing has a lack of dedicated drying spaces, utility rooms or other suitable spaces in which to dry clothes within the home.

Not only can the sun, even in Scotland, help to dry our clothes, it is also a natural disinfectant.



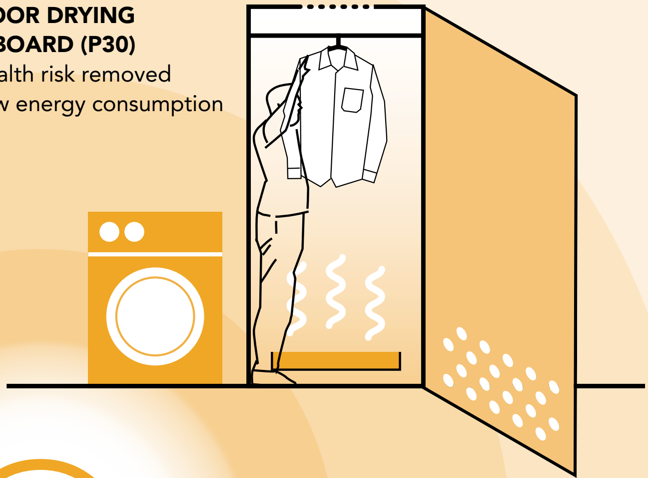
COVERED OUTDOOR DRYING (P34)

- Sun disinfects washing
- Zero energy consumption



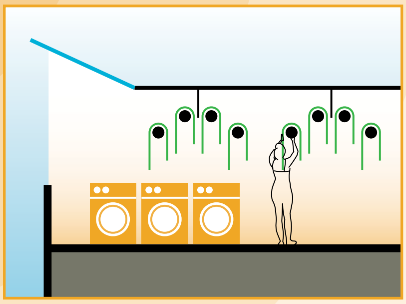
INDOOR DRYING CUPBOARD (P30)

- Health risk removed
- Low energy consumption



COMMUNAL DRYING SPACE (P34)

- Make waterproof but well ventilated
- Take advantage of sunshine
- Remove drying from homes



EXECUTIVE SUMMARY

WHY IS DRYING SPACE A SIGNIFICANT PROBLEM?

The issue of drying domestic washing is a common problem in all housing types across private and social housing sectors, and is one which does not appear to be adequately tackled in new housing, even in exemplar low energy projects.

Due to awareness of the energy consumption of tumble dryers, many residents are choosing to dry clothes passively within their home. The impact of this incurs not only a severe energy penalty via increased heating demand, but also a potential health risk due to higher moisture levels.

High moisture is associated with dust mites and increased mould spore concentrations as well as generally poor indoor air quality.

Based on the Glasgow research, a weekly average of at least 15% of moisture released as water vapour in homes, and up to 30% on wash days for a single load, is attributable to indoor drying.

THE GLASGOW SURVEY FINDINGS – ATTITUDES TO DRYING CLOTHES WITHIN THE HOME:

95% of respondents used some form of passive drying and 50% perceived internal drying as a problem or issue.

All housing types had a lack of dedicated drying spaces, utility rooms or other suitable spaces in which to dry clothes within the home.

Of those surveyed during the heating season from September to May, 87% dried passively indoors and, of those, 64% dried on or near heat sources. 23% also admitted to turning up heat to speed up the drying process; and 37% to always opening a window while drying.

WHY IS IT A PARTICULAR PROBLEM IN SCOTLAND?

This is particularly pertinent in Scotland where precipitation limits opportunity for exterior drying and outside air is already frequently moisture laden. The Glasgow laundering study confirms that current ventilation provisions within housing do not address the problem of lengthy moisture injections within living spaces, often relying on occupants to open windows and consequently losing heat in cold weather.

The current UK trend towards airtight construction and spatially restrictive homes potentially intensifies the moisture build-up from all sources, and with the lack of any current requirement in statutory building standards for a designated drying space to be enclosed, it leads to further moisture circulating around living spaces.

Levels of fuel poverty in Scotland are already excessive and increasing the domestic heating load during the drying process makes a bad situation worse. It is a 'catch 22' situation because tumble drying is more energy intensive than 'open window' passive drying.

This situation is also contradictory to the UK Government's attempts to create increasingly low energy homes to reduce CO_2 emissions.

The Glasgow laundering study provides a strong case for funding retrofits to address this problem, as well as amending new-build standards.

THE RESEARCH

Mackintosh Environmental Architecture Research Unit (MEARU) has thoroughly investigated the laundry habits across a wide demographic mix of residents within social housing in Glasgow and undertaken detailed analysis of air quality

and energy consumption relative to domestic laundering habits. This has been augmented by laboratory testing of materials by the Centre for Research on Indoor Climate & Health (RICH) at Glasgow Caledonian University, in turn supported by advanced moisture modelling by the Energy Systems Research Unit (ESRU) at Strathclyde University.

This design guide distils extensive findings to provide a critical body of knowledge of impacts on both energy consumption and indoor air quality, the second being significant for the health and wellbeing of occupants.

Based on the evidence, this design guide provides technical guidance on design upgrades to existing building stock to mitigate energy consumed and any undesirable side effects with respect to air quality or the fabric and contents inside homes. Such guidance is equally applicable to new low-carbon to zero-carbon housing.

KEY FINDINGS

Passive indoor drying and dust mites

- Although there has been a large body of research relating damp housing to ill health, this study is the first to track the specific implications of passive indoor drying.
- In terms of dust mite growth, known to be causal for asthma in sensitised individuals, passive indoor drying adds to the problem in already over-moist and poorly ventilated homes.
- The heating season average of 87% drying passively indoors rises to 96% in spring.
- Over 75% of households had average absolute moisture levels above the recognised upper threshold for dust mite growth linked to asthma risk in vulnerable groups.

Passive indoor drying and mould spores

- In terms of mould growth and its association with asthma, no consistency was found between indoor drying and its visible presence.
- However, a strong relationship was found between spore concentration in the air and presence of passive drying – average 300% more than Finnish health standards.
- This also carries a health risk to those prone to asthma, hay fever and other allergies. For example, Aspergillus fumigatus, found in 25% of the dwellings sampled, is known to cause lung infections in people with weakened immune systems.

Passive indoor drying and softeners

- Over half of households use fabric softeners. Although fragrances in such products are unregulated, softeners can produce a hazardous carcinogenic – acetaldehyde.
- All such water-soluble off-gassed chemicals increase in concentration with increasing moisture. Further research is needed to establish safe limits as for radon.

Passive indoor drying – reduces well being, adds to heating bills

- The presence of mould or damp smells, and even the inconvenience of indoor passive drying, may also detract from psychophysical wellbeing.
- The trend of opening windows and/or boosting heat while drying has been calculated to more than double a space heating load in January in a naturally ventilated home.

Appliances – washing, drying and ironing

- The alternative of machine drying all clothes is estimated to have significantly greater primary energy impacts and carbon impacts compared with passive drying in a dedicated enclosed space.
- Of those using tumble dryers, the average power use expressed per person annually is three times greater than for washing machines.
- Expressed per hour of running time, the energy consumption of washing machines vary by a factor of five; and per cycle by a factor of over four – energy ratings not corresponding well with respective high and low values measured in use.
- Ironing is estimated to use some five times less power than washing machines but also adds moisture to indoor spaces.

WHAT IS THE SOLUTION?

Based on the analytical evidence gathered during survey work and detailed monitoring of residents' homes and laundry habits across a variety of social housing types in Glasgow, this guide suggests changes to the current Scottish statutory standards for passive indoor drying, as well as related best practice.

A key proposal is to ensure that a drying space is isolated from the rest of the house with its own heat and ventilation, and its minimum volume and linear hanging space enlarged. Associated best practice guidelines suggest methods by which these designated spaces can be integrated into new and existing homes.

In addition, recommendations are made for the provision of individual and communal exterior covered drying spaces, the opportunity to upgrade balconies and sunspaces, and to provide communal laundry facilities in high density housing.

These recommendations are made to suit typical existing house types based on survey information but could be easily integrated into new build scenarios.

If such solutions are adopted, moisture levels in homes will reduce substantially while air quality improves, minimising adverse health impacts and improving quality of life.

Together with heat recovery from grey water, solar energy capture and more efficient appliances, domestic energy consumption and CO_2 emissions would be significantly reduced.

The symbiosis of the potential health and energy savings, the latter with linked commercial stimulation, could have a highly significant impact on the UK economy.

WHO SHOULD HEAR ABOUT THE SOLUTIONS?

This design guide will be of compelling interest to UK and Scottish governments (Scotland, the context for the study, but relevant to public health, environment and communities throughout the UK and beyond), social housing providers and related bodies (e.g. Scottish Federation of Housing Associations), private sector housebuilders, architects and those supporting the move towards carbon neutral housing.

WHAT CAN POLICY MAKERS DO?

The research supporting this guide gives strong justification in terms of health and wellbeing, and associated economic impacts, to modify current statutory and advisory standards in Scotland to ensure healthy and energy efficient drying facilities.

This design guide therefore advocates minor changes to the wording of the regulations, but changes that would have multiple beneficial consequences.

Policy makers should also stimulate uptake from the commercial and industrial sectors to meet demand for innovative appliances, components and materials.

1.0 Introduction

This design guide forms part of the conclusions from a three-year funded research project carried out across three leading academic institutions[1]. The Engineering and Physical Sciences Research Council (EPSRC) funded the work, under the title **Environmental Assessment of Domestic Laundering**. Work commenced in late 2008 and the research team has thoroughly investigated the laundry habits across a wide demographic mix of residents drawn mainly from within social housing in Glasgow.

The team focussed on energy consumed and indoor environmental impacts. This design guide distils extensive findings to provide a critical body of knowledge in both these areas – with environmental impacts having significance for the health and wellbeing of occupants. Based on the evidence, this design guide provides technical guidance on design upgrades to existing building stock to mitigate energy consumed and any undesirable side effects with respect to air quality or the fabric and contents inside homes. Such guidance is equally applicable to new low-carbon to zero-carbon housing.

It is stressed that consumed energy relates partly to electricity used by appliances and partly to indirect impacts on space heating and moisture, predominantly due to indoor passive drying methods (i.e. natural drying on an airing device) but also including steam ironing. It is this aspect that can significantly affect air quality as well as mould spore concentration, presence of mould itself and dust mite populations. This is where the health and wellbeing concerns lie, especially for the young and elderly.

This design guide therefore aims to be of immediate use to housing enablers and providers, and their architects. However, it is also intended that specific aspects, in particular those related to indoor and outdoor drying, and the detailed technical evidence that supports it, will lead to improved statutory standards, i.e. incorporated within the Scottish Technical Handbook. In this regard, the evidence clearly indicates that current regulations fall short of what is needed.

This guide and related technical information is available at www.homelaundrystudy.net.

1 ***Mackintosh Environmental Architecture Research Unit*** (MEARU), Mackintosh School of Architecture, The Glasgow School of Art; ***Centre for Research on Indoor Climate & Health*** (RICH), Glasgow Caledonian University; ***Energy Systems Research Unit*** (ESRU), University of Strathclyde.

2.0 Context and Outline Methodology of Research

2.1 CONTEXT

Surface mould growth

Outdoor laundry drying has become increasingly unfeasible due a number of factors, e.g. lack of secure and convenient space, working commitments, poor weather. Hence progressively more residents resort to drying indoors either by tumble dryer, passively within various rooms and on various devices, or a combination of both. Survey data indicates that due to the energy intensive nature of tumble dryers, many residents favour drying naturally, thereby adding significantly to the moisture load or the heating load. This is due to a trend towards parasitic use of radiators and opening windows more than would otherwise be the case. Ironing also adds moisture and may lead to window opening while heating is on. One consequence of such circumstances is to extend the heating season, but increased moisture levels over several hours can tip the environmental balance in other key respects – namely, increasing mould spore concentration in the air, making surface mould growth more likely and accelerating dust mite population. Each of these aspects adds to health risks, in particular for those who are atopic (e.g. prone to asthma or hay fever), and in this group particularly children. The presence of mould or damp smells, and even the inconvenience of indoor passive drying, may also detract from psychophysical wellbeing.

Excess humidity leading to mould is well documented as is its extent in the UK. The link between excess humidity and bio-contaminants such as the dust mite is also now more widely known with a causal link to asthma proved for over a decade and a maximum recommended absolute moisture threshold for dust mite growth established. Moreover, there is a previous significant body of epidemiological evidence linking dampness in housing to occupants' health.

Statutory standards in the UK (building regulations) for indoor drying do not currently tackle this issue effectively, and therefore impact on ventilation and air quality in existing and new build homes. This issue is particularly pertinent at a time when airtightness is considered a prerequisite in the design of low energy homes. Investigations into home laundering in Glasgow, and parallel MEARU projects, have highlighted that existing housing stock already lacks adequate levels of ventilation. Poor air quality and moisture resulting particularly from drying practices further intensify this problem, which is attributable partly to poor systems of control and partly to poor operation of such systems.

The UK's new housing stock is increasingly space restrictive and, due to inadequacy of minimum space standards, this is not likely to change in the near future. Few new homes have any designated space for laundry activity, in particular passive indoor drying, leading to a trend of moisture-laden living spaces; and although older stock usually had facilities like drying cupboards when first built, these are seldom used for that purpose now.

