PHIUS Monitoring Protocol

Version 0.3

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Definitions

ACCA	Air conditioning contractor's association
CT	Current transformer
CO2	Carbon dioxide
IAQ	Indoor air quality
PHIUS	Passive House Institute US
PM2.5	Atmospheric particulate matter (PM) that have a diameter less than 2.5 micrometers
RESET	A trademarked indoor air quality standard (regenerative, ecological, social & economic targets)
RH	Relative humidity
VOC	Volatile organic compounds

1 Purpose

Passive buildings should be comfortable, healthy, and durable – all while using very little energy in operation. The certification requirements of the PHIUS+ program are designed to produce these outcomes. But currently those requirements pertain to the design and construction of the building; certification ends as building occupation and operation begins. The purpose of this monitoring protocol is to verify that the desired outcomes are being achieved, to at least detect problems in case they are not, and preferably to diagnose problems as well.

1.1 Scope

This protocol covers planning for monitoring for projects at various phases from design through already-occupied.

2 Priorities and equipment tiers

2.1 Research questions

Here are some questions we would like monitoring to shed some light on:

2.1.1 *Does actual energy use match predicted/modeled energy use?*

The modeling for certification is based on annual numbers and makes predictions at monthly time scale as well. Therefore, annual and preferably monthly energy utility bills are the first point of interest. The predictions assume a standard occupancy and climate, and adjusting for actual occupancy and weather is usually the first place to look to explain any discrepancy, therefore information about actual occupancy should be reported as well.

2.1.1.1 If not, why? In particular, are our standardized-occupant assumptions for residential lighting and plug loads valid on average?

The next point of interest is "energy end-use breakdown." To diagnose a discrepancy between modeled and measured energy use, it's critical to monitor by use type. If the monitored data is off by, for example 20% from the modeled data, it's important to know if every category was off by a small fraction, or if one category was off by a lot. That helps improve modeling methodology and assumptions moving forward. The end-use for which measured data is most important is "Miscellaneous," and in general the more subject to the whims of the occupants it is, the higher the priority. "Hot water" is probably second in line. Heating and cooling should be more predictable and thus lower priority IF the thermostat settings are reasonable. Occupants can throw off even heating and cooling calculations with nonstandard settings and therefore thermostat settings can also be important to monitor.

2.1.1.2 How steady is the daily electrical load profile?

One of the expected benefits of passive design is that the energy demand on the electric utility is less variable than for standard construction, on both daily and seasonal cycles. Monthly data will indicate the seasonal pattern but for the daily cycle, total electrical use needs to be reported at least hourly.

2.1.1.3 What kind of dashboard would motivate the occupants to save energy?

Energy monitoring systems may or may not include feedback to the occupants. The effectiveness of such feedback is a research question in itself; experiments could be done with different kinds of dashboards and "blind" control cases (monitored with no feedback.)

2.1.2 *Is thermal comfort being delivered?*

The first point of interest is in the "ACCA manual RS" sense of comfort, that is, room-to-thermostat, room-to-room, and floor-to-floor temperature differences, relative humidity, and temperature 4 inches above the floor.

2.1.3 *Is the indoor air quality (IAQ) good?*

PHIUS recommends the RESET Air Standard v2.0, and RESET Grade B qualified IAQ monitors. Such monitors measure temperature, RH, CO2, TVOC, and PM2.5.

PHIUS has RESET Accredited Professionals and can help with selecting monitors, defining their locations, and developing a maintenance plan. There are two paths in RESET, an "Interiors" path focused on actual conditions in the occupied zones and a "Core and Shell" path focused on the quality of the air delivered at the supply ducts.

Radon is also of interest. It can't yet be monitored in real time but must be spot checked with canister testing.

2.1.3.1 What is the frequency of "ventilation bind"?

Sensor-controlled ventilation systems based on indoor CO2 or VOC may assume that indoor air quality can be improved by ventilating, but that may not be true in rural areas (that may be subject to smoke from wildfires, campfires, outdoor boilers.) Monitoring the outdoor air quality will indicate how often it will do more harm than good to ventilate.

2.1.4 *Is a high-tech / complex / innovative mechanical system (or device) performing as expected?*

Data is needed on measures that aim to save energy by sensors and controls, such as demand-recirculation hot water, and occupancy-sensor controlled lighting. The same goes for renewable energy systems that incorporate on-site storage, such as batteries, thermal or phase-change tanks, and also sub-soil heat exchangers. Likewise, integrated systems that do energy cascade, such as co-generation, or solar thermal for both hot water and space heat, and any kind of new or innovative mechanical device, are candidates for monitoring to verify performance calculations or claims.

