The Advantages and Limitations of UAVs for External Thermographic Building Facade Inspections in Canada

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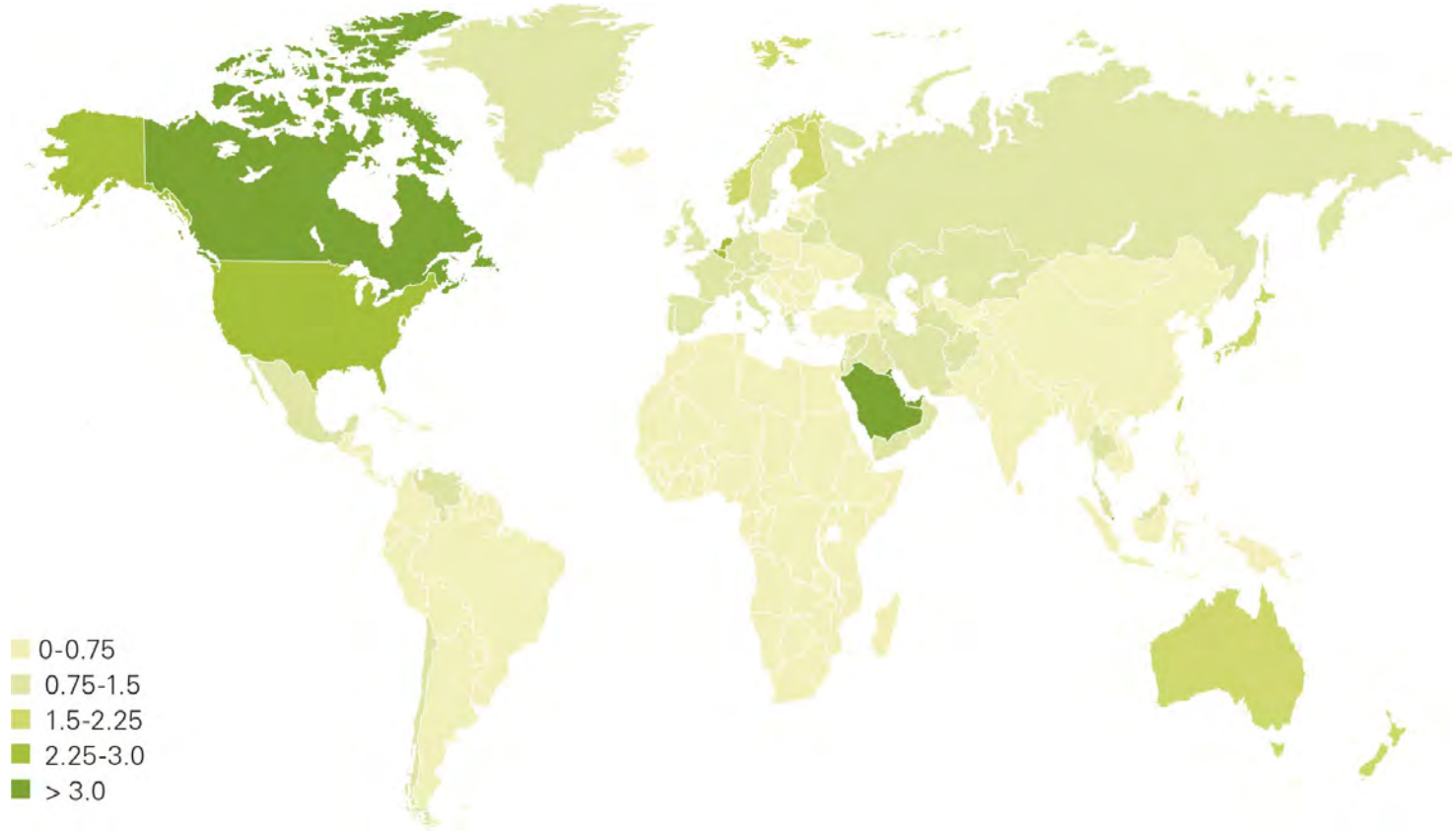
Background

