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# Energy Efficient Smart Lighting Needs and Possibilities

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# Artificial lighting is everywhere

## Multiple usages...

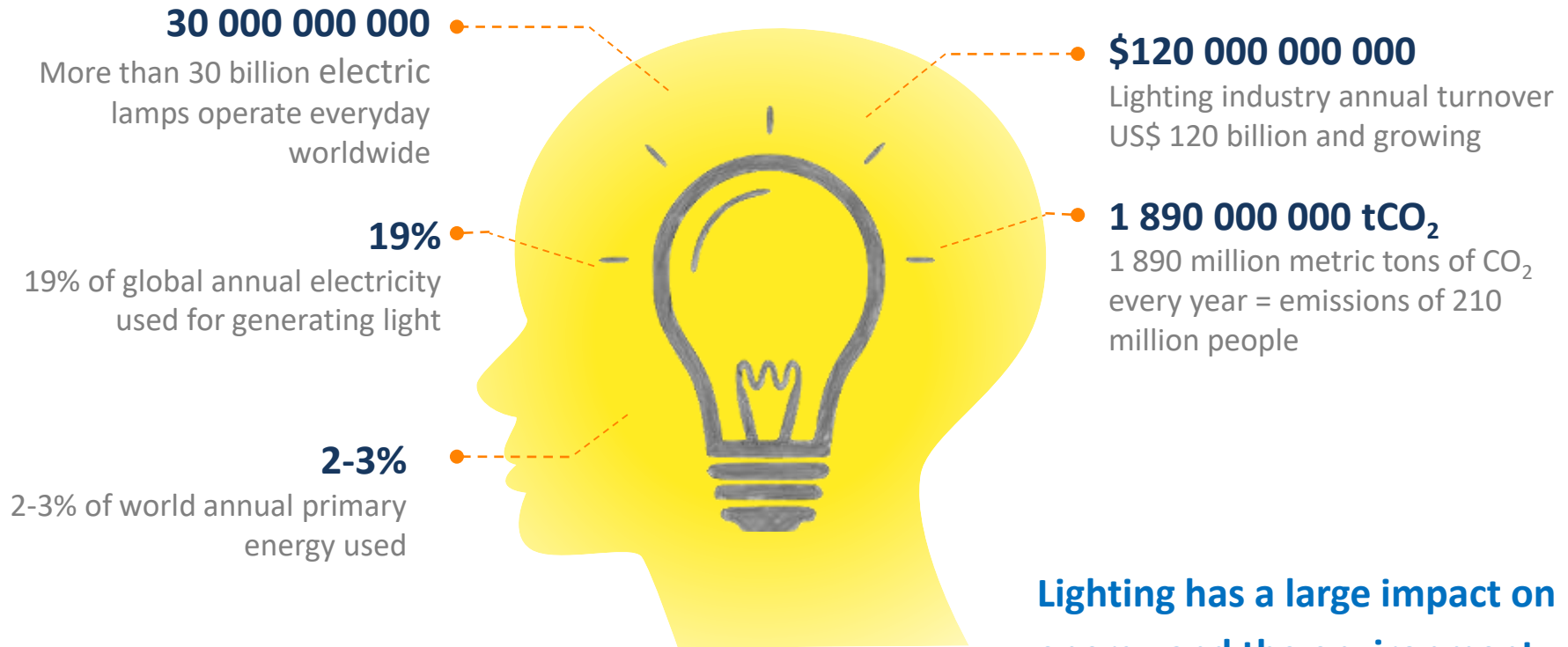Indoor Lighting

Signage & displays

Industrial Applications

Street Lighting

Vehicles & transport

Monument Lighting

# Figures in Lighting

**30 000 000 000**

More than 30 billion electric lamps operate everyday worldwide

**$120 000 000 000**

Lighting industry annual turnover US$ 120 billion and growing

**19%**

19% of global annual electricity used for generating light

**1 890 000 000 tCO$_2$**

1 890 million metric tons of CO$_2$ every year = emissions of 210 million people

**2-3%**

2-3% of world annual primary energy used

**Lighting has a large impact on energy and the environment but also on every day life.**

**Electricity consumption in lighting:**

- **Industrialized countries: 5% - 15%**
- **Developing countries: up to 80%**

# Lighting and Environment

The carbon dioxide produced by generating electricity for lighting amounts to 70% of global emissions from passenger vehicles, and is three times more than emissions from aviation. *IEA*

- Lighting energy use
- Materials used to produce lighting equipments
- Disposal of used equipments
- Wasteful escaped light at night