This scenario is further exacerbated by the current construction trend towards low thermal capacity (lightweight) domestic buildings and the previous tendency to high thermal capacity (heavyweight) but low levels of insulation. Also, one of the tasks for this study was to analyse hygrothermal (relating to moisture and heat) properties for common building materials, including their ability to buffer or dampen moisture variations in the indoor air over time.

Addressing this widespread and composite problem, with which indoor passive drying is particularly associated together with ironing to some extent, should be in tandem with improved efficiency of appliances, employment of waste heat, solar technology etc. This will also contribute towards the UK energy savings and carbon reduction targets, as well as generally helping to create healthier and more convenient environments in the home.

The findings of this research suggest practical retrofit solutions which can be applied to most existing house types, including enhanced outdoor drying facilities, and which are particularly evident for cost-constrained social housing providers. The solutions embodied in this guide will also transpose readily to new housing in the public and private sector.

2.2 METHODOLOGY

Investigating the impact of domestic laundry on energy use, indoor air quality and health in housing, and addressing the specific issues described above, involved three stages:

STAGE 1 – undertaken by Mackintosh Environmental Architecture Research Unit (MEARU), Mackintosh School of Architecture

Surveying, monitoring and analysing variables relevant to the impact of laundering processes on energy consumption and indoor environment was carried out.

An initial survey of 100 households within a range of mainly social housing types in Glasgow was undertaken during March 2009 to January 2010. This survey took the form of face-to-face interviews in the resident's home, with a questionnaire focussed on laundry habits, but taking in fuel bills, heating and ventilation provision and use. It also included measurements of temperature, CO_2 and humidity (at time of day according to time of visit).

During a further, more detailed monitoring phase, a selection of 22 residents from a variety of these dwelling types and demographic mix were asked to keep a diary of their laundry habits over a two-week period. Temperature, CO_2 and humidity readings were continuously logged over the monitoring period, and air samples taken on the first day in all relevant spaces within the dwelling. Where practicable, the

HOW MUCH MOISTURE IS PRESENT IN OUR HOMES?

5 –10 litres

AVERAGE DAILY MOISTURE PRODUCTION IN HOME+

2 – 2.5 litres

MOISTURE IS ADDED TO THE HOME IN ONE TYPICAL DRYING LOAD++

OVER

30%

OF MOISTURE IN HOMES IS ATTRIBUTABLE TO CLOTHES DRYING+++

+ Based on a family with two children: TenWolde , A and Pilon, C L (2007) 'The effect of indoor humidity on water release in homes', Thermal Performance of the Exterior Envelopes of Whole Buildings X, Atlanta, USA.

++ RICH experiment extrapolated to a typical wash load of 15-17 items – typical load being 4-5 kg when dry.

+++ on a typical laundry day based on a family with two children assuming two laundry loads are dried on one day.

energy consumption of washing machines and tumble dryers was logged directly. Glasgow weather data for the periods in question was also obtained.

The purpose of this stage was to evaluate all significant environmental and health-related impacts (as found and potential) arising from domestic washing, drying and ironing, taking into account the use-patterns of occupants, as well as the constraints of the accommodation and building fabric. This, in turn, involved identifying any key statistical links between variables, especially concerning moisture-related problems and potential health risks; and the stage also established a representative set of scenarios for later parametric dynamic modelling.

STAGE 2 – undertaken by the Centre for Research on Indoor Climate & Health (RICH), Glasgow Caledonian University

RICH conducted a series of laboratory tests on common existing finishing materials found within housing, specifically to define moisture buffering potential for passive drying; this information in turn adding to the modelling capability of Stage 3.

The hygrothermal properties of a limited range of flooring and furnishing materials were measured for the validation of heat and mass transfer models used for the prediction of bio-contaminant environments. This stage also looked at drying rates under different environmental conditions.

STAGE 3 – undertaken by Energy Systems Research Unit (ESRU), University of Strathclyde.

The final stage involved generating a theoretical framework enhancing the capabilities of an advanced computer programme, ESP-r, to dynamically model transient moisture transport; to develop a procedure for undertaking parametric tests to cover the large number of factors that influence health and comfort risks; and, based on scenarios devised in Stage 1 and material and moisture release tests in Stage 2, to extract the important performance metrics for the design variables studied.

This included heating and ventilating regimes relative to passive indoor drying methods in different house types and constructions. The scenarios tested allowed the quantification of energy consumption and humidity levels resulting from the dominant effect of ventilation and the influence of other important variables such as moisture buffering materials, levels of insulation and climate. Specific scenarios were also developed to predict the additional energy consumption associated with user habits such as drying with open windows and boosted heating.

3.0 Analytical Evidence

Our survey research indicated that housing provision (across a wide range of types in terms of age, form and construction) influences the diversity of drying methods adopted. Passive indoor drying dominates, but lacks the means of isolating and exhausting moisture, related mould spores, odours and even undesirable chemicals. Overall, many of the 100 respondents perceived drying in particular as a problem or issue. In almost all housing types there is a lack of dedicated drying spaces, utility rooms or other potentially suitable spaces in which to dry clothes passively without adversely affecting other rooms or spaces. However, most dwellings could be adapted to provide this facility, sometimes by restoring what was built to its original use. Only half of the respondents in the survey declared access to outdoor or covered semi-indoor drying, and almost half of that number indicated drawbacks including lack of security and lack of line space. Again, there is scope for improving existing provision.

Continuous monitoring in 22 case studies indicated both poor air quality and high moisture levels. This reflects lack of adequate ventilation control relative to indoor passive drying and other 'wet' activities, with the intensity of occupation and high ambient humidity an added, and partly seasonal factor.

Neither do the 'spot' (virtually instantaneous) readings taken during daytime for the full set of 100 households promote confidence in terms of an environment that can readily accommodate additional moisture inputs from laundering activities.

The lack of a specific facility for indoor drying, which is heated and ventilated independently of the main spaces in the dwellings, makes those living spaces particularly vulnerable to any additional migrating moisture.

Those who passively dried indoors, with windows liberally opened during autumn, tended to have high absolute moisture levels (denoted by vapour pressure or VP), even though the air quality (measured by carbon dioxide or CO_2) was reasonably good. This indicated that better control of ventilation was required, both to exhaust moist air at source and to limit ingress of damp ambient air at certain times of the year and/or in humid weather conditions.

Similarly regarding inadequate control of ventilation, migration of moisture from one space to another, for example kitchen to adjacent living room, would mean that further moisture from passive drying of washing loads would add to an already poor situation.

Also more than one fifth of the 100 households surveyed passively dried indoors in the absence of any mechanical extract. In such cases,

ATTITUDES TO DRYING CLOTHES WITHIN THE HOME

95%

OF RESPONDENTS USED PASSIVE DRYING+

50%

PERCEIVED INTERNAL DRYING AS A PROBLEM OR ISSUE

All housing types had a lack of dedicated drying spaces, utility rooms or other suitable spaces in which to dry clothes within the home.

50% of the respondents declared access to outdoor or covered semi-indoor drying, and almost half of that number indicated drawbacks including lack of secure, convenient space, working commitments and poor weather.

Of those surveyed during the heating season from September to May, 87% employed passive indoor drying, and of those 64% dried on or near heat sources and over the heating season an average of 23% boosted heat to aid drying (19% in autumn, 21% in winter and 32% in spring).

+ 100 responses from residents surveyed in Glasgow study.

TUMBLE DRYING USE

33%

OF THE TOTAL 100 SURVEYED USED A TUMBLE DRYER

5%

USED A TUMBLE DRYER AS THE SOLE METHOD OF DRYING

MOST OTHERS CITED CONCERNS OVER ENERGY INTENSIVE AND ASSOCIATED COST IMPACT.

ventilation control would be reliant on window opening and operation of trickle vents. However, only half of respondents stated that they used trickle vents. A further factor evident from the survey was that awareness of built-in mechanical extract in high rise towers was poor, as was overall awareness of manual versus automated control. There was no evidence that presence or absence of extract fans either helped or hindered relative to presence of mould. More than half of the 100 households had mould in at least one room, and nearly 80% of these had at least one mechanical extract.

Exterior drying spaces have proved unsuccessful in Glasgow due to climatic conditions with limited exposure to dry windy days, as well as poor security and general inconvenience. Given Glasgow's current climate and increasing rain predictions, exterior drying is not a feasible solution unless it is in a covered location. Feedback from a housing association survey[1] indicated that, disappointingly, 20% did not allow residents to dry clothes on their balconies, which provides a secure, easily accessible and covered method of drying. Drying externally on a balcony is a sensible option as it is a covered secure space easily accessible from the apartment – especially on a high rise there is a good wind resource which can aid the drying process. It was noted that many housing blocks in the laundering study were designed so that apartments could share a drying space – for example, a semi-outdoor room in maisonettes or flats; or rooftop (covered) communal drying spaces in some tower blocks. Some are better used than others, but all are capable of upgrade. Indeed, in general, most outdoor drying spaces could advantageously enhance solar capture, air movement and shelter from rain.

BALCONY DRYING
Passive solar housing in Graz, Austria

In addition, communal laundries (either for washing and drying or for drying only) have proven to be popular if well managed and maintained. Where these have been provided in housing blocks, the housing associations include a subsidised charge for this in the rent, which usually is an economically favourable facility for residents (perceived as free in some cases).

1 Survey results from 20 responses from local housing associations in Glasgow regarding their policies and practices related to communal laundering provisions. Carried out by MEARU, 2009.

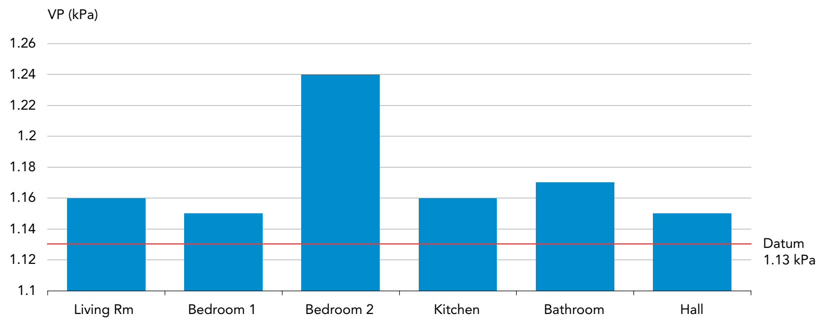
3.1 KEY INDOOR ENVIRONMENTAL CONCERNS

(detailed monitoring of 22 dwellings from 100)

3.1a Moisture & mould spores

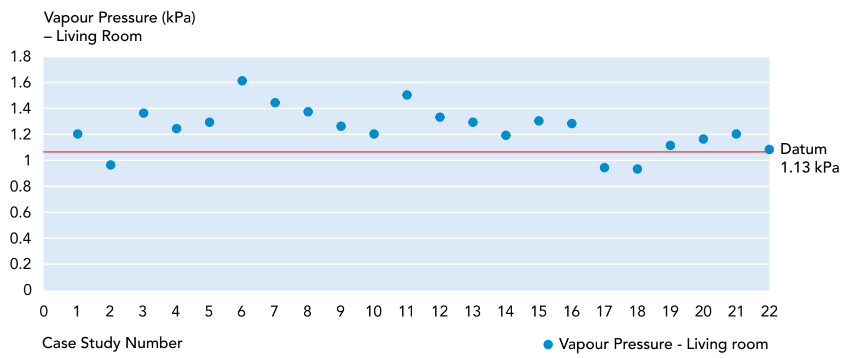
Given the amount of moisture generated by passive drying within in the home, one of the key investigations was to check the moisture level present in each of the 100 household surveyed and then monitor this over a period in 22 case studies drawn from the larger sample – this in order to determine whether it is at a desirable level. A causal link between high humidity levels, dust mites and health problems such as asthma has been established for over a decade[2]. Initially spot measurements of temperature and relative humidity in 100 homes were used to calculate the vapour pressure (VP) in kPa to denote absolute moisture level.

GRAPH 1 Spot data (100 dwellings) – average vapour pressure per room



Graph 1 indicates spot measurements where vapour pressure is above desirable maxima in terms of dust mite growth. The humidity levels in all rooms is above the recommended dust mite threshold of 1.13kPa[3] by some 2-10%. In the more in-depth continuous monitoring the average of vapour pressures in the 22 case studies is significantly higher than the equivalent spot averages for the sample of 100.

GRAPH 2 Durational data (22 case studies) – average vapour pressure in living room



These data indicate environmental conditions within living rooms that are subject to poor ventilation control, and where passive drying and

VENTILATION IN HOUSING

49%

NEVER USED TRICKLE VENTS

21%

WERE UNSURE HOW TO OPERATE THE VENTS

Of the 51% who said they used them, 31% claimed to regularly adjust the vents and the remaining 20% only occasionally.