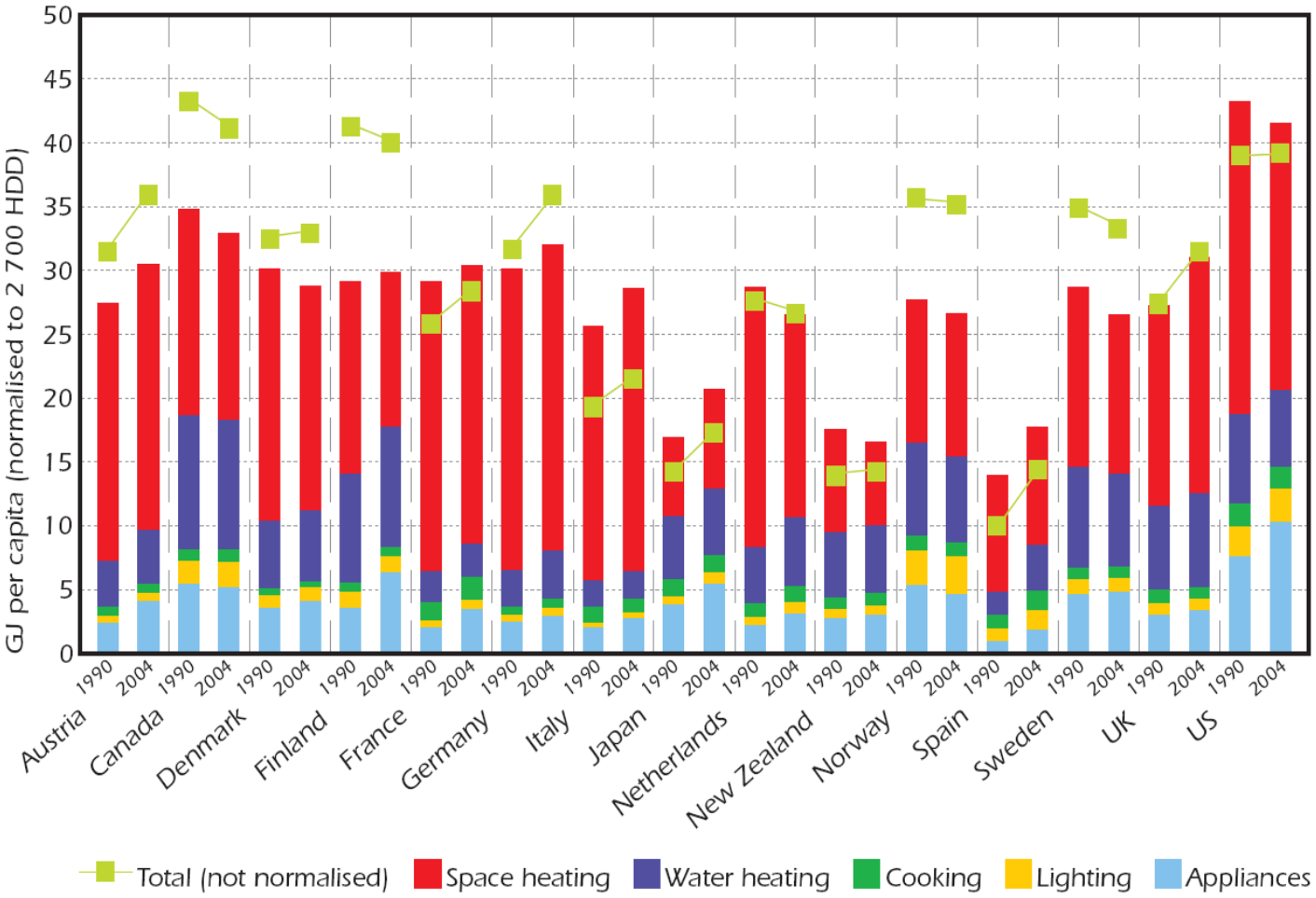
Oil Consumption Per Capita 2012
Tonnes



Source: BP (2013)

Up to 40% of Total Energy demand is Consumed by Buildings
(Up to 60% for Urban Areas).

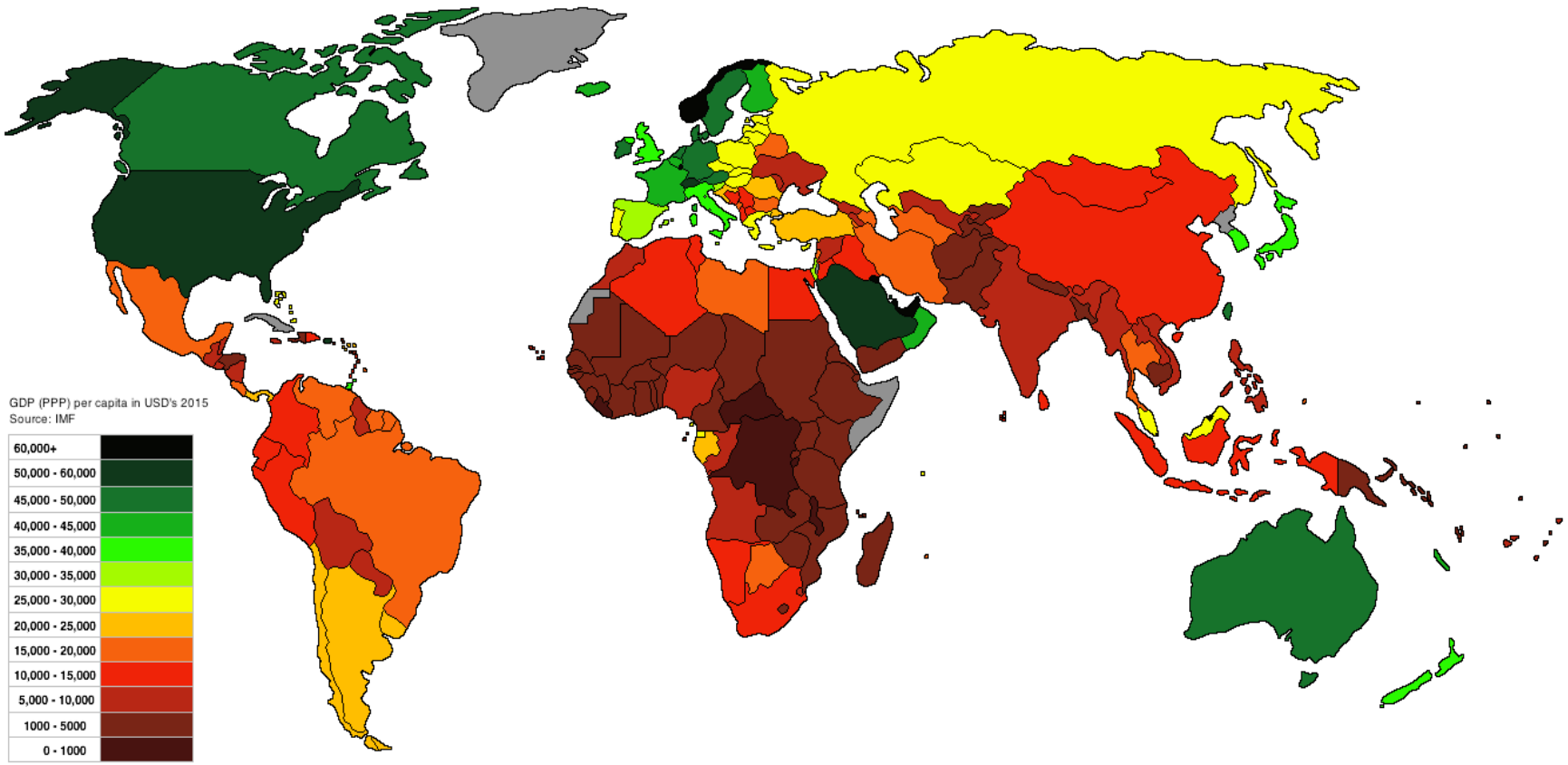
Some Countries are Doing Better



(Energy Use in the New Millennium -Trends in IEA Countries)