2.1.5 *Is an "edgy" moisture design for an assembly staying dry enough?*

Because there is less heat flow through super-insulated walls / roofs / floors, there is also less drying potential. While it is mostly known prescriptively how to avoid moisture problems in high-R assemblies, for cost reasons projects are still submitted for certification with riskier assemblies that call for WUFI analysis or engineer's stamps. Any assembly that needed this extra level of scrutiny in certification could be a candidate for moisture monitoring.

2.1.6 *What are the conditions in attached unconditioned spaces, especially below grade?*

Monthly-method energy calculations represent attached unconditioned spaces simply with a reduction factor on the heating-degree days applied to the adjoining wall. Usually a conservative guess is made. For projects with such attached spaces it would be interesting to know what actually happens.

The humidity conditions in unconditioned crawlspaces and basements are even more important because they can impact the moisture risk to the floor assemblies above.

2.2 Equipment budget tiers

There is clearly a cost tradeoff with monitoring – more equipment gets more information but also costs more. The list of "tiers" below is intended to get the most useful information possible at different budget levels. Currently, it seems that monitoring temperatures and electrical circuits is relatively low-cost, compared to sensors for other things.

PHIUS recommends the Powerwise / Sitesage system (formerly known as eMonitor) for monitoring electrical energy, water, gas, indoor environment, and site weather, and the RESET system if indoor air quality also including PM2.5 monitoring is a particular concern.

Tier Zero (no monitoring equipment)

Report monthly utility bills, or arrange for utilities to allow PHIUS access or report directly.

Tier One (existing monitoring equipment)

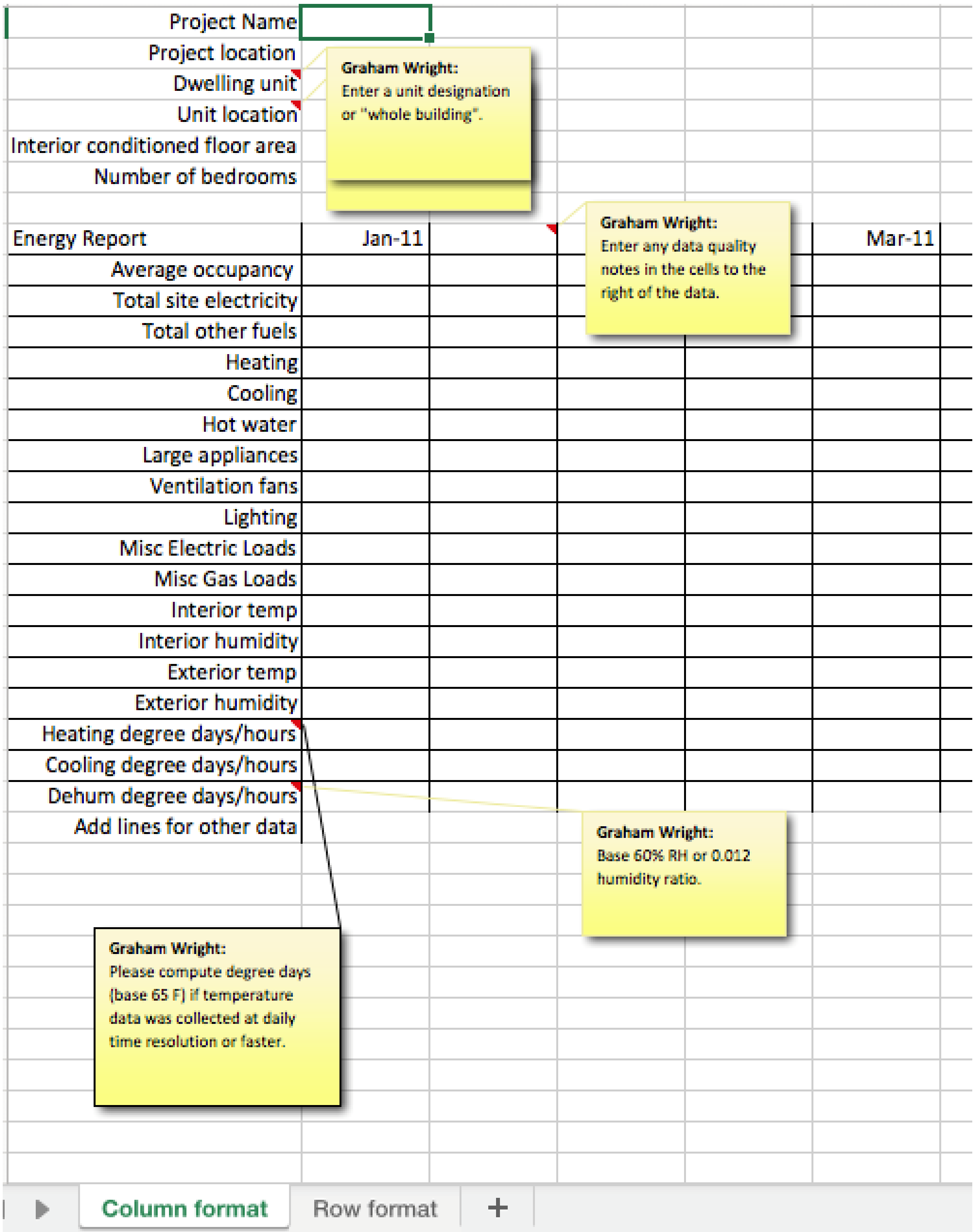
Guideline: Use monitored data reporting form to report monthly totals/averages.
(Add actual occupancy to the form.)
See screenshot in Figure 1.