64%

HAD MECHANICAL EXTRACT IN THE BATHROOM

34%

DID NOT KNOW IF THE EXTRACT WAS MANUAL OR AUTOMATIC

42% HAD MECHANICAL EXTRACT IN THE KITCHEN. **27%** KNEW THIS WAS MANUAL

---

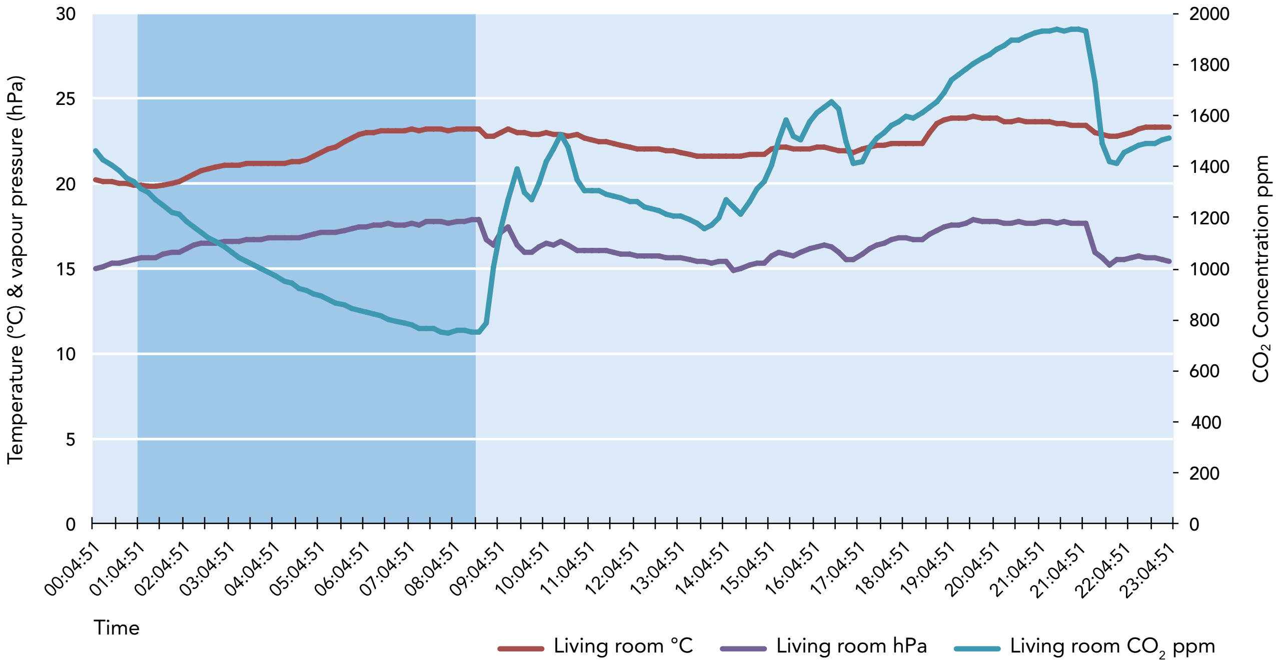
2 Institute of Medicine (2000) 'Executive Summary' and Ch5 'Indoor Biologic Exposures' in *Clearing the Air, **Asthma and Indoor Exposures (National Academic Press, Washington***, DC, USA) pp5 in 1-18 & 144,173 in 105-222.

3 Platts-Mills, T A E and De Weck, A L (1989) 'Dust mite allergens and asthma – a worldwide problem', ***Journal of Allergy & Clinical Immunology***, Vol 83, pp416-427.

steam ironing are bound to exacerbate matters. A direct relationship between overnight passive drying and increased vapour pressure is evident from monitored data indicated in Graph 3.

Graph 3 shows the vapour pressure beginning to rise just after the end of the wash cycle from about 1.4 kPa, eventually peaking at 1.78 kPa at 8.30 a.m. Meanwhile, because the room was without occupants during the same period, the CO_2 values correspondingly fall – from about 1,450 ppm at midnight to about 750 ppm at the same time as the vapour pressure maximum, and averaging 1,138 ppm. There is therefore no doubt that the gradual rise in vapour pressure corresponds with the release of water vapour while drying.

GRAPH 3 Vapour pressure (hectopascals – hPa) peak during overnight drying



In this particular instance, the extra overnight rise in moisture occurs in the absence of other daytime moisture sources, and the rate of drying benefits from the heat lost from the storage unit while it receives its nocturnal charge. However, in most cases, passive drying occurs in tandem with other moisture sources. Although this may tend to mask the impact of passive drying on a graph, it does not mean that the drying is not contributing to the moisture problem.

Mould Spore Concentration – Colony Forming Unit (CFU) Count

During the more detailed monitoring (over a fortnight) of the 22 case studies, air sampling was undertaken in each home to identify mould spore count measured in CFU/m^3. The value of 1,000 CFU/m^3 'colony forming units' or fungal spores is considered high and a risk to health. It should be noted that Finland[4] sets a limit value at 500 CFU/m^3.

Both Aspergillus, present in all the dwellings sampled and Penicillium, present in all but one (95%) "contaminate indoor spaces biologically" and "are important sources of allergens"[5].

4 Ministry of Social Affairs and Health (2003) 'Health Protection Act, Instructions regarding physical, chemical and biological factors in housing', *Guidebook No. 1*, Finland (in Finnish).

5 Haas, D et al (2007) 'Assessment of indoor air in Austrian apartments with and

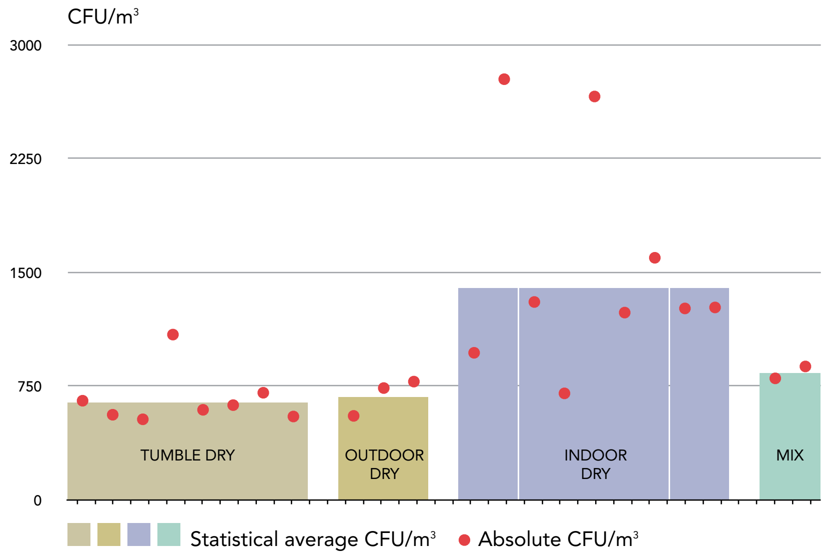
Perhaps more importantly, Aspergillus fumigatus was found in 25% of the sample. This "causes invasive allergenic disease" where immune systems are vulnerable[6] and "can be very dangerous"[7].

The Glasgow data shows an apparent association between absence of indoor passive drying and the CFU/m³ count, which consistently tends to be lower when it is absent than when it is present. This trend was evident and presents strongly in statistical analysis, taking into account other potential influences such as open windows, mechanical extraction, floor coverings and houseplants.

It was further evident from monitoring of 22 case studies that the presence of mould is usually associated with high moisture levels, but that does not mean that high moisture levels will necessarily result in mould, as dew point of bounding surfaces is dependent on the temperature regime and air movement.

For eight case studies, which either tumble dry exclusively or predominantly, the average spore count (geometric mean) for living rooms and bedrooms is 644 CFU/m³; and for three where outside drying is the only or dominant means, the average is very similar at 680 CFU/m³. But for nine where all washing is dried passively indoors, the average rises to 1,398 CFU/m³ as illustrated in Graph 4.

GRAPH 4 Mould spore concentration (CFU/m³) for predominant drying methods



CFU = colony forming unit (mould spores), expressed per m³ from analysis of air samples; where more than 1,000 is regarded as 'high'; 700-1,000 as 'moderately high'; 500-700 as 'moderately low'; and less than 500 as 'low'.

Due to the influence of 'outliers', the arithmetic means display an even greater contrast. Taking the above into account, with statistical analysis to back it up, it would seem that the presence of damp material drying slowly over a period of several hours tends to be more potent in terms of fostering fungal spores, compared with other common household moisture sources.

AIR QUALITY ISSUES IN EXISTING HOUSING STOCK

Poor indoor air quality was evident in existing housing before the Glasgow laundering study highlighted this in monitored data from 22 case studies.+

Current trends towards airtight construction suggest increasing reliance on mechanical heat recovery ventilation (MHRV) to provide an adequate level of ventilation, which is not necessarily the case.

Scottish Technical Standards, Section 6 Energy – Limiting Uncontrolled Air Infiltration (6.2.4) recommends acceptable airtightness levels of 10 m³/h.m² @ 50 Pa.

Current building regulations state that where infiltration rates of less than 5m³/h.m² @ 50 Pa are intended, a MHRV system should be used.

Passivhaus standard stipulates airtightness lower than 5 m³/h.m² @ 50 Pa.++

+ Also identified in other MEARU-supervised projects[3]. Fung, J W (2008) 'The Unintended Negative Consequences of Decision-making in Glasgow's Social Housing Sector', PhD thesis, Mackintosh School of Architecture, Glasgow.

++ Passive House, Passivhaus or Passive (Energy) House is a voluntary industry standard that results in buildings that require little or no energy use for heating or cooling.

without visible mould growth', *Atmospheric Environment*, 41, pp 5192-5201.

6 Cramer, RA et al (2011) 'Immune responses against Aspergillus fumigatus: what have we learned?', *Current Opinion in Infectious Diseases*, 24, pp 315-322

7 University of Cambridge (2011) 'Fungi and Lichens', *Map of Life* website http://www.mapoflife.org/browse/category_30_Fungi-and-Lichens

For example, moisture generated by cooking or showering is more concentrated but in shorter durations, as well as generally more convectively driven and often exhausted rapidly at source either by extract fans or by opening windows. However, neither the presence or absence of fans, nor any of a series of other potentially confounding variables, indicated statistical significance relative to the spore concentrations.

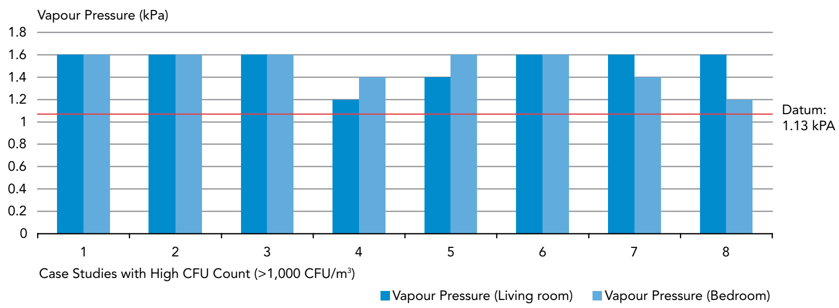
A lower CFU count, which predominantly corresponds to internal drying being absent or not dominant, has potentially positive implications for health; while the opposite is true for the higher counts, particularly for the atopic or sensitised group who are vulnerable to asthma. It is the combination of high CFU counts with high moisture levels that is concerning for health.

Summarising in terms of moisture, visible mould and mould spores, three key relationships are evident: firstly, there is no consistency between visible mould and spore count; secondly, effective ventilation is critical for activities that involve rapid moisture production; and thirdly, despite several potentially influential variables, the indications are that slowly drying fabric has an association with relatively high spore counts. This last association could constitute a health problem for atopic occupants who are allergic to asthma, hay fever, eczema etc.

Furthermore, recent work in USA has shown that fabric softeners give off a cocktail of chemicals including at least one that is potentially hazardous, and indeed carcinogenic[8]; and it has also been shown that this particular volatile organic compound (VOC) is water-soluble and increases in concentration with increased humidity[9].

Graph 5 below indicates that, of the eight case studies where the CFU counts are classified as 'high', six of the living room and five of the bedroom vapour pressures (VPs) are also 'high' (over 1.4). This means that sensitised individuals are at risk from at least two sources – mites and fungal spores – and possibly also from certain water-soluble VOCs.

GRAPH 5 Vapour pressure (kPa) levels in case studies with high CFU count



8 Steinemann, A C ; MacGregor, I C; Gordon, S M; Gallagher, L G; Davis, A L; Ribeiro D S and Wallace, L A (2010) 'Fragranced Consumer Products: Chemicals emitted, ingredients unlisted', ***Environmental Impact Assessment Review***, Vol 31, pp 328-333.

9 Arundel, A V; Sterling, E M; Biggin, J H and Sterling, T D (1986) 'Indirect Health Effects of Relative Humidity in Indoor Environments, ***Environmental Health Perspectives***, Vol. 65, pp 351-361.

3.1b Indoor air quality

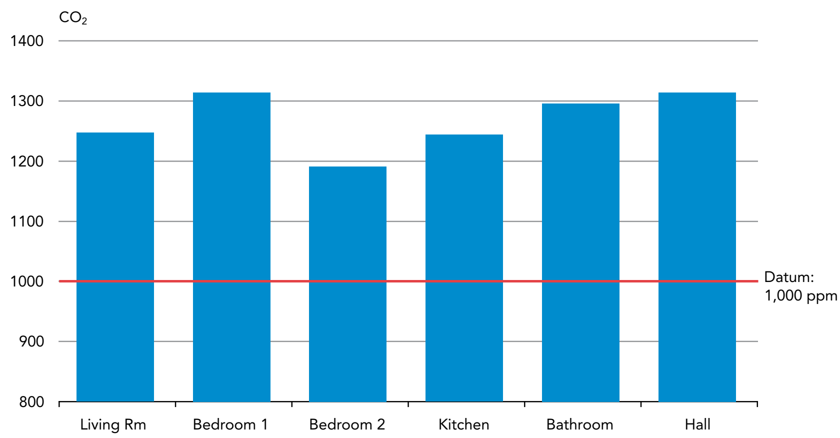
Indoor air quality (IAQ) in each of the 100 homes was assessed using CO_2 as the indicator alongside temperature and moisture. Spot or 'snapshot' measurements were taken in each room of each home.