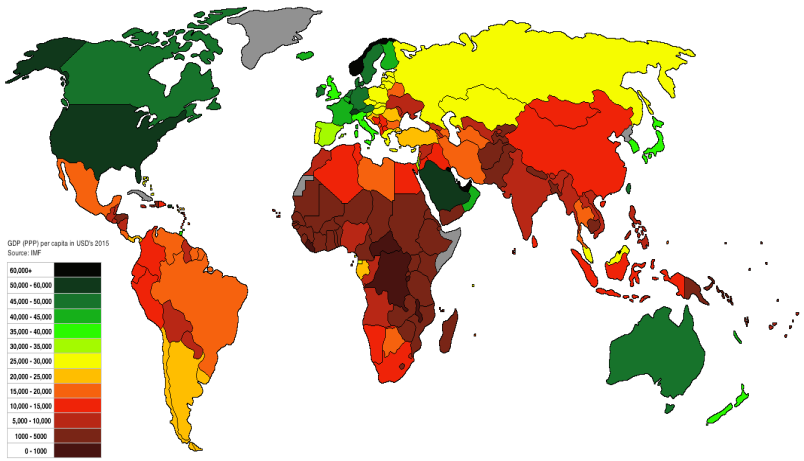
Background

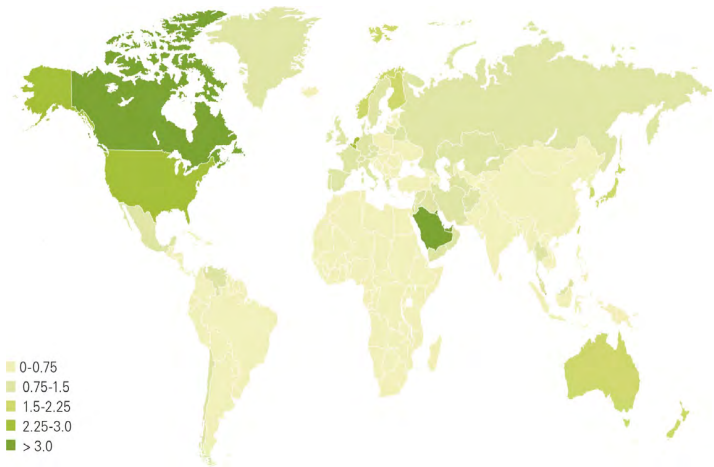
GDP (PPP) Per Capita in USD's 2015



Source: IMF (2015)

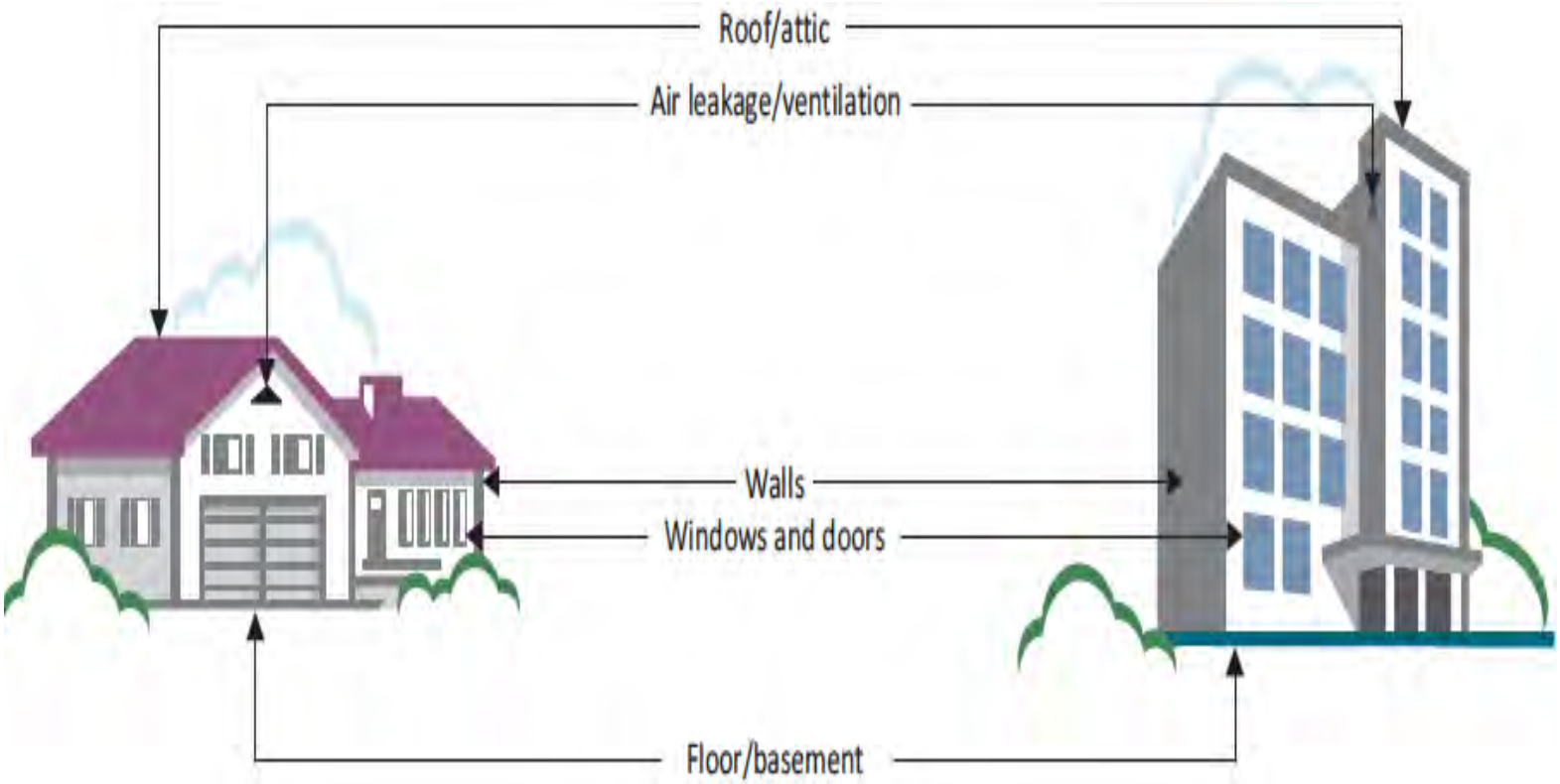
Background





How to Decarbonize GDP ?

Available Options



- **Highly Insulated Walls, Roofs, Floor etc.**
- **Energy efficient Windows & Doors**
- **Air Leakage**
- **Building-Integrated Photovoltaic**
- **Passive Solar Design**
- **Heat Recovery Ventilation**
- **Heat Pump**
- **LED lighting**

IEA Technology Roadmap: Energy Efficient Building Envelopes

Background

- Sustainable buildings
- Passive house
- Green buildings
- Net-zero buildings
- Net-zero ready buildings
- LEED buildings
- Energy code compliance buildings (NECB, ASHRAE, BC Step Code …… etc)
- ……

Principles of Thermography

Infrared / Thermographic Cameras

- A technology which allows for easy and accurate non-contact surface temperature measurements? No.