Tier Two (post-construction installed monitoring equipment, up to $500)

2A (with dashboard visible to occupants)
2B (blind, no real-time feedback to occupants)
Monitor electrical mains and miscellaneous plug loads
Monitor indoor temperatures as budget permits. (for room-to-room and room-to-thermostat temp diffs.)

Tier Three (new construction designed for monitoring, equipment up to $1000)

3A (with dashboard)
3B (blind)
Monitor electrical mains, miscellaneous plug loads, lighting, and hot water if electric/heat-pump & budget permits.
Use thermostats whose settings can be monitored.
Monitor indoor temperatures as budget permits.


Project Name
Project location
Dwelling unit
Unit location
Interior conditioned floor area
Number of bedrooms

Graham Wright:
Enter a unit designation or "whole building".

Energy Report	Jan-11				Mar-11
Average occupancy					
Total site electricity					
Total other fuels					
Heating					
Cooling					
Hot water					
Large appliances					
Ventilation fans					
Lighting					
Misc Electric Loads					
Misc Gas Loads					
Interior temp					
Interior humidity					
Exterior temp					
Exterior humidity					
Heating degree days/hours					
Cooling degree days/hours					
Dehum degree days/hours					
Add lines for other data					

Graham Wright:
Enter any data quality notes in the cells to the right of the data.

Graham Wright:
Base 60% RH or 0.012 humidity ratio.

Graham Wright:
Please compute degree days (base 65 F) if temperature data was collected at daily time resolution or faster.

Column format
Row format
+

Figure 1. Screen shot of Monitored Data Reporting form for existing monitored projects.

Tier Four (new construction designed for monitoring, equipment > $1000)
Full energy end-use breakdown: heating, cooling, ventilation fans, hot water, major appliances, lighting, plug loads, renewables.
Thermostat settings, Operative temperatures, relative humidity
CO_2
VOC
PM2.5
Radon (main living area)
Window opening behavior
RH/Temp in Crawlspace, unheated basement, other "attached zones" if present, otherwise Outside.
Outdoor VOC

Tier Five, special situations
Moisture in assemblies
Site weather (microclimate)
Complex/advanced mechanicals
Other special situations

2.3 Caveats

PHIUS has found that when it comes to real world monitoring design and installation, each project presents a unique scenario. Therefore, use the tiers above as starting points, with the knowledge that you may need to mix and match from them to create a system that works for a particular design.

In addition, to optimize monitoring, it's critical to take it into account at the design phase, and clearly communicate sensor and other installation requirements to the builder team, so that they can build those requirements into their staging. Finally, it's vital to follow through with the builder to confirm that monitoring is not treated as an afterthought.

3 Roles and responsibilities

3.1 Residents

Cooperate with study:

- Make sure there is always one among them who is the contact person for the system/study,
- Allow access for system installation and maintenance/repair,
- Report disturbance/damage to sensors & equipment,
- Sign a waiver of release of data to PHIUS with protections of privacy defined, so that there is minimal risk to building occupant.
- Optional: Allow two 36-hour simulated outages, one summer, one winter, during the study period.