The overall trend of daytime 'snapshot' readings, which vary both above and below 24-hour averages is of concern. It is one where air quality is predominantly poor, with CO_2 levels above the accepted 1,000 ppm maximum by some 20-30%. It indicates an environmental context redolent of poor ventilation control, whereby passive drying and steam ironing are bound to exacerbate matters.

In the home laundering study, residents certainly had poor awareness, convenience or use of trickle vents was an issue, and there was unknown or indeterminate use of manual fan control and window opening. This combination of user habits is a recipe for poor standards of ventilation and hence poor air quality with moisture from passive drying and ironing indoors only adding to this problem.

This suggests a greater need for effective ventilation. However, introducing fresh air at a time when outdoor humidity can be high, for example in summer and autumn, may also raise indoor humidity. The environmental context is therefore one which mitigates against passive indoor drying and ironing without precautionary measures. The twinning of poor air quality and high moisture level indicates a lack of adequate ventilation control relative to the intensity of occupation, lifestyle habits and seasonal factors.

GRAPH 6 Spot Data (100 dwellings) – Average CO_2 above desirable maximum in terms of IAQ



Air quality indicators (CO_2 ppm = parts per million):
GOOD = CO_2 mean value less than 1,000 ppm and maximum less than 2,000 ppm;
MODERATE = CO_2 mean value less than 1,000 ppm, maximum greater than 2,000 ppm;
POOR = CO_2 mean value greater than 1,000 ppm, maximum greater than 2,000 ppm.

At present, it would appear that we are beginning to satisfy the mantra 'seal tight', but are nowhere near satisfying its second part, 'ventilate right'. Tackling the various activities associated with domestic laundering is an integral part of this critical dichotomy.

PASSIVE DRYING IMPACTS

Of those 72 surveyed during the heating season from September to May,

87%

EMPLOYED PASSIVE INDOOR DRYING

64%

DRIED ON OR NEAR HEAT SOURCES

Averaged over the three seasons from autumn to spring, **23%** admitted to turning up heat to speed up the drying process, rising to **32%** in spring; while **37%** always opened a window, rising to **50%** in autumn.

Some 2.0-2.5 litres of water are released into the home per washing load if dried indoors; and how much that raises humidity depends on heat and ventilation.[+]

Room temperature needs to be raised 3°C in presence of damp laundry to keep relative humidity (RH) levels constant – based on computer modelling in typical conditions.

Trickle vents on their own will not suffice in the presence of damp laundry, but opening windows when heating is on increases energy consumption and affects comfort.

Drying clothes on radiators with heating on is likely to increase space heating.

+ 2.0-2.5 litres for a full 15-17 item load are pro rata values recorded by RICH experiment at a mean temperature of approximately 21°C and RH 47.5%, losing 88% moisture in first 4 hours, or about 1 litre in the first two hours. This will vary according to specific conditions.

HOUSEHOLD ENERGY CONSUMPTION IN THE UK

19,800 kWh

AVERAGE HOME CONSUMPTION IN SCOTLAND ANNUALLY

5.2 tonnes of CO_2+

AVERAGE HOME EMISSION ANNUALLY IN SCOTLAND

Households are considered by the UK Government to be in 'fuel poverty' if they would have to spend more than 10% of their household income on fuel to keep their home in a 'satisfactory heating regime' condition.++

Household energy costs in the UK have risen 71% in just over five years.+++

The UK department of Energy and Climate Change indicated in mid 2011 that Scottish fuel poverty was running at 32.7% while the rate in the UK as a whole is 20.1%.+++

\+ A typical UK household uses 3,300 kWh of electricity and 16,500 kWh of gas annually. Ofgem statistic, Typical domestic energy: Consumption, Factsheet 96, January 2011. http://www.ofgem.gov.uk/Media/FactSheets/Documents1/domestic energyconsump fig FS.pdf. Using conversion factors of 0.540 kg/kWh for electricity and 0.206 kg/kWh for gas.

++ Note: The 'condition' is taken, for example, to signify a 'satisfactory' heating regime where the main living area is at 21°C with 18°C in the other occupied rooms. Household income is disposable household income before deducting housing costs, with housing benefit and income support for mortgage interest both counted as income. Costs are those arising from fuel used for space heating, water heating, lighting, cooking and household appliances.

+++ *Annual Report on Fuel Poverty Statistics* 2011, July 2011, *Department of Energy and Climate Change.*

3.2 ENERGY IMPACT

Domestic laundry not only has a concerning environmental impact on UK homes, primarily associated with indoor air quality and moisture, but also a corresponding energy impact in a context of resurgent fuel poverty, rising fuel costs and pressure on the UK government to cut CO_2 emissions. The UK Climate Change Act 2008 requires an 80% cut in greenhouse gas emissions by 2050, and at least 34% by 2020. The Climate Change (Scotland) Act 2009 also requires 80% by 2050, but an increased reduction of 42% by 2020; and Ministers must also prepare and publish a plan 'promoting energy efficiency' and 'improving the efficiency of living accommodation' in Scotland.

As approximately 29% of all energy consumed in Scotland is used to heat and power homes[10], it is important to highlight domestic laundering as a major contributor to higher electricity bills – firstly via appliances such as energy intensive tumble dryers, and secondly via the impact on heating costs attributable to passive drying habits within the home.

The recommendations noted in Section 5 of this design guide are therefore aimed at strengthened statutory regulations. These would enable residents to reduce their energy consumption and save on their fuel bills, whilst simultaneously enhancing indoor air quality (IAQ). Enhancing indoor air quality includes better moisture control, with consequent positive effects such as lower dust mite populations and lower concentrations of potentially harmful volatile organic compounds (VOCs). In other words the aim is to achieve a more 'virtuous circle' in terms of energy efficiency and environmental quality.

3.2a Heating cost associated with drying clothes on radiators

Of those residents surveyed during winter season who season who reported passive indoor drying clothes, 64% acknowledged drying them on or near heat sources. Many admitted to turning up their heating to speed up the drying process and, from a visual survey of homes, evidence could also be seen of additional plug-in heaters in rooms where washing was drying.

Where either perceptions or reality lead to window opening while heating is on and passive drying is present, it will have an impact on energy for space heating that can at least partly be attributed to the issue of laundering. There is convincing evidence from both the initial survey of 100 households, and also the monitoring of 22 of these over a two-week period, that passive indoor drying impacts significantly on space heating demand during the heating season.

A broad brush energy calculation based on one case study suggests that the increased energy for gas central heating in cold winter months more than doubles from a base situation of 21°C with doubling rate of air change (42 kWh daily in January at just over 1.0 ac/h) and modest rise in temperature up to 23°C (88 kWh daily in January at just over 2.0 ac/h). The energy impact from passive drying is intensive given that the moisture laden air needs more energy to heat than air with a lower moisture level. While comfortable average room temperatures may lie between 18-20°C, with the presence of

10 Conserve and Save: Energy Efficiency Action Plan, Scottish Government http://www.scotland.gov.uk/Publications/2011/10/04142510/3

damp clothes this often needs to be boosted to 21-23°C to offset the cooling effect of evaporation and thus to maintain comfort.

These differences could increase further if the property was designed to thermal levels prior to 2007 standards or indeed if the property type was an end of terrace or semi- detached. Sophisticated dynamic energy modelling supports the significance of boosted temperature and ventilation rates.

Modelling by ESRU using ESP-r software enabled a more accurate assessment of the thermal impacts of passive indoor drying for various scenarios relating to ventilation rate and demand temperature – both in terms of additional energy demand and rise in moisture level.

Simulations for a whole year, assuming a family with a large amount of washing and drying confined to one room for 7 hour periods, confirm the significance – a total increase of approximately 40 kWh/m^2 or 3,600 kWh for a typical semi-detached house. However, in practice drying is usually left for longer than 7 hours and window opening often involves more than one room.

These figures indicate that the current common practice of clothes drying within the home is significantly increasing residents' fuel bills at a time when many efforts are being made to lift residents out of fuel poverty.

Drying laundry in a purpose-built space

The previous simulations clearly indicated the energy penalty associated with providing adequate ventilation to dry clothes and mitigate high humidity levels by open windows throughout a dwelling. An alternative approach is the provision of a designated drying space within a dwelling, which is ventilated to prevent moisture permeating throughout the buildings. To this end, the impact of a specific space for clothes drying in a dwelling was investigated using a model based on existing dwellings in which a cupboard may be suitably converted for drying.

Simulations make a case for connection to MHRV systems, operating up to 30 l/s and using considerably less energy than extract without heat recovery – both operated continuously over the drying cycle (timed switching envisaged). In turn, it would be advantageous to 'borrow' heat gains from a source such as a boiler, hot water cylinder or even a non-insulated 'flow' section of a 'wet' central heating system – ensuring minimum net volume is not compromised. Laboratory experiments also indicate that moisture-absorbing linings such as untreated timber or clay board would help to damp down a peak in humidity during a drying cycle - absorbency increasing significantly with rising RH.

3.2b Use of tumble dryers – with comparison to washing machines and irons

The trend towards individual energy intensive domestic washing and drying appliances in dwellings is well documented with a recent survey indicating that 90% of home owners now own a washing machine and 59% own a tumble dryer within their home[11]. Drying by use of tumble dryer represents a significant amount of electricity use in the UK, accounting for 4.3% of the total domestic power consumption.

11 DEFRA Market Transformation Programme, Briefing Note BNW06

ENERGY CONSUMPTION OF TUMBLE DRYER

59%

OF UK HOME OWNERS HAVE A TUMBLE DRYER; SIGNIFICANTLY LESS IN WEST OF SCOTLAND SOCIAL HOUSING SECTOR.

It is estimated that households using tumble dryers in the Glasgow survey consumed an average of just over 400 kWh of electricity annually.

An average electric tumble dryer runs at over 3.5 kWh per cycle emitting 1.9 kg CO_2 per cycle.+

+Using a grid electricity carbon conversion factor of 0.54 kg CO_2 emitted per kWh.

This may be a national statistic but the Glasgow survey on which this guide is based (mainly social housing) indicated that tumble dryer ownership was not as high as expected and of those who own tumble dryers many are reluctant to use it due to high energy consumption, or sometimes unsuitability for certain materials, preferring to dry passively within living spaces.

The mean average estimate for users of tumble dryers is 207 kWh annually for each person in a household (from the available evidence of 22 Glasgow case studies, with infants counted equally). This is just over three times greater than that for washing, 67 kWh, and 16.6 times that for ironing at 12.5 kWh – these averages based on those using respective appliances within the sample[12].

It should also be noted when making this comparison that, although nearly all of the washing machine data was measured on site, most of tumble drying estimates were based on diary information[13] with respect to frequency of use together with manufacturers' estimates of energy consumption for full cotton loads.

Although the 207 kWh average per person indicates that a typical family of four might use over 800 kWh annually on tumble drying, the case study household average was half of this, and so averaged just over 400 kWh.

Again, if one particular case study, whose consumption was measured on site and did all drying by this means, is taken as a norm for full-load and full-cycle tumble drying, its estimate of 360 kWh annually for the small household of three closely matches the 354 kWh of the 2008 estimate of DEFRA (Department for Environment, Food and Rural Affairs).

Overall, while our survey indicated many residents choose to dry by a combination of methods, and would thus tend to consume less than a national average, larger households that choose to dry exclusively by tumble dryer would consume more. The main point to bear in mind is that tumble drying is inherently energy intensive and many households are understandably cautious using this method.

Simulations indicated that tumble drying the same number of washing loads as an 'open-window' and 'raised-temperature' passive drying regime could use less primary energy, and the gap could widen for CO_2 emissions (due to significantly different respective conversion efficiencies). However, an enclosed, heated and ventilated drying cupboard could comfortably undercut equivalent use by a tumble dryer, especially if MHRV is augmented by 'borrowed' heat from

12 Only 10 out of 22 used tumble dryers, compared with 20 for washing machines and 19 for irons. If the figures are adjusted to an average per household that uses each appliance, average consumption for tumble dryers reduces to 94 kWh annually for each person, compared with 61 kWh for washing machines and 11.0 kWh for irons. In other words, averaged over an entire sample of those who use and do not use this method of drying, tumble dryers still consume 40% more than washing machines.

13 Similar, and somewhat more tenuous, assumptions were made in relation to ironing. This was due to practical difficulties occurring with respect to measurement of all appliance use. It must further considered that the range of measurements and estimates for appliances was large, even though the sample was small, this partly due to the relative efficiency of the appliances and partly due to the demography and habits of individual households

the hot water system. Such a provision would also eliminate added moisture to habitable spaces with all its negative health implications.

Improvements are also being made to the energy efficiency of appliances although market penetration will take time. Modern condenser sensor tumble dryers with integral heat pumps use less than half the full-cycle power of the vented type with heating elements and more energy efficient dryers are currently under development.