- High Level – Conversion of Sensed Radiative Flux to Surface Temperature *Estimate*

- More accurately, it is the estimation of surface temperature based on sensed radiative flux and an idealized model of emission and reflectivity

Principles of Thermography

Bands of Thermographic Imaging

Short, Medium, and Long Wave IR Bands

Plank's Law informs the use case

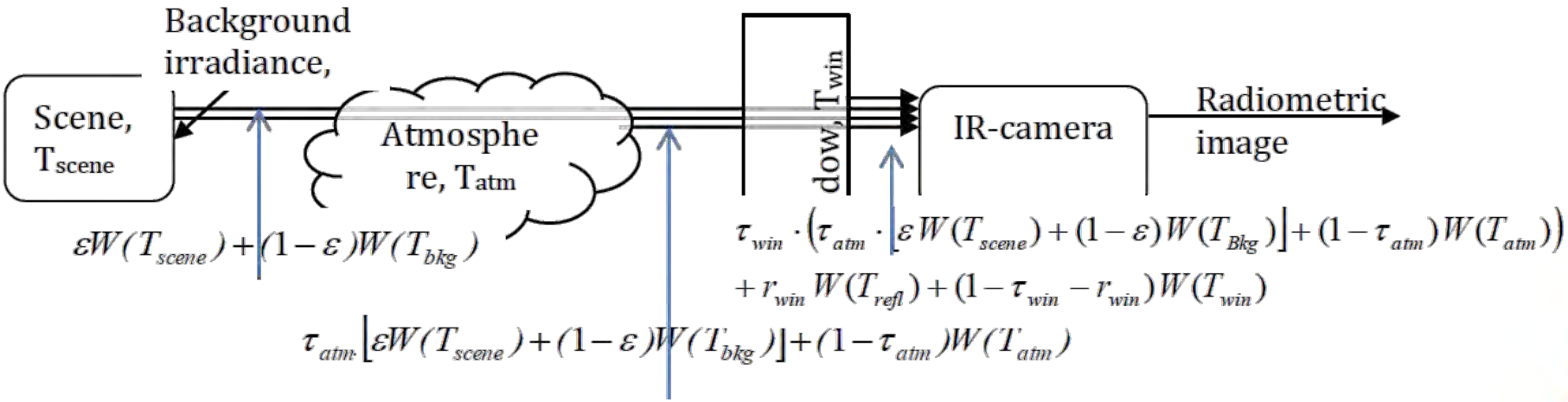
Short / Medium Wave - High Temperature Subject

Long Wave – Ambient Temperature Subject

Principles of Thermography

What an IR Camera 'Sees'

A complex signal, composed of many components, whose influence is subject to many factors!



$$S = \tau_{win} \cdot \left(\tau_{atm} \cdot \left[\varepsilon W(T_{scene}) + (1-\varepsilon)W(T_{Bkg})\right] + (1-\tau_{atm})W(T_{atm})\right)$$
$$+ r_{win} W(T_{refl}) + (1-\tau_{win} - r_{win})W(T_{win})$$

Source: FLIR

Principles of Thermography

Types of Thermography

- Passive vs Active
- Capture Methods – instantaneous, Time-sequence, Continuous
- Common Methods in Building Science

Today's IR Cameras

- Since first commercial availability of *real-time* sensors in the late 1960s, IR cameras have only grown smaller in size, while increasing in **portability, sensitivity, and affordability**.
- Several common types of sensors for different applications and regions of the IR Spectrum exist
  - SWIR – 0.5 – 1.7 µm
  - MWIR – 3 – 5 µm / 1 – 5 µm
  - **LWIR** – 7.7 – 9.5 µm / 7.5 – 12 µm / **7.5 – 13.5 µm**
- Sensitive to changes as small as 0.02°C / **20 mK**
- 8-bit False Colour Images, 12 to16-bit Radiometric data

All Shapes and Sizes! [and Prices]

FLIR X8500sc

FLIR Boson

FLIR One

FLIR T1030sc

FLUKE Ti10

Estimating Surface Temperatures

- IR Cameras pack small on-chip computers which perform image analysis of the sensed radiative flux, comparing to factory calibration data
  - Based on Black Body Radiation and Plank's Law, and periodic NUC (non-uniformity compensation)
- Advanced sensors provide inputs to compensate for a limited number of factors including
  - Emissivity
  - Apparent Reflected Temperature
  - Atmospheric Attenuation
  - These values are collected in the field at the time of inspection

Current Applications in Building Science

Current Standardized Practices in Qualitative Investigation

ASTM C1060 – Thermographic Inspection of Insulation Installations in Envelope Cavities of Frame Buildings

ASTM C1153 – Location of Wet Insulation in Roofing Systems Using Infrared Imaging

ASTM E1934 – Examining Electrical and Mechanical Equipment with Infrared Thermography

Current Applications

- Detection of **Thermal Anomalies**

How many parked cars were running recently?