CO$_2$

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# Lighting Impacts on HVAC
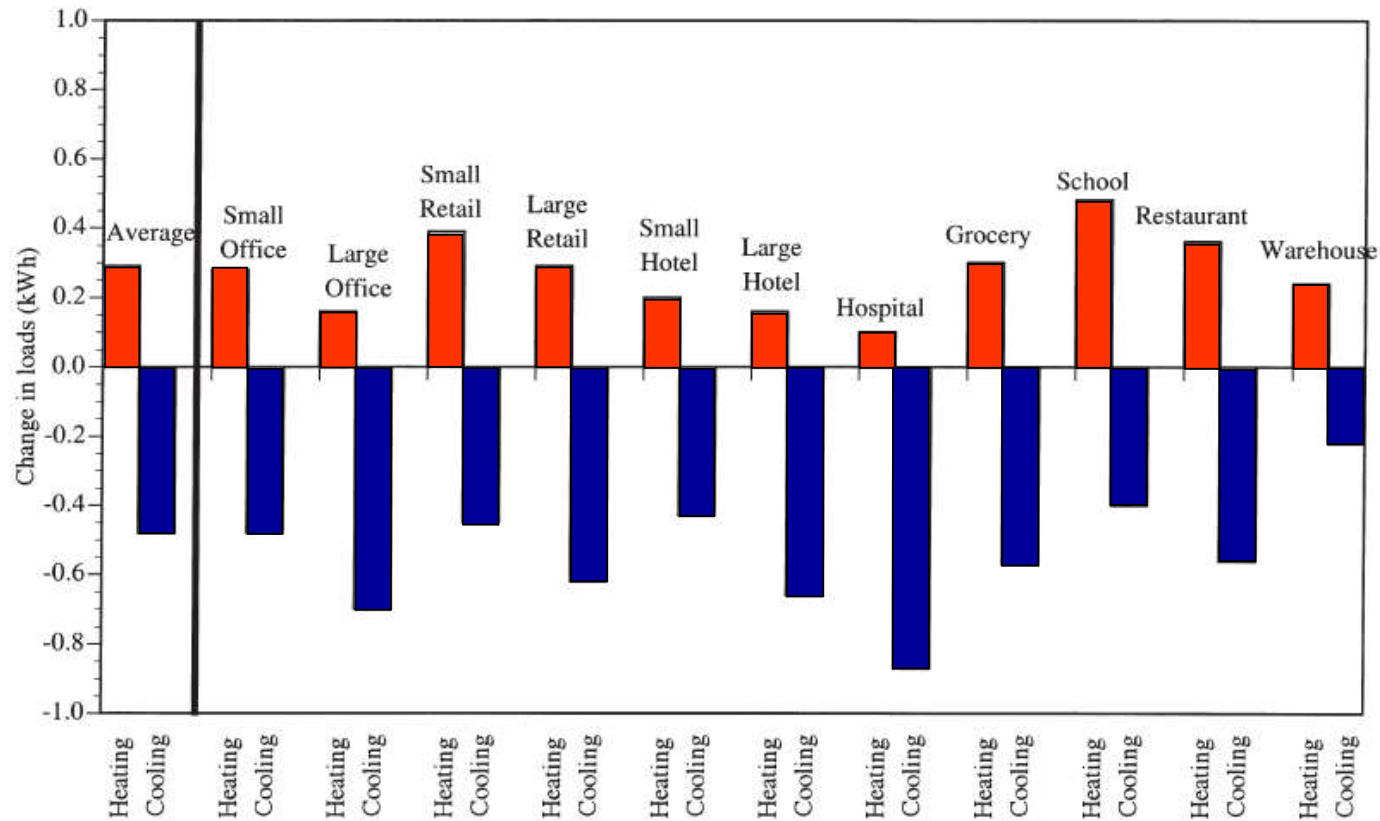


Change in heating and cooling loads caused by a 1 kWh decline in lighting loads in existing US commercial buildings

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# Lighting and Peak Electricity Load

- Peak electricity:
  - Development stage of country
  - Geographical location
  - Season of year
- Residential lighting
- Commercial lighting
- Combination of lighting peak with other end use peak

# Lighting in Developing Countries

- About 1.3 billion people - without access to electricity
- Fuel Based Lighting
- Intermittent Access of electric lighting
- Population growth rate > Electrification rate

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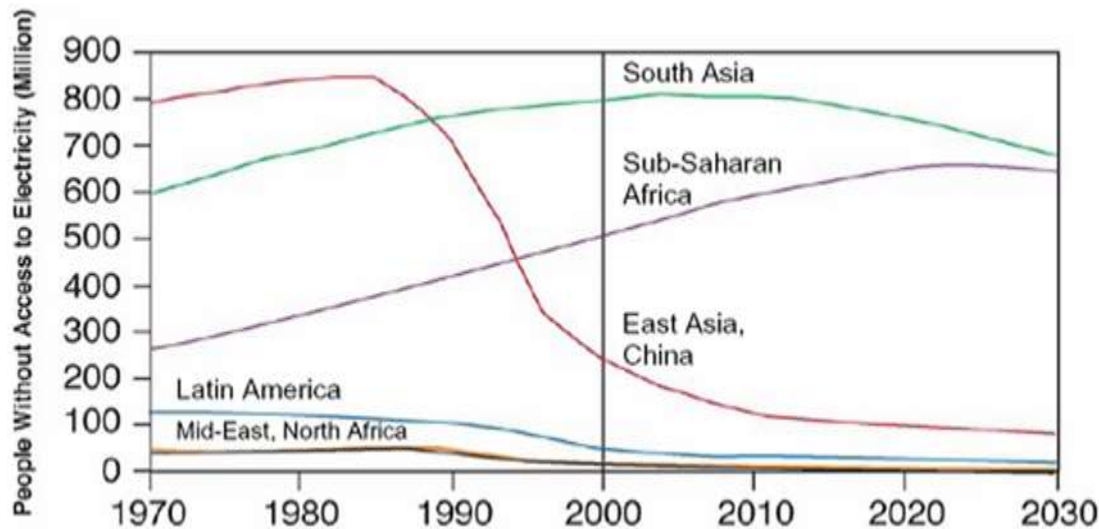
# Light sources used in households in Myanmar