3.2 PHIUS

- Monitor the system remotely, interpret data, comply with reporting requirements.
- Work with developer on maintaining data quality.
- Designate a PHIUS point of contact person for builder/developer.
- Optional: Devise a short subjective-experience questionnaire about comfort and energy, suitable for administering to the residents by phone at least annually.

3.3 Builder/developer

- Coordinate with equipment providers and PHIUS on installation and maintenance of the system.
- Familiarize Residents with the system & study, serve as / designate a Point of contact for Residents and PHIUS.
- Administer questionnaire on resident subjective experience periodically.
- Collect radon data monthly, if it cannot be monitored remotely.

Appendix - Other equipment options

- E-gauge – Normal cost to monitor the electrical mains, a circuit for PV, as well as 3-4 circuits (each E-gauge can handle up to 12 circuits) is about $675, though a non-profit was able to negotiate to $450. Web interface comes at no additional charge, though there are only some basic graphs and ability to download the historical data. The eGauge can read data from compatible auxiliary devices via the local network using hardwired Ethernet or powerline communication (HomePlug). (Source: John Semmelhack)

- Efergy True Power Meter - for basic monitoring of whole house electricity usage, without circuit by circuit monitoring. It's only $170, so obviously a real nice price for "entry level" monitoring. No extra fee for the web/smart phone interface. (Source: John Semmelhack)

- Open Energy Monitor – Wireless data monitoring system for sensors could make installation/removal easier. Free software and access to webserver. Hardware system will require some configuring depending on what we want to measure. $299. (Source: Ginger Watkins)

- WEGO Wise –Free or low cost monthly and on delivery utility bill aggregation – setup once (hopefully) and WegoWise downloads utility data (energy and water) into a database for analysis. Manual entry is also supported.

- TED Pro Home has both a two CT version and a ‘spyder’ version with individual CTs to 32. http://www.theenergydetective.com/prohome (Source Mike Duclos)

- Curb is also a multi-CT home electrical monitor. http://energycurb.com

- There are a variety of other low cost electricity monitors, including WattVision, BlueLine, EED, EnviR, Eyedro EHEM1, etc. Low cost tends to mean ‘whole house’ and limited capabilities, like a graph of aggregated use. Neurio ($250) seems the most interesting of these. http://neur.io/ - CTs on mains only, no specific circuit count. Claims use of smart pattern detection algorithms to identify appliances, starting with a training mode and all breakers off, identify each appliance, turn on and identify to the app. Provides alarms, notifications. Has a "Lowest Power" challenge to help identify baseload waste, has an "Always On" score. General pricing from $150 to $250. (Source Mike Duclos)

- Sense Labs, Inc. Appears to be similar to Neurio – smart algorithms to identify appliances. https://sense.com/product.html

- OmniSense – $200 gateway Ethernet/WiFi/Cellular data, plus sensors. Data collection and analysis in cloud, free account: http://www.omnisense.com (Source Mike Duclos) Best known for Wood Moisture Equivalent monitoring of wall/roof assemblies, sensors include

    - Temp/RH/Wood Moisture Equivalent $84/ea
    - AC Energy Meter 15 circuits $1000
    - Weather station interface – for Anemometer tipping bucket, solar radiation - $160
    - Wireless manometer – from 0.01 Pa to 250 Pa – $400
    - CO2 sensor 0 – 2000 PPM- $300
    - Others like ultrasonic flow, vibration, particle counter, sound pressure level, etc.

- Onset RX3000 series – $900 + sensors, free limited use data plan **-** Communications via Ethernet/WiFi/Cellular telephony. Web based graphs, downloadable .csv for analysis. Scientific/Commercial/Industrial markets. Can be used outdoors, battery backup, solar power and alternative power option, and 2MB memory for uninterrupted data collection during power/communications outages. Use their system configurator to access their compatible sensor page, they also have analog adapter modules for interfacing other analog devices. http://www.onsetcomp.com/products/data-loggers/rx3000 (Source Mike Duclos) Sensors include:

- Split core CTs from 5 amp to 600 amp
- 150 to 600 VAC voltage monitoring
- Air velocity sensors from 30 to 2000 fpm
- Amp hour/power factor/reactive power, VA reactive, VA, Watts, etc.
- CO2 via Telaire 7001 – I've used this
- Compressed air flow
- DC Current
- Differential pressure (think DG700 manometer)
- KWHR/WattNode (recording/analysis) interfaces
- Pulse/contact closure interfaces
- Temp/RH sensors
- VOC via TVOC analysis module
- Water flow via potable water meter Minol-130

References

https://www.reset.build/standard