Current Applications

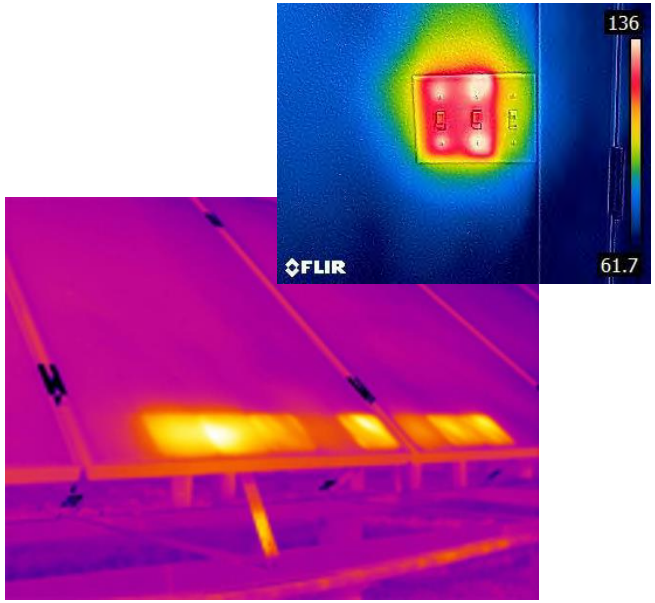
Public Safety and Security

- Night Vision, Search and Rescue, Fire Fighting, Surveillance

Current Applications

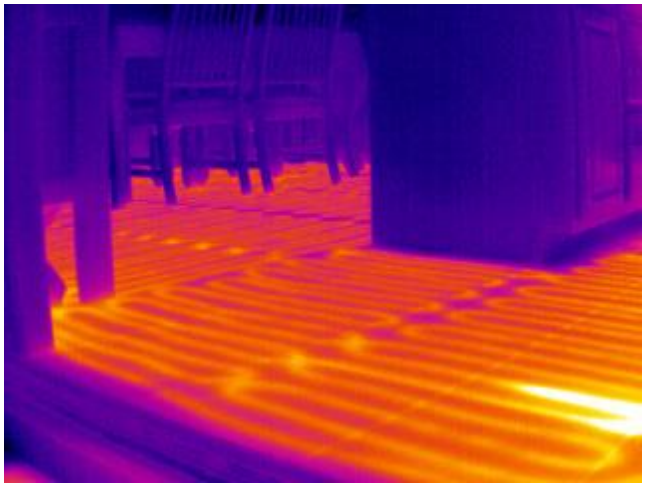
Electrical Systems Inspection

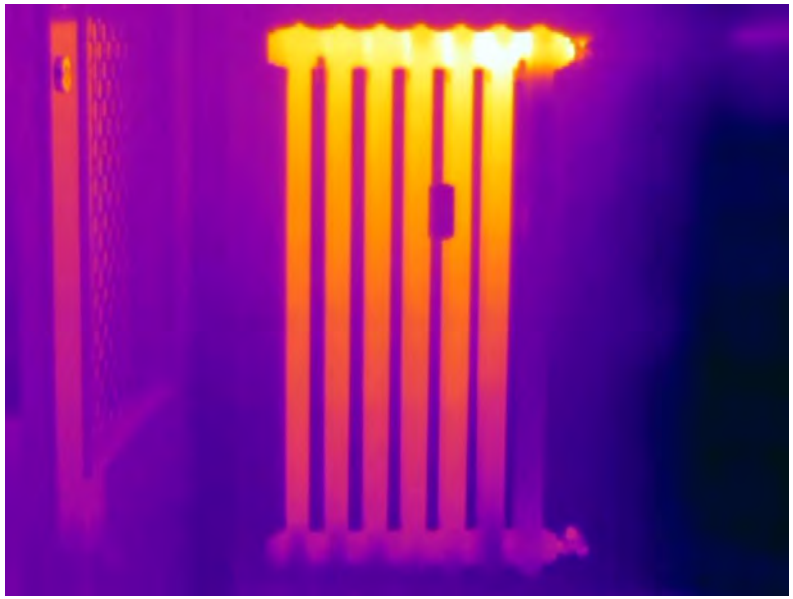
- Malfunctioning components often ‘run hot’



Current Applications

Heating Systems Inspection

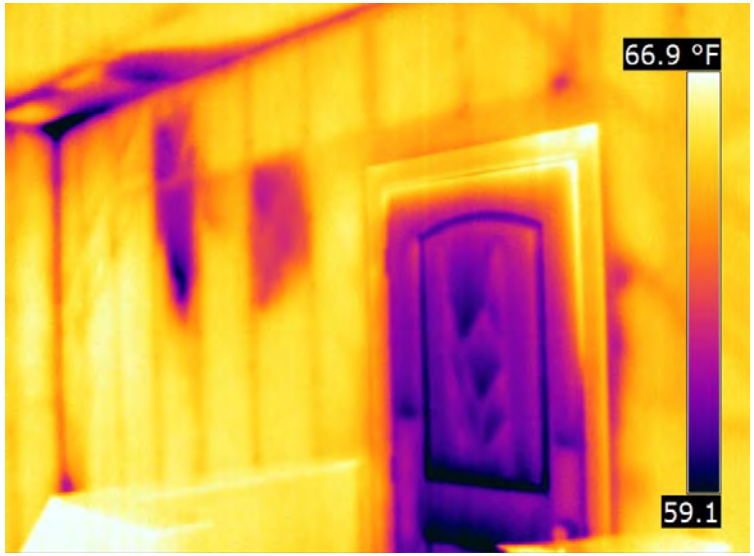




Current Applications

Finding Insulation Voids

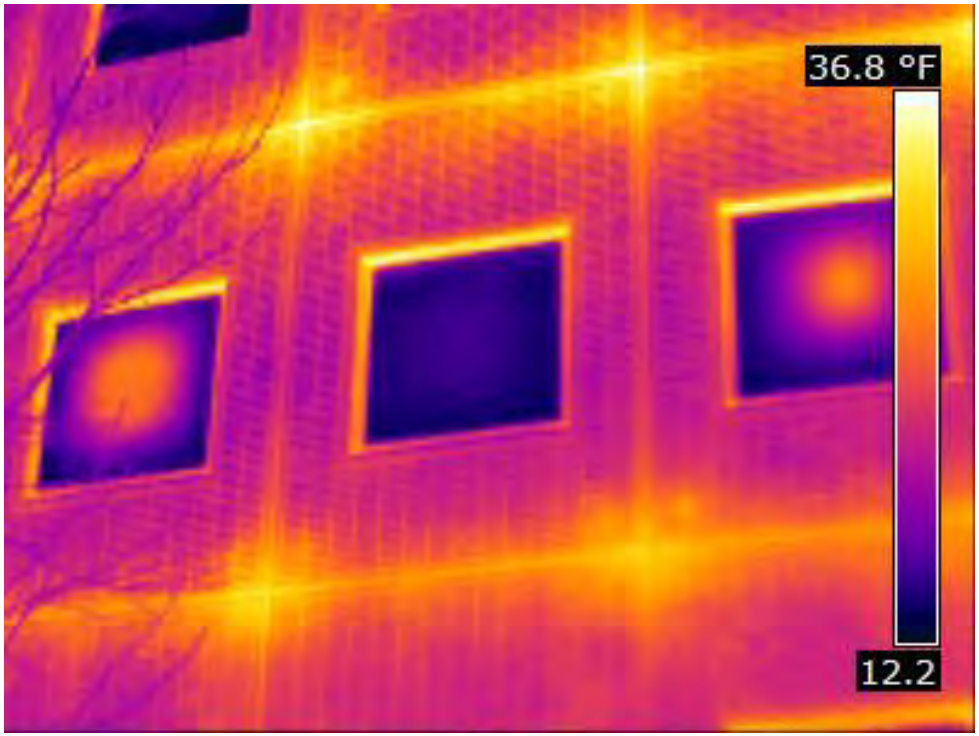
- With a thermal stimulus, or large temperature gradient, insulation voids are easy to spot!