Energy Consumption Comparison of Tumble Dryer Types

TUMBLE DRYERS	ENERGY USED PER CYCLE	COST PER CYCLE+
Electric- vented	3.24 kWh	42.70p
Electric- condensing	1.9 kWh	25.04p
Heat pump + condenser	1.35 kWh	17.79p

+ UK Average Tariff of 13.18p per unit – Department of Energy and Climate Change.

The table above recognises that there are alternatives to the energy intensive electric vented tumble dryer. A comparison of CO_2 emissions shows gas dryers more favourably than any electric dryer. Given that electricity is more expensive than gas, a gas dryer is also significantly cheaper to run than an electrical alternative. However, gas is a fossil fuel and a finite resource. One potential advantage of an electric tumble dryer is that it can be powered using renewably generated electricity. A more remote renewable option for a gas-powered dryer would be biogas, for example from food waste.

On the other hand, unlike electrical dryers, gas tumble dryers must be installed and maintained by a registered gas fitter (in the UK), and any maintenance will require a similarly qualified person. Also, all gas tumble dryers must be air-vented to the exterior, which may produce limitations on where it can be located. A similar limitation is in housing developments such as multi-storey housing, where gas is often prohibited.

An alternative to the tumble dryer is a manufactured drying cabinet, an appliance that may be used very successfully in utility rooms. However, the energy consumption is likely to be higher than an integrated drying cupboard. The dimensions of an off-the-peg cabinet may also be limiting in terms of placement within a kitchen or utility room; and, as they do not allow for connection to a mechanical heat recovery ventilation (MHRV) system, the extracted hot air is effectively dumped and not re-used. Moreover, such appliances are subject to warranties and maintenance, while a simple extract fan within a dedicated drying space is less likely to malfunction.

Another issue is that a significant number of residents noted concerns regarding the degradation of clothes from tumble dryers as a reason for passive drying. Therefore, this indicates that simply providing a low energy drying appliance will not prevent passive drying. Also the current culture of replacing appliances after five years or so once parts are worn is an unsustainable practice, taking account of the energy created in the mass production and the environmental impact of their disposal.

In addition to drying appliances, this study recognises the energy impact of the washing machines is very dependent on hot or cold feeds. Washing machine manufacturers have phased out hot-fill washing machines where the hot supply took pre-heated water from the central heating system rather than the appliances using an integral and energy-intensive electrical water heater. Even with the wash temperature reduced to 30°C, this still means using a lot of energy to heat the water from mains temperature (about 8°C). Measured profiles of power use indicate that water heating consumes a large proportion of the total to operate an automatic washing machine. Also, energy ratings on appliances do not necessarily correspond to measured consumption per hour of use or per cycle.

The washing machine spin speed can have a significant impact on the amount of moisture in the clothes, which then reduces drying time whether by tumble dryer or passively in the home.

Residual Dampness Comparison of Washing Machine Speeds+

SPIN SPEED	RESIDUAL DAMPNESS++	ENERGY USED TO TUMBLE DRY
800	70%	4 kWh
1000	60%	3.7 kWh
1200	53%	3.3 kWh
1400	50%	3.1 kWh
1800	42%	2.6 kWh

+ The Dooyoo Washing Machine Guide 2009, www.dooyoo.co.uk/buyersguide/washing-machine.

++ The residual dampness refers to the percentage of additional weight of a typical laundry load (6 kg cottons) after spinning compared with its dry weight

This table, based on A-rated condenser machines, demonstrates clearly that the difference in efficiency between a machine spinning at 800 and one spinning at 1,800 rpm is considerable – 35% overall. However, 800 rpm is not commonly used. From 1,000 – 1,200 the fall is just over 10%, and from 1,000 – 1,400 rpm, the most commonly used range, over 14%. Overall, an average achievable reduction of 10% would be a worthwhile target.

Condenser dryers also have a distinct advantage compared to a vented type with a flexible hose passed through an ajar window – the latter inviting moisture blow-back as well as adding to heating costs.

A potential drawback is that although the production of a low energy appliance may appear to be the solution to the problem, it is acknowledged that greater ownership of more efficient appliances often leads to greater usage[14].

Therefore, a key aim of the proposals in this guide is to improve statutory standards and best practice in order to promote energy efficient and healthful passive indoor drying. Such measures are seen as a practical aid to moisture mitigation in tandem with better overall systems of ventilation control, in turn lowering demand for space heating and helping to control populations of dust mites, concentrations of mould spores and off-gassed VOCs.

14 Monbiot, G (2006) Ch4 Our Leaky Homes, in ***Heat, How to Stop the Planet Burning***, Allen Lane, London, UK, pp61-62; citing Khazzoom, J D (1980) 'Economic Implications of Mandated Efficiency Standards for Household Appliances', ***Energy Journal***, Vol 1, pp21-29.

The objective is minimum harmful environmental impact and maximum positive economic impact. Without such regulatory and cultural change, the Glasgow research indicates that present laundering habits constitute a significant drain on household energy consumption, as well as constituting a significant and expensive threat to health and wellbeing.

Therefore, the recommendations highlighted in Section 5 of this report provide some answers to this challenge – options to mitigate the power consumption of appliances and lower heating costs within the home, the latter as part of a strategy of improved ventilation and air quality.

4.0 Current Statutory Regulations and Best Practice Guidance

Historically, in the 1963[1] version of the Building Standards (Scotland) Regulations, very clear requirements for clothes drying spaces were defined. The standards were designed initially to tackle health issues and the removal of moisture from the home – internal drying cupboards and external drying spaces helped to ameliorate problems of dampness in housing in the 1960s. However, in more recent times, with the increasing popularity and affordability of tumble dryers, these became the accepted alternative to passive drying spaces – especially for housing providers as it involves a floor area of only 0.36 m^2. Current statutory standards do acknowledge the need to make provision for passive drying within the home but do not address the problem adequately. Likewise, sustainable housing best practice such as EcoHomes (and Code for Sustainable Homes in England) also recognises the problem, but surprisingly does not significantly address the problem with regard to environmental impact.

4.1 SCOTTISH TECHNICAL STANDARDS

Current Scottish Technical Standards, 2010 Technical Handbooks – Domestic Section 3 Environment, Section 3.11, Facilities in Dwellings, acknowledges the risks and impacts associated with clothes drying and has re-defined both outdoor and indoor drying space.

OUTDOORS: where it is reasonably practicable, an accessible space for the drying of washing should be provided for every house. The area provided should allow space for at least 1.7 m of clothes line per apartment (i.e. habitable room in a dwelling). However, for a two-person, two-apartment home, likely to wash two to three full loads weekly, it may be noted that this would only provide enough space for roughly half of a normal washing load.

INDOORS: in recognition of the climatic conditions in Scotland, Section 3.11.6 Drying of Washing also indicates that a designated space for the drying of washing should be provided inside every dwelling, this to be in addition to the external space. It defines a minimal volume of 1m^3 of clothes drying within a designated space (having no dimension less than 700mm), allowing 1.7 m of clothes line per apartment.

Apart from the inadequate length of clothes line specified, a major weakness is that the designated indoor space is not required

1 The first was Statutory Instruments 1963, No. 1987 (S. 102), Building and Buildings, The Building Standards (Scotland) Regulations 1963; and the second was Statutory Instruments 1971, No. 2052 (S. 218), Building and Buildings, The Building Standards (Scotland) (Consolidation) Regulations 1971.

to be an enclosed dedicated space. It could be as minimal as a floor space within a dwelling on which to set out a clothes horse or space for a ceiling mounted pulley. Given that migration of moisture to the rest of the house is detrimental to moisture levels and air quality (mould spore, dust mite concentrations and potentially harmful VOCs), this does not sufficiently address the problem.

Moreover, the standard designed to address ventilation from a passive indoor drying space has drawbacks and does not tally with normal custom and practice.

Section 3.14.4, 'Ventilation of areas designated for drying of washing' indicates that this space should either have mechanical extraction capable of at least 15 l/s intermittent operation – the fan should be connected through a humidistat set to activate when the relative humidity is between 50 and 65% – or a passive stack ventilation system in compliance with a further clause.

This certainly begins to tackle the issue of the moisture generated in locations other than kitchens, bathrooms and utility rooms. However, in order to meet the regulations, housing providers often specify the minimal provision of a retractable line in the bathroom with a mechanical extraction and residents' habits can prevail thereafter.

Bathrooms are not suitable drying spaces due to intermittent heating and already high levels of moisture from baths/showers, the drying of damp bath towels and so forth. This all too frequently accompanied by the inadequate operation or non-operation of fans (e.g. default humidity setting too high or completely disabled).

MOULD IN BATHROOM
Bathrooms are not suitable drying places.

In summary, current regulations are not sufficient and lead to a culture of clothes drying on or near radiators in habitable spaces, which exacerbates fuel poverty, reduces air quality and could impact on health – in particular those groups who are chemically sensitive, prone to allergies or vulnerable to asthma.

Theoretically, in a new build house, for habitable rooms to comply as suitable locations for a clothes horse, they would need to comply with the ventilation standards. In practice few living rooms or bedrooms have this facility. It may be that full mechanical heat recovery ventilation (MHRV) systems will become the norm for new build homes, but it is most unlikely to prevail as a universal retrofit solution.

Therefore, the opportunity should be taken to link requirements for indoor passive drying to improved standards for ventilation control in the remainder of the home.

This should recognise the drive towards airtight building envelopes, but also acknowledge the weakness of current statutory standards for mechanical ventilation – namely that they do not guarantee the capability of an adequately variable supply rate to ensure 8 l/s for each occupant of a room[2] taking account of normal social activity in a home.

2 Note: 8 l/s for each person corresponds with 1,000 ppm (parts per million) of CO_2, the recognised maximum limit for good air quality. The relationship between progressively lower values than 8 l/s and CO_2 is non-linear, i.e. an exponential curve results in rapidly rising CO_2 levels. To give some indication of this in practice in the case of the Glasgow survey, the maximum instrument value of 5,000 ppm was reached on several occasions. Moreover, the arithmetic mean value in the living rooms of the 22 case studies was above 1,000 ppm in over 40% of the

Such a supply system should not involve opening windows or associated devices other than from a suitable pre-heated source (e.g. solar air collector; dynamic insulation component), but may include MHRV that can guarantee a sufficient variable supply. Given the current airtightness regulations in the Scottish Technical Standards, it is assumed that MHRV systems will become prevalent in new homes in Scotland.

In retrofit situations, enclosed drying spaces could be linked to simple exhausts or these might be upgraded to individual heat recovery units (i.e. an option to whole-house MHRV).

4.2 SUSTAINABLE HOUSING BEST PRACTICE GUIDELINES

The environmental performance rating system, EcoHomes[3], became mandatory for social housing in Scotland built from 2003. Similar to the Scottish Building Standards[4], it does acknowledge that clothes drying has both an environmental impact in terms of air quality and energy consumption, but makes a limited provision to deal with it.

As part of a points-based scheme, section ENE 3 gives three credits for a 6 metre clothes line either internal (in a ventilated space) or external (hanging space for approximately 80% of a typical wash load). Internally this would take the form of a retractable clothes line over a bath. As an environmental advisory scheme, this falls short of providing a satisfactory solution to an issue which has been identified as critical to energy performance within homes, as well as the side effects associated with moisture – already described and all carrying a health risk.

The related Code for Sustainable Homes (CSH), which is mandatory for all new homes in England, details a similar provision, which again does not suggest a designated and enclosed drying space to adequately tackle the problem of moisture and air quality.

It has become customary for social housing providers to either supply a washer/dryer, or to designate a 600 x 600 mm space with associated plumbing in the kitchen to allow the resident to install their own washer/dryer appliance. In the majority of new build social housing situations, there are no alternative drying spaces provided in the form of an airing cupboard, utility room or communal drying space (either externally or internally). Instead, as indicated above in

---

sample, and the mean for the entire group of 22 homes was still over 1,000 ppm (1,026 ppm). This poor standard occurred with only two homes surveyed in the winter months from December to February, while seven were in the summer months from June to August and the remainder in autumn and spring, i.e. most were measured when we would anticipate windows being regularly opened depending on the prevailing weather. In accordance with the 'bad company' principle for CO_2 as an indoor air quality (IAQ) indicator, high levels frequently correspond with high humidity, which may in turn increase concentrations of mould spores and VOCs, especially if moisture sources other than the occupants themselves are present.

3 'EcoHomes' assessment is administered by the Building Research Establishment (BRE).

4 Although informally known as 'building regulations', these are formally regulated by the 'Scottish Building Standards Technical Handbook 2010 – Domestic', often shortened to TH10, and which came into force on 1 October 2010.

relation to the Scottish Technical Handbook, many of them rely on a retractable line over the bath as a suitable provision in order to satisfy the indoor passive drying regulation.

The Scottish Housing Quality Standard (SHQS) is the Scottish Government's principal measure of housing quality in Scotland. Annex E covers healthy, safe and secure housing and identifies the need for adequate ventilation to maintain a healthy home. Given the health implications associated with passive indoor drying, there should be scope for including recommendations within this document.

There is a strong case for an amendment to refine statutory building standards for passive drying, both indoors and outdoors. This should provide: firstly, a specific facility for indoor passive drying that is larger than the present standard and isolated or 'quarantined' with its own source of heating (ideally fortuitous) and ventilation exhaust; and secondly, a secure and convenient outdoor or semi-outdoor space that is covered and solar enhanced.