- Electric lamps powered by grid electricity

- Electric lamps powered by electricity from fossil-fuel generators

- **Kerosene lamps (eg. hurricane lamp)**

- Lamps powered by dry batteries

- Lamps powered by solar cells

- Solar lanterns

- **Candles**

# Electric Lighting in Developing Countries

- Growth rate of lighting electricity use in developing countries is increasing.

  - Rural areas: New electrification where electric light does not exist at the moment

  - Urban areas: New construction, rise in illuminance level

- By 2030 developing countries are expected to account for 60% of global lighting electricity demand

- Dominated by inefficient lighting practices

# Energy Efficient Lighting

*"The cleanest and cheapest watt-hour of energy
is one that isn't consumed at all"*

- Conservation of limited  energy resources, improve energy security

- Saving of energy bills for consumers, investment costs for govt.

- Greenhouse gases, Environment

# Energy Efficient Lighting

"Increases in energy efficiency take place when either energy inputs are reduced for a given level of service or there are increased or enhanced services for a given amount of energy inputs."
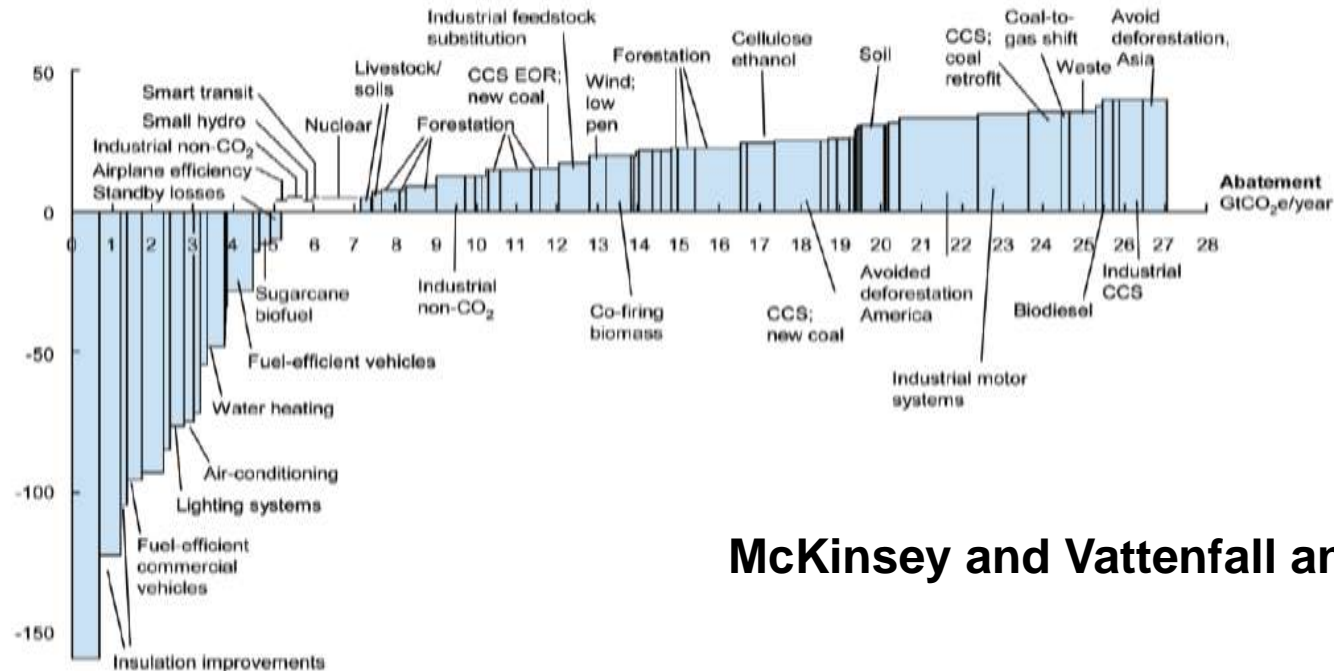
(source: eia.doe.gov)