Current Applications

Locating Failing Windows

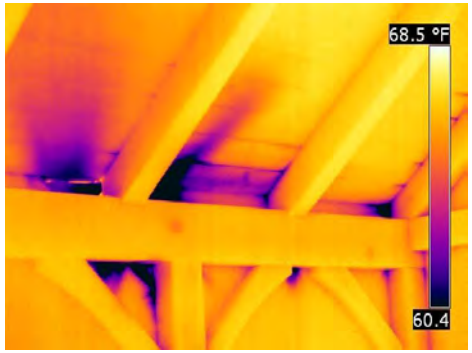
- High Performance Windows incorporate a sealed gas section which acts to offer greater insulation, if intact

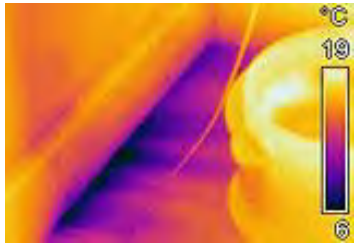


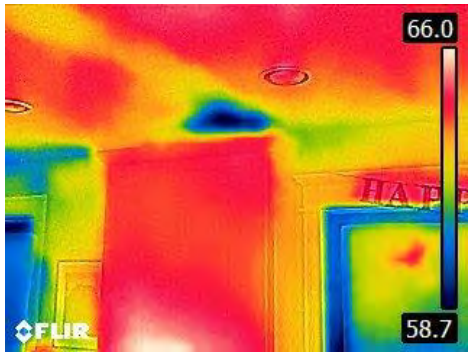
Current Applications

Air-tightness Inspections

- Detecting ventilation and draught issues



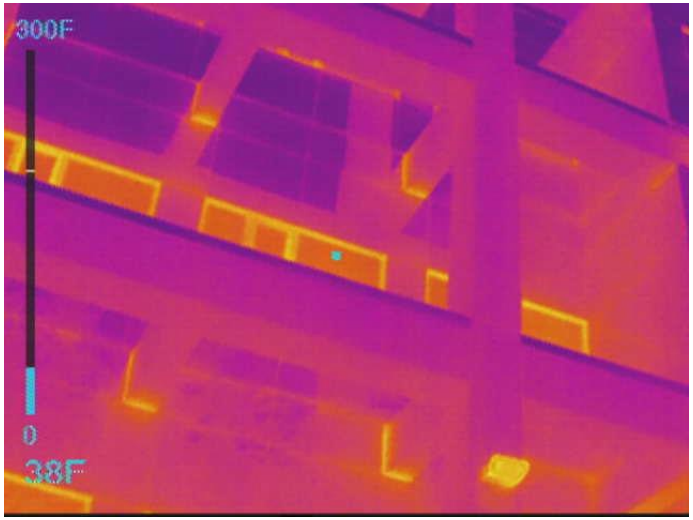


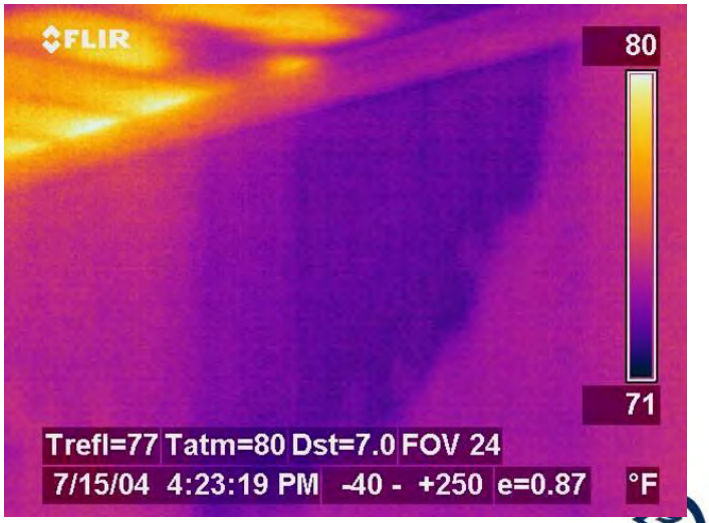


Current Applications

Finding Thermal Bridging

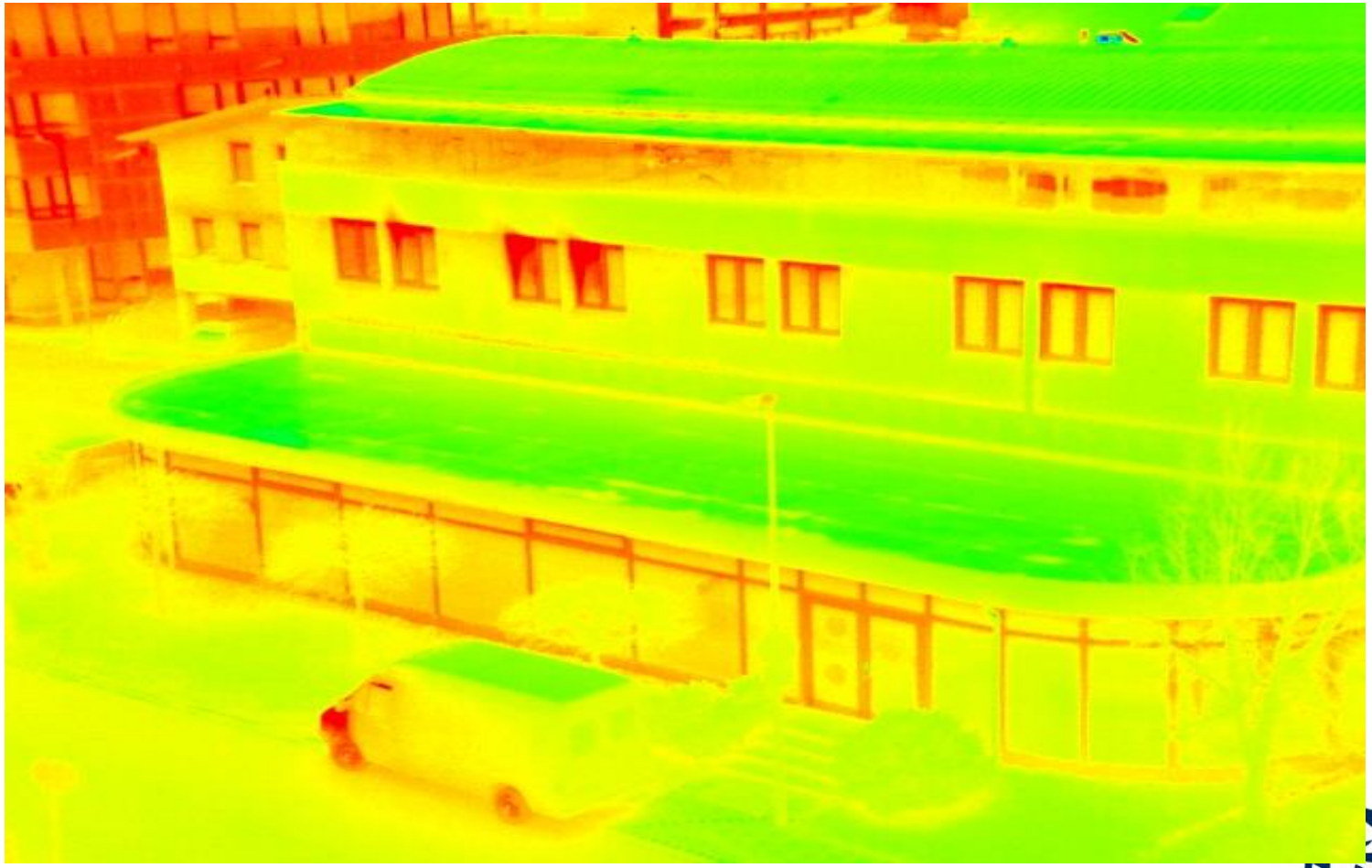
- Thermal bridges bypass insulation efforts and increase energy loss, but they are easy to find for repair with IR





Current Applications in Building Science