It is anticipated that these design guidelines could form the basis for amendment not only to the Technical Handbook 2010, but also to environmental performance rating schemes (EcoHomes) and housing quality measures (SHQS) in Scotland.

5.0 Design Recommendations

The recommendations, with accompanying drawings and diagrams, refer to suggested changes to current Scottish Building Standards, Technical Handbook 2010 – Domestic (Sections 3.11.6 and 3.14.4), which would be mandatory in new build housing, together with recommendations which are indicative of best practice (which may be included within Section 7 – Sustainability, of current Building Standards).

It is recognised that a degree of flexibility and choice is desirable in terms of individual and shared approaches. This guide therefore aims to make suggestions for a range of measures that might be readily incorporated, but which provide scope for implementation that is not difficult to meet. Recommendations for communal facilities are indicated which suggest options for new build and the upgrade of existing facilities.

The recommendations are based on existing social housing types from within the 22 monitored case studies of the Glasgow laundering study. This is on the assumption that what will work for retrofit, which is a key housing priority in terms of CO_2 mitigation, will work more easily for new build housing where standards do not have to be retrospectively applied. Indeed, these guidelines are particularly pertinent to new housing given that current new build homes are increasingly space restrictive and progressively more airtight.

5.1 DEDICATED INDOOR DRYING SPACE

The suggested mandatory change in Scottish Building Standards, Technical Handbook 2010 – Domestic, Section 3.11.6 Drying of Washing is textually minor, but important in terms of impact.

Given the analytical evidence of the effect of passive indoor drying on air quality and the associated health implications, it is evident that a designated **enclosed** drying space, which is **independently** heated and ventilated, is required for this purpose.

Mandatory standard 3.14.1 already requires: "Ventilation should have a capability of: …removing pollutants that are a hazard to health…" This guide has made the case that excess humidity is a hazard in this regard, as are high concentrations of mould spores and specific water-soluble VOCs that increase in concentration with rising humidity; the last produced by both common building materials and laundering products such as fabric softeners.

The only changes to the existing standard sought thus far are the words 'enclosed' and 'independently'. Standard 3.14.4 presently gives the impression of meeting ventilation needs responsibly, and uses the word 'designated'. But it is not explicit on the discrete nature of the space. Indeed 3.11.6 allows a designated drying space within the volume of any room, which has a ventilation system in compliance with 3.14.4 (mechanical extraction capable of 15 l/s intermittently, or passive stack ventilation to the standard detailed in 3.14.6).

To amplify this point, introduced in 4.1 above, theoretically, the present combination of 3.11.6 and 3.14.4 prohibits the use of a clothes horse in a living room or bedroom, where windows are the only means of ventilation; or within an unventilated hallway. Unfortunately, the custom and practice that the present standards in this regard engender mean that clothes horses or other airing devices are commonplace in such rooms or circulation spaces, even if the houses are new and comply with the literal 'letter' of the mandatory standards.

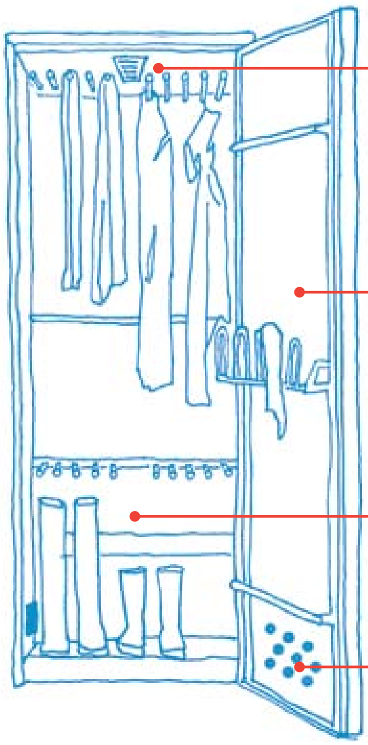
Surveys showed that where convenient drying cupboards existed, residents used them and many indicated a desire to have a dedicated space of this kind. In a modern house, for example, this might double as a sunspace or conservatory. On the other hand, it was also apparent that drying cupboards, which were designed into housing before and after the 1963 building regulations, have become redundant in many cases and the means of extracting air removed. However, with appropriate guidance, such spaces could be re-activated in existing homes and designed into new build housing.

A suitable alternative to a drying room or cupboard would be a dedicated utility room with independent heat source and ventilation. An unheated variation on the latter might be a sun porch or conservatory doubling as a utility space – see 5.1.1 below.

The only change proposed to statutory standards thus far is that designated drying spaces require discrete enclosure as in a cupboard, except if they are incorporated within a utility room. Critically, this excludes as suitable a space over a bath, a ceiling mounted pulley arrangement other than in a utility room, or floor space in any room on which to set out a clothes horse – all as presently permitted under 3.11.6, albeit constrained in terms of ventilation by 3.14.4. On the other hand, an independently heated and ventilated drying cupboard could be sited within a bathroom, any other room, or a circulation space.

5.1.1 Dimensions

There is, therefore, a case for requiring such discrete spaces inside all homes, and to accommodate a typical washing load, a minimum net volume of 1.75 m^3 is deemed necessary, i.e. 75% greater than the current minimum in the Scottish statutory standards, which do not require a dedicated enclosed space for this purpose. This volume would also allow an increased linear length of drying space, currently set at 1.7 m per 'apartment'



(i.e. habitable room). It is estimated that a normal washing machine load would require a minimum of 7.2 m, and, since even a single person is liable to wash in full loads, this implies that 7.2 m should be the minimum hanging length for any dwelling, with more for larger families, who frequently wash more than one load in a day. This in turn might be dealt with by providing auxiliary drying space in a utility room and/or providing alternative facilities such as a communal drying room or a suitably designed outdoor space.

For indoor passive drying that meets the above conditions, there are dimensional options:

For example, a 1.75 m^3 cupboard could be 2.3 m high by 0.9 m wide by 0.85 m deep; with two rows of four slats or retractable 'pulleys' each 0.9 m long giving 7.2 m hanging length.

SUNSPACE
Glazed utility sunspace at Easthall, Glasgow

Alternatively a defined space of the same minimum volume but different dimensions within a larger utility room – for example a space above a worktop 2.1 long by 0.6 m deep by 1.4 m high – could provide 7.2 m of hanging; and at the same time implies a suitable minimum volume for the utility room of 7.2 m^3 (2.1 m long x 1.5 deep x 2.3 high). A double-tier vertical hanging space similar to the cupboard example might also fit within an even tighter utility volume – say 6 m^3 for dimensions of 1.75 m x 1.5 x 2.3 high.

There are also precedents, indeed EU-funded retrofit precedents[1], which are glazed sunspaces used as utility rooms. Such tactics are to be encouraged as passive solar gain will aid the drying process in an otherwise unheated space. Such a space may also double in terms of a pleasant amenity for relaxation, also adding financial value to a property e.g. making shared equity more attractive. Dimensionally, such solar spaces can be of the same order as a utility room e.g. 2.4 m wide x 1.1 deep x 2.3 high, possibly as a converted balcony, and within a volume of approximately 6 m^3.

Such options then suggest specific minimum dimensions for drying spaces, whether enclosed cupboards or within a utility room – width 0.9 m, depth 0.6 m (open), 0.85 m (closed), height 1.4 m for single-tier and 2.3 m for double-tier hanging – to enable design flexibility without compromising viability, and providing a minimum linear hanging length of 7.2 m in all cases.

5.1.2 Ventilation

The drying cupboard should enhance the existing standard in 3.14.4 – mechanical extraction with intermittent capacity of 30 l/s, or MHRV. Continuous operation on a time-switch is required and for MHRV this would also operate a setting of 30 l/s.

The ventilation extract in a utility room should be 30 l/s intermittent mechanical capacity (in accordance with 3.14.2), passive stack (in accordance with 3.14.6), or connected to a whole house 'mechanical heat recovery ventilation' (MHRV) system (in accordance with 3.14.8 and 3.14.10), i.e. all in compliance with existing statutory standards, but with a range of exhaust rates up to 30 l/s.

The opportunity should be taken to link requirements for indoor passive drying to improved standards for ventilation control in the

1 Porteous, C D A and Ho, H M (1997) 'Do sunspaces work in Scotland? Lessons learnt from a CEC solar demonstration project in Glasgow', *International Journal of Ambient Energy*, Vol. 18, No. 1, pp 23-35).

remainder of the home. This should recognise the drive towards airtight building envelopes and resultant demand for mechanical heat recovery ventilation (MHRV) systems. If the home has an MHRV system then the drying cupboard should be connected to this, at least for extract, and ideally for supply as well in order to avoid odour transfer from adjacent spaces to the freshly washed material.

5.1.3 Heat input

In order to avoid scenarios where residents turn on heating to facilitate drying, it is important that the drying cupboard has its own heat source which can be operated independently of the primary heating system within the home. This low-grade heat source does not require to be onerous and could be onerous and could be 'borrowed' as indicated in p31 (sketch of drying cupboard).

A utility room should be provided with a dedicated heat source that is capable of maintaining a temperature of 18°C when the outside outside temperature is minus 1°C (regulation 3.13.1 and assumed not classed as a storage room of up to 4 m^2), or suitable alternative, e.g. heat gains from a boiler or appliance such as a freezer.

If an MHRV system already exists in the house, the drying cupboard or utility room could be connected to it to gain the required heat input. A sunspace used as a drying space would not require to be heated (an exception would have to be stated in the technical handbook to this effect). However, it would require to be ventilated in such a way that its air is not allowed to circulate freely into the heated rooms, e.g. a solution would be to link it to a MHRV system.

5.1.4 Moisture buffering lining materials

It is further recommended that internal linings and finishes of dedicated drying spaces should be of a suitably hygroscopic (moisture absorbing) nature. The resultant moisture buffering of the bounding surfaces of a dedicated drying space may assist in reducing the drying time and /or rate of ventilation required. In particular, by absorbing some of the peak moisture emitted during the first hour or so after hanging up, it will help to smooth out excessive peaks in humidity (that risk mould growth) during an entire drying period[2].

The moisture absorption properties of various materials have been an important part of the laboratory investigations which have provided a list of possible such materials. These data have then enabled more advanced computer moisture modelling – the aim being to provide optimum standards and design guidance in terms of heat and ventilation, and for the composite standard to eliminate risk of mould growth. It is therefore recommended that the walls and ceiling of drying cupboards or drying spaces within utility rooms be of a suitably hygroscopic material such as untreated timber or clayboard.

2 Absolute Humidity (AH) is commonly expressed as vapour pressure (VP), which can be calculated from RH and temperature, or a mixing ratio (MR) of moist to dry air. In habitable rooms, as opposed to specific drying spaces, it is AH (MR or VP) that is normally used as a maximum threshold or benchmark for dust mites – MR 7 g/kg or VP 1.13 kPa. For example, in a room where the temperature is 18°C, say a bedroom, 7 g/kg MR coincides almost exactly with 55% RH. Such conditions might also be deemed suitable for a utility room or a drying cupboard.

5.2 EXTERNAL COVERED INDIVIDUAL HOUSEHOLD DRYING SPACES

Sketch of transparent covered canopy

Exactly half of the 100 dwellings surveyed in the Glasgow project had access to some form of outdoor or covered semi-indoor drying, but almost half of that number (22 occupants) saw some drawback in using these – ranging from unpredictable weather in the case of completely outdoor spaces to lack of security and convenience.

Similar to the current building regulations, this guidance acknowledges that not all housing will have access to outdoor space. However, it is recommended that where possible an external line of a minimum length of 7.2 m per household, rather than the Technical Handbook 2010 standard of 1.7 m per apartment (habitable room). Additionally, a transparent covered canopy should be provided, where practicable – normally in most cases.

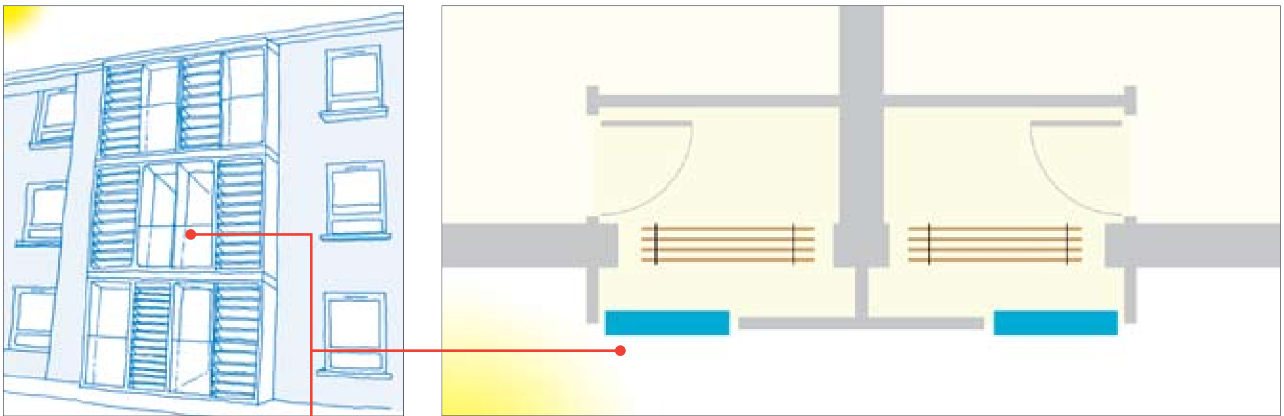
Both length and cover represent an increase from current standards. The first has been tested to be the minimum length required to dry a typical load of washing. Likewise the covered canopy acknowledges the prevalence for rain in Scotland, but with the transparency allows for sunshine, i.e. beneficial trapping of solar heat due to a building-integrated 'greenhouse effect' – to be maximised when possible.