Detecting Envelope Leakage and Optical Gas Imaging



Current Applications

Many other applications

- All of the applications above utilize a *passive thermography* methodology
- Several other applications in Building Science alone
- Even more in other industry segments
  - Heavy Industry – Mining / Pulp + Paper / Oil + Gas
  - Tailing and Waste Water Pond Management
  - Renewable Energy Generation
  - Agriculture, Forestry, and more!

Current Applications in Building Science

In-situ U-Value of Building Elements using Thermography

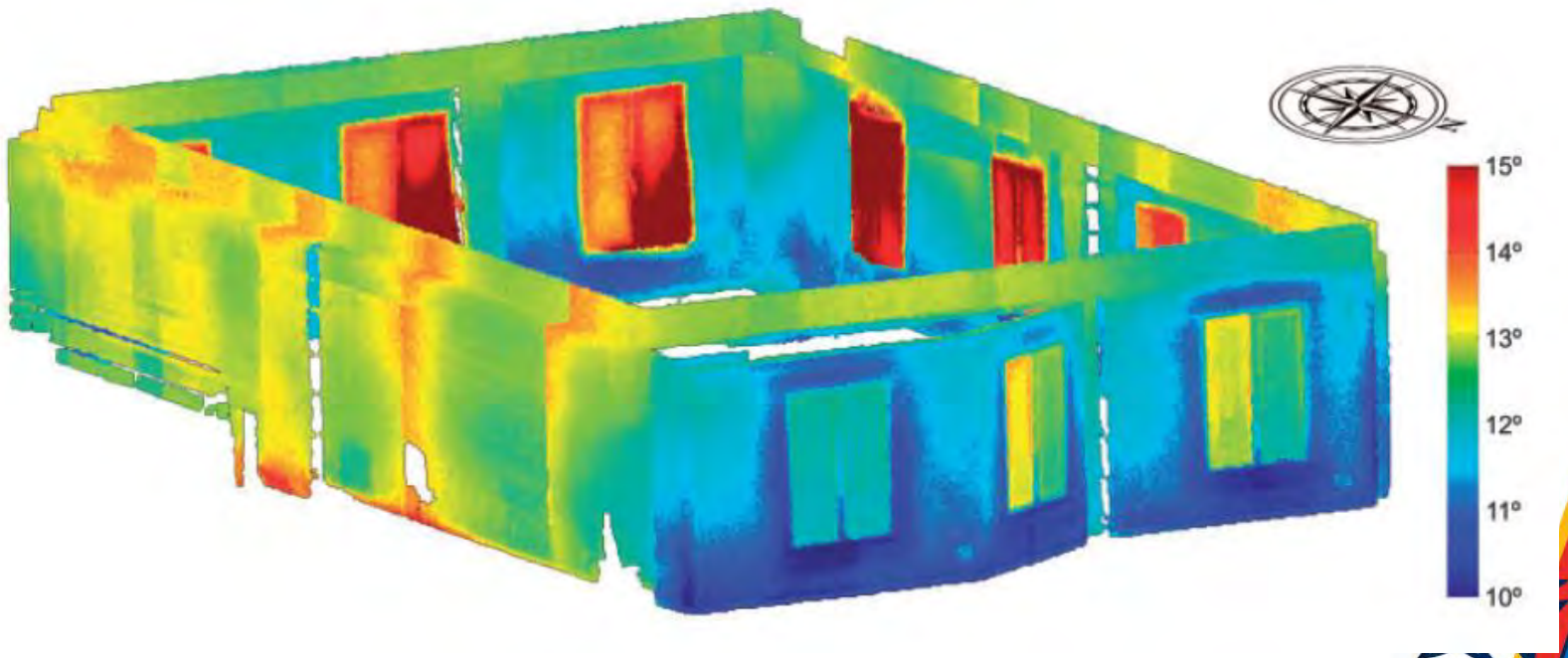
- Albatici, Tonelli and Chiogna (2015) over the past few years have devised and validated a method for in-situ U-value measurement of a building element using Thermography.

- Compliment to existing ASTM C1046/C1155 Practice using HFS

Current Applications in Building Science

Infrared Photo Mosaics and 3D Reconstructions

Applying photogrammetry to infrared thermography, Lopez-Fernandaz et al (2016) showed the ability to construct complete 3D thermographic models



Current Applications in Building Science

Energy Loss Estimation

Gonzalez et al (2013) shows a simple 3D approach to the calculation of heat loss through a façade based on surface temperature estimates of an exterior façade and idealized internal temperature

Challenges in Building Science Applications

Building Material Properties

- Emissivity (ε)
- Changes over building lifespan and with viewing angle
- Modern Building Designs involve many materials: Wood, Sheet Metal, Concrete
- Standardized In-situ Calibration Method ASTM E1933

Challenges in Building Science Applications

Building Surroundings

- Ambient Radiation Sources
- How do we model the surroundings?
- Today's IR Cameras idealize the surroundings as a uniform black body at a temperature equal to the ambient air, negating potential 'hot spots'

FLIR, Radiometry Application Note, May 2014

Challenges in Building Science Applications

Meteorological Conditions

- Rain - Affects on Building Material Properties
- Evaporation from a surface changes the apparent temperature sensed by an IR camera [Barreira 2007]
- Wind – Convective and Radiative Losses

A need exists to minimize the wind condition before, and more importantly, during exterior surveys to minimize convective losses [Albatici 2015]

Challenges in Building Science Applications

Meteorological Conditions

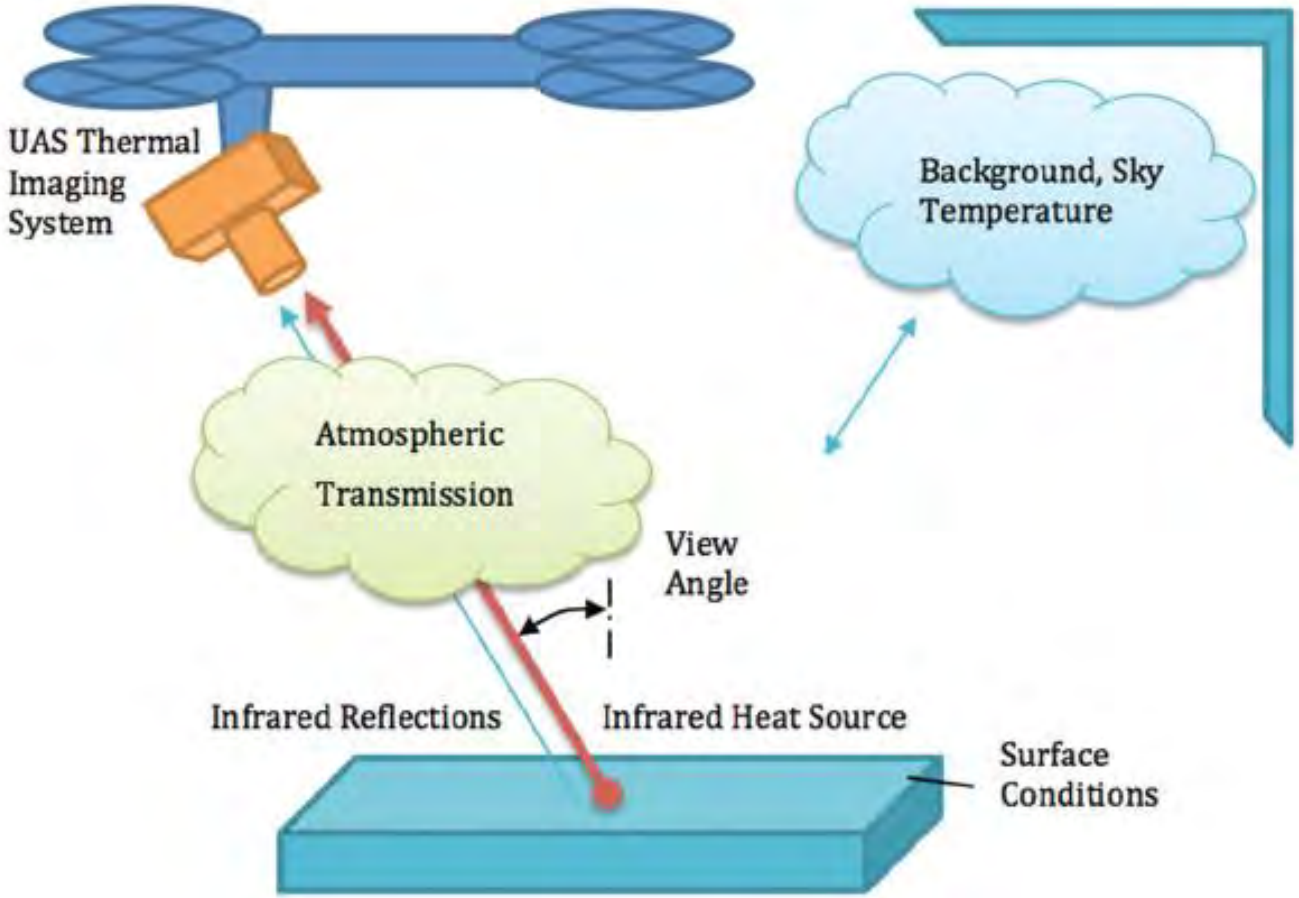
- Sun – Solar Loading and Shading
- Existing methods do not account for the thermal mass of the element [Fox 2014]
- Ambient Temperature – Affects on Building Material Properties

Small variations in emissivity in the LWIR band were observed over ambient temperature ranges [Avdelidis 2003]

Opportunities Ahead

- Infrared/Thermographic cameras continue to drop in price and size, with increasing sensitivity and resolution.
- Rapid exterior surveys for regular energy use inspections, and long exposure surveys for quantitative study and ongoing building design optimization
- **Drone surveys…**
- Create a ‘best practices’ guide for thermographic surveys of building envelope exteriors.
- Move to larger scale experiment and validate energy model to simple scale structure.

Opportunities Ahead



Source: http://www.flir.co.uk/uploadedFiles/sUAS/Products/Drone-Packages/FLIR-Aerial-Tech-Note.pdf

Thank You !!

Questions ??