A private facility of this nature could involve the upgrading of an existing opportunity, e.g. a transparent canopy to provide rain protection over a pulley or similar device on a balcony (recessed, partly recessed or projecting from facade) or garden (lean-to or freestanding).

Alternatively, a facility may be added where none exists, e.g. balconies to flats.

5.3 COMMUNAL EXTERNAL DRYING SPACES

A shared external drying facility is recommended where appropriate and feasible.



Sketch plan and facade of balcony drying space conversion

Glazing and glass louvres create sunspace for drying

Retrofit could provide opportunities for enhancement similar to those for individual dwellings, e.g. rooftops, back courts – with the potential for integration of active solar thermal or photovoltaic (PV) arrays functioning as canopies, depending on over-shading; and again providing passive solar enhancement of such spaces where possible.

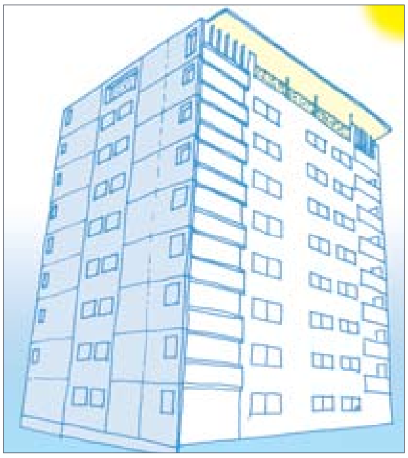
With new build housing, similar communal solar and weather-proofed provision can be provided, noting that semi-outdoor sun traps add amenity and value to a development.

5.4 COMMUNAL INDOOR DRYING FACILITY

In a flatted development of more than 20 units it is recommended that communal facilities for indoor drying are mandatory.

This could take the form of:

- room for passive drying, or
- laundry room with washing and drying appliances, or
- drying cabinet room



Sketch perspective of rooftop drying space

Communal laundry room – passive drying

This may take the form of a passive or hybrid passive-active drying room, which may function as a giant drying cupboard. It would have the following provision:

- Good access to sunshine (both plan and section important; 'greenhouse' trapping of solar heat adding value) and cross ventilation (e.g. via glass louvres)
  and/or
- Dedicated heat source (if possible using active solar thermal or photovoltaic collector in association with small heat pump) and mechanical ventilation to enhance natural convection (e.g. large, slow-rotation, ceiling-mounted fan, and/or connected to an MHRV system)

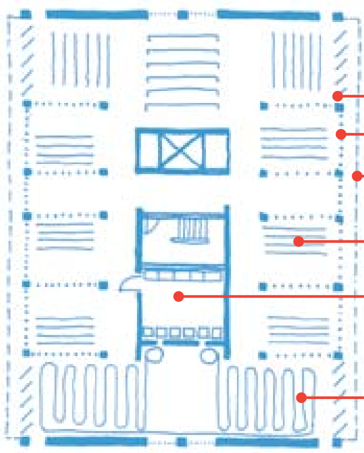
Communal laundry – washing and drying appliances

As an alternative to the passive drying space, a communal laundry with both large format washing and drying machines, or large format drying machines/cabinets only, would be a viable option to serve a flatted housing development of more than 20 units. An area of 20 m^2 should be designated as a communal laundry space, this to be well ventilated and capable of holding two large tumble dryers.

Energy savings through economies of scale could be made together with the introduction of energy-efficient and large-scale washers/dryers through through the use of a renewable fuel (e.g. bio-gas from food waste or rape-seed oil), heat pump tumble dryers (possibly associated with photovoltaic arrays) and even improved electrically-heated tumble dryers using more sophisticated heating programmes controlled by moisture sensors rather than timers.

Other innovative methods of integrating technologies to improve the energy and water efficiencies are discussed below – see 5.5.

With regard to such facilities, it is noteworthy that of the housing associations which responded to an auxiliary survey associated with the Glasgow laundering study, 20% confirmed they had a communal laundry facility, which either provided both washing and drying machines or a drying facility only. Many of these laundry spaces are located on the ground floor within 1960s and 1970s tower blocks, and these facilities could be significantly upgraded in terms of energy-efficiency.



Sketch plan of rooftop drying space

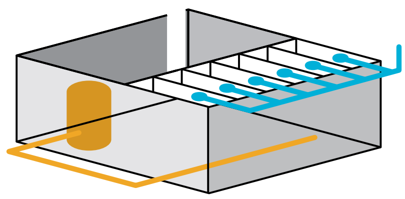
Drying cabinet room
A suggested option for a room of drying cabinets would address issues of privacy and would be a less energy intensive provision given the slower drying rate. It would also allow residents to have their own dedicated cupboard for which they were responsible. This may allow more flexibility for residents who find the rota system of a communal laundry rather time constraining. Low energy means of heating and ventilation would again be paramount.

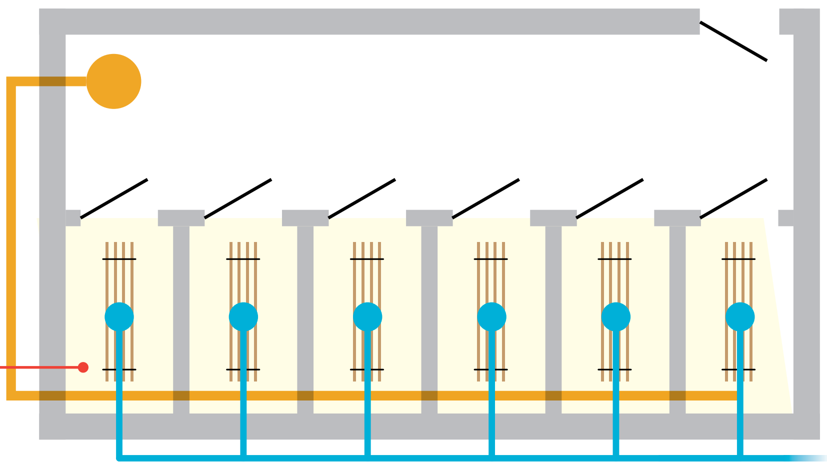
This guidance acknowledges that a culture shift would be required if communal laundries were to become the preferred method of clothes drying. However, location in a secure designated space, which is well managed and where residents can see the energy and resultant cost benefits, would help to engender a suitable incentive. If, by using the laundry, residents were made aware of the health benefits from their improved indoor environment and associated removal of unsightly laundry in living spaces, they may be more receptive to using such a facility. Moreover, if the facility was designed holistically using innovative technology, then the running costs to the housing provider or building manager would be minimised.

5.5 LAUNDRY ROOM – FUTURE APPLIANCES AND TECHNOLOGIES

There is scope for improvement to laundering appliances – the Glasgow survey indicates particular potential for washing machines and tumble dryers, the former capable of being linked to grey water re-use and both capable of mitigating thermal demand as well as further reducing electrical demand.

Sketch plan of drying cabinet room



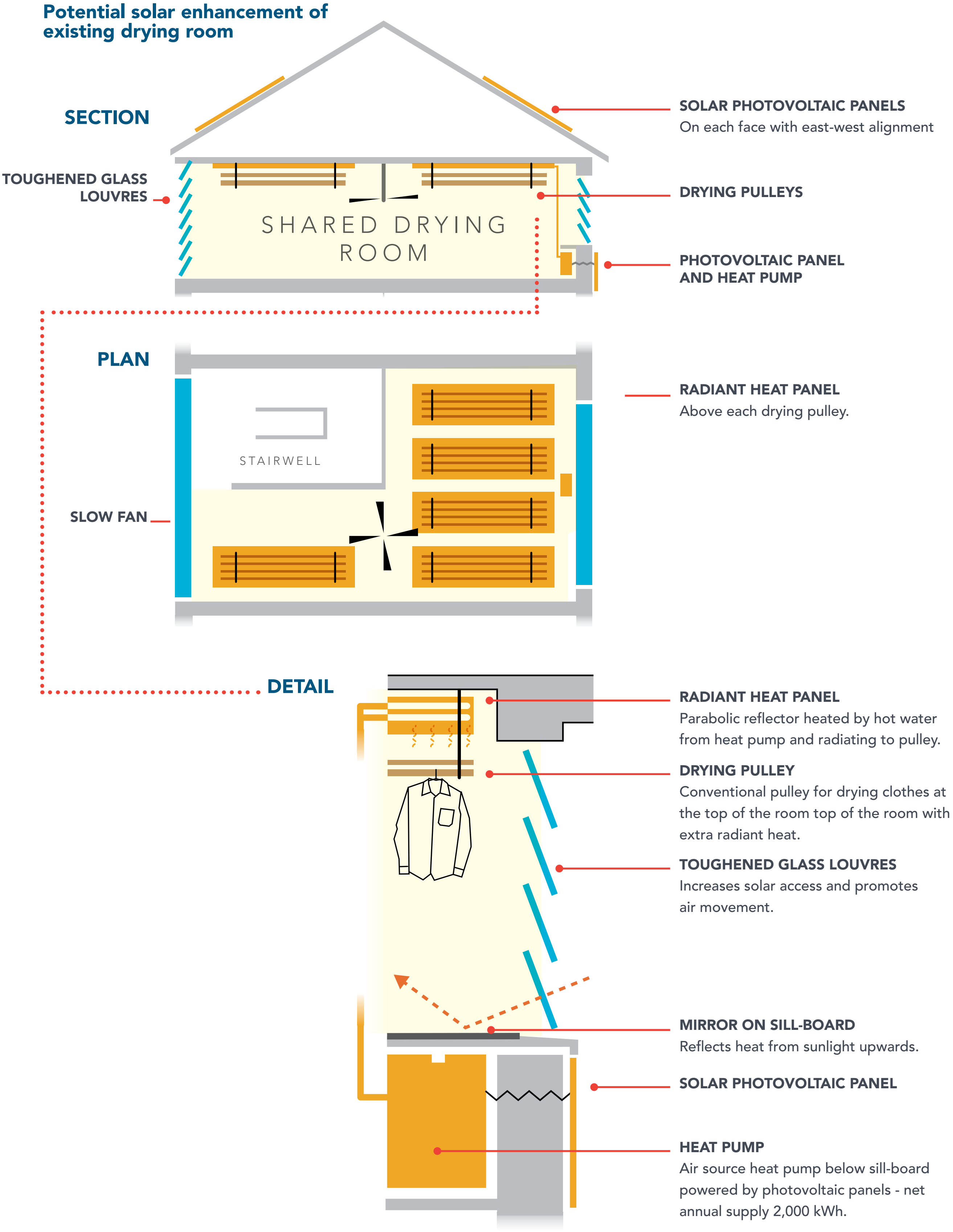


Therefore, the most appropriate method of reducing the energy impact of washing would seem to be a holistic integrated approach, which accepts realities but also exploits viable opportunities. One reality is that recycled grey water, including that from washing machines, saves only a small amount of CO_2.

However, more usefully, a holding tank for all grey water could be used as the ambient source for water-source heat pumps. Depending on overall energy efficiency of a dwelling these could provide domestic hot water, possibly in tandem with solar thermal collectors, and at least some space heating, particularly if this were delivered by low-temperature embedded serpentine systems.

Solar photovoltaic (PV) arrays, with net annual generation equivalent to to the consumption of such heat pumps, would further reduce carbon emissions (benefiting from 'feed in tariff' or FIT, albeit now no longer so financially attractive).

Potential solar enhancement of existing drying room



6.0 Economic Impact of the Design Recommendations

The economic impact of the recommendations contained within this design guide is relevant not only to the costs associated with domestic energy reduction but also to the wider Scottish and UK economy.

In the first instance, this regulatory and best practice advice has significant cost implications for health and wellbeing. Rather than attempting to compute quantities, the guide concentrates on the principle of significant potential savings, which could be made to the health service for treatment and to the UK economy for lost productivity days – a principle supported by inference from the evidence in the preceding sections.

In the second instance, impacts relate partly to more disposable income in people's pockets due to savings in energy – both electricity and other dominant fuels such as gas; and partly to industrial opportunities in relation to new or improved appliances, components and materials.

This latter aspect implies a prospect of substantial financial gain from businesses developing and selling products identified within this study, with careful tapping of the market and a boost to employment. These may include ventilation hardware, hygroscopic lining boards and drying appliances and devices.

6.1 HEALTH AND WELLBEING

This document takes the stance that suggested changes to statutory building standards (i.e. regulations) and the best practice advice noted above could have significant economic impacts on today's society if they were adopted and became mainstream practice. This assertion is predicated on a considerable body of evidence arising from the Glasgow laundering study, which associates indoor drying in particular to a prevailing, and worrying, context of poor indoor air quality and poor control of ventilation – often related to lack of awareness of this as an environmental health issue.

The building standards currently require new housing and major housing refurbishments to be constructed so that the health of occupants is not threatened. For existing social rented stock, the Scottish Housing Quality Standard (SHQS) also requires dwellings to be healthy, safe and secure. However, this Glasgow research has highlighted particular adverse health links between indoor drying and associated moisture levels within the home.

There are three potential areas of health risk:

- **Firstly** moisture levels denote risk, if consistently above a threshold recommended to limit growth of dust mite populations. This in turn has a proven causal link to asthma (i.e. between dust mite allergen exposure and exacerbation of asthma individuals who are specifically sensitised to dust mites). In addition, a recently published Finnish study suggests that children who have been newly diagnosed with asthma are more likely to have been exposed to moisture damage and mould growth in their homes than children who have not[1].
- **Secondly**, high mould spore concentrations of approximately 1,000 CFU/m^3 (colony forming units per metre cubed) and above denote risk; noting that Finland sets an upper threshold value of 500 CFU/m^3 for urban areas in winter. It is also estimated that 6-10% of the population and 15-55% of atopic people (those vulnerable to hay fever, asthma and eczema) are sensitised to fungal allergens. The Glasgow laundering study indicates a strong statistical link between drying indoors (on clothes horses etc.) and high CFU levels, allowing for other potential confounding variables.
- **Thirdly**, fabric softeners are commonly used and have been associated with one particular chemical, acetaldehyde. This is a known carcinogen, is classified as a hazardous substance, and it is also water-soluble and increases in concentration with increasing moisture.

However, in relation to the first two risks, there are many possible causes (and triggers) of asthma other than dust mites and mould spores. While much research is progressing in this area, the dominance of dust mites has still to be defined, and the extent of fungal-related asthma remains unknown. It must also be stressed that the scope of the Glasgow laundering study did not include an attempt to link the environmental conditions as found to the health of occupants. Nevertheless, it is well established that the impact of asthma is significant to the UK economy. Therefore, it is reasonable to conclude that removal or reduction of known causes or triggers generated through domestic laundering is likely to be significant.

A report carried out for Asthma UK in 2004[2] gives the most recent estimated economic impact to the UK economy together with key statistics. The Office for Health Economics estimated that the costs to the health service in 2001 totalled £889 million[3]. However, given the increase in the numbers of adults with asthma, the impact that asthma has on productivity and costs to society also demands attention. The Department for Work & Pensions estimated the cost of social security benefits at £260 million. The number of work days lost

ASTHMA IN THE UK

The UK has one of the highest rates of people with asthma of any country in the world.

There are 5.2 million people with asthma in the UK.

Asthma accounts for at least 12.7 million work days lost each year.

Asthma is responsible for one hospital admission every 7.5 minutes.

(Asthma UK, Lung and Asthma Information Agency, 2004)

1 Pekkanen, J; Hyvarinen, A; Haverinen-Shaughnessy, U; Korppi, M; Putus, T and Nevalainen, A (2007) 'Moisture damage and childhood asthma: a population-based incident case-control study', ***European Respiratory Journal***, March 1, Vol. 29, no. 3, 509-515.

2 The Asthma Audit 2004, ***Asthma UK***, Lung and Asthma Information Agency. http://www.asthma.org.uk/document.rm?id=18.

3 The Office for Health Economics, ***Compendium of Health Statistics***, Fifteenth Edition, 2003-2004.

PASSIVE DRYING CONCERNS

We found residents noted the following concerns with indoor passive drying:

- impediment to space
- unsightliness of clothes hanging in rooms
- staining (associated with drying on radiators)
- adding dampness to the air
- presence of mould
- damp smells.

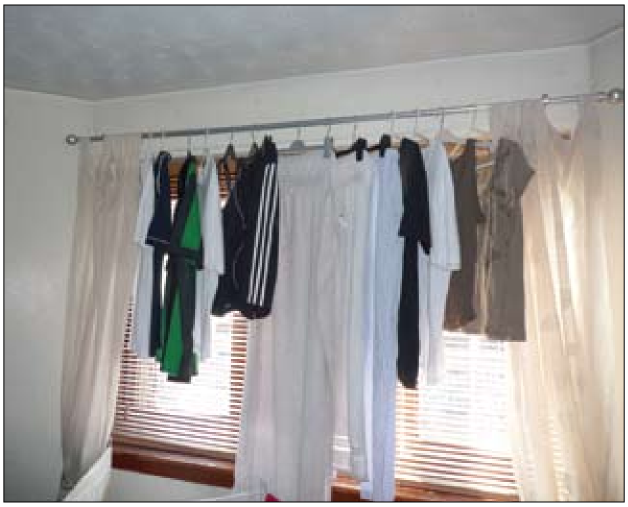
to asthma is at least 12.7 million, leading to an estimated bill for lost productivity of £1.2 billion[4].

The third potential health risk associated with fabric softeners has been brought to light by recent work in Seattle, which found that acetaldehyde could be a 'secondary pollutant resulting from a reaction between product ingredients'[5]. It is the unregulated aspect of fragranced consumer products such as those in fabric softeners that is of concern. Earlier work, further up the western seaboard of North America in Vancouver, found that the concentration of water-soluble VOCs such as aldehydes increase in concentration with humidity[6]. Hence it is reasonable to conclude that humid interiors, at least in part due to indoor drying, would tend to increase the environmental impact of VOCs such as acetaldehyde where fabric softeners are used.

Again, although negative health consequences may be inferred, it is important to stress that neither the work of the team in Seattle, nor the present study in Glasgow, sought to produce, or has produced, any evidence of an association between use of fabric softeners or detergents and the health of the occupants in question. Although estimates of costs to the health service lie outside the scope of this guide, they may well be significant.

Whilst the introduction of designated drying spaces, which are independently heated and ventilated, addresses the physical aspects of healthy dwellings in relation to air quality, there is much more that can be done to address the wider notion of wellbeing within the home. The World Health Organisation defines health as 'a state of complete physical, mental and social wellbeing' and much research indicates that if our homes provide a stimulating and relatively stress-free environment our sense of wellbeing improves.

AESTHETIC BLIGHT
Clothes drying on a curtain pole



For example, higher density homes have been shown to be associated with more psychological distress and psychiatric illness[7]; and a study has shown that occupants of high rise dwellings feel more socially overloaded compared with those in low rise housing[8].

When surveyed as part of the Glasgow laundering study, residents noted their concerns that the current practice of drying clothes has negative associations. It It impedes spaces within the home and creates unsightly clothes hanging in living spaces. Complaints of staining near radiators, condensation on windows and mould on walls

4 Office for National Statistics. Average weekly wage in 2003 was £476

5 Steinemann, A C; Gallagher, L G; Davis, A L and MacGregor, I C (2008) 'Chemical Emissions from Residential Dryer Vents During Use of Fragranced Laundry Products', ***Air Quality, Atmosphere and Health***, Vol. 1, No 1.

6 Arundel, A V; Sterling, E M; Biggin, J H and Sterling, T D (1986) 'Indirect Health Effects of Relative Humidity in Indoor Environments, ***Environmental Health Perspectives***, Vol. 65, pp351-361.

7 Evans,G W; Palsane, M N; Lepore, S J and Martin, F (1989) 'Residential density and psychological health: the mediating effects of social support', ***Journal of Personality and Social Psychology***, 57, pp994-999.

8 McArthy, D P and Saegert, S (1978) 'Residential density, social overload and social withdrawal', ***Human Ecology*** 6, pp253-272.

combine to add a sense of dampness to the air. All of these could account for a feeling of stress and lack of wellbeing within the home.

This highlights the relationship between people, their laundry habits and their dwellings in terms of health-promoting design. However, another recent study in Glasgow found that poor air quality conditions did not appear to correspond with a decrease in satisfaction or mood ('affectivity') scores, indicating that occupants may be unaware of potentially harmful health or wellbeing stressors[9].

While the economic impact of any lack of wellbeing or health is difficult to quantify, and beyond the scope of this guide, it also seems probable that the nature of the problem may be largely unidentified by the victims. Therefore, although there can be little doubt as to the presence of environmental health stressors associated with home laundering, and ad-hoc drying methods used indoors in particular, more work requires to be done to raise awareness and assess the consequences.

In summary, it is accepted that there are still unknowns such as predictions of health and wellbeing costs, and lack of appreciation by users as to some aspects of 'indoor air quality' (IAQ) issues. Nevertheless, it is posited that significant IAQ-associated health and wellbeing impacts could be addressed through the suggested changes to statutory standards and best practice – in particular, by providing a dedicated enclosed drying space within each home, healthier and happier habitable living spaces would be created.

6.2 ENERGY, MOISTURE REDUCTION AND TECHNOLOGY

Some areas of economic opportunity in this regard have been introduced in Sections 3.0 to 5.0 of this design guide. It is not the intention here to go further into technical detail, but rather to summarise or highlight two particularly promising areas for development. Both of these would lead to reduced energy consumption, lower moisture levels in homes, and greater disposable income for householders, as well as stimulating the industrial and service economy:

1. **Energy and moisture reduction, and limiting chemical pollution, by domestic process:**
   - avoiding uncontrolled passive indoor drying
   - optimising controlled drying in bespoke heated and ventilated cabinets or cupboards (with practical hygroscopic linings in standard panels which fit with industry standard sizes) as well as covered outdoor and semi-outdoor drying
   - minimising use of tumble dryers and need for ironing by such passive indoor/outdoor practices
   - appropriate selection of washing temperatures and products etc.
2. **Appliances and components to aid energy reduction and avoid chemical pollution:**
   - improved market penetration of the most efficient tumble dryers
   - a market return to hot-feed washing machines

9 Fung, J W (2008) 'The Unintended Negative Consequences of Decision-making in Glasgow's Social Housing Sector', PhD Thesis, Mackintosh School of Architecture, Glasgow, pp(7)-6].

- development of hygienic low-temperature detergents without contentious chemical by-products
- parallel research and development of fabric softeners with regulated ingredients including fragrances
- grey water recycling components for washing machines and other domestic sources
- associated heat pumps and solar thermal or solar photovoltaic collection devices (linked to heat pumps and outdoor or semi-outdoor drying facilities)
- industrial size drying cabinets; gas heated dryers; accessible trickle vents which are wind-sensitive as well as moisture sensitive
- window-integrated solar air collectors with wind-sensitive trickle vents and associated passive stack exhaust
- variable flow, humidity and CO_2 switched ventilation systems, especially balanced systems with heat recovery etc.

In addition to the health-related economic impacts outlined in 6.1, these recommendations provide a framework for commercial opportunities to further develop and market both new and emerging technologies relating to domestic laundering.

6.3 CONCLUDING REMARK

Overall, the symbiotic relationship between the economic impacts related to health and wellbeing and those related to energy efficiency, represents a set of constituents or ingredients of a win-win sustainability recipe – one that will help to provide a healthier, happier, more comfortable, affordable and renewables-oriented generation of homes.

Georgian Laundering Quotes

Georgian chemist and inventor Charles Sylvester from Sheffield presciently wrote ***The Philosophy of the Domestic Economy*** in 1819. In it he describes a very early mechanical washing machine:

> "The steam engine works a forcing pump, which raises water from a well to a cistern at the top of the building from which the house is supplied with cold water. It also gives motion to a horizontal shaft communicating with the wash-house, and turns the washing machine."

> "The velocity of the cylinder should be such that the linen may be heard to fall from one side to the other every time it is raised out of the water. This discharges most of the water from it, and it becomes filled with a fresh portion every time it dips into the water below. … When the machine moves at a proper speed, one charge of linen will be washed in less than half an hour."

He also gives practical drying advice remarkably similar to that in this design guide:

> "The laundry should be provided with a hot closet, through which a current of hot air is constantly passing, …" "… by this means the heated air is compelled to pass from the top to the bottom of the hot closet, affording the most effectual means of carrying off the moisture, with the least expense of fuel."

MACKINTOSH ENVIRONMENTAL ARCHITECTURE RESEARCH UNIT
THE GLASGOW SCHOOL OF ART

The Mackintosh Environmental Architecture Research Unit (MEARU) was established in 1993 within the Mackintosh School of Architecture and has an established track record of high quality research into environmental architecture.

MEARU undertakes strategic and applied research into a wide range of aspects of sustainable environmental design, including solar technology and indoor air quality and responding to a growing commitment to user-centred, low energy, eco-sensitive architecture in the context of increasing global concerns.

The unit is also well networked with similar European partners, is represented on the International Energy Agency, ISES Europe and publishes regularly at the Eurosun, PLEA, and WREC conference circuits.This activity contributes greatly to the learning and teaching culture of The Mackintosh School of Architecture and has also established the research unit as a significant global research player in scientific and architectural circles.

MEARU has completed a number of research-based consultancy contracts with corporate clients, private architectural practitioners and public sector organisations including local authorities and housing associations. Ongoing research is funded by the UK's national innovation agency, the Technology Strategy Board; the Engineering and Physical Sciences Research Council (EPSRC) and the Arts and Humanities Research Council (AHRC). MEARU is also partnered with a progressive housing association via the Knowledge Transfer Partnership scheme.

Rosalie Menon and Colin Porteous
MEARU (Mackintosh Environmental Architecture Research Unit)
The Glasgow School of Art

www.homelaundrystudy.net ISBN: 978-0-9571595-0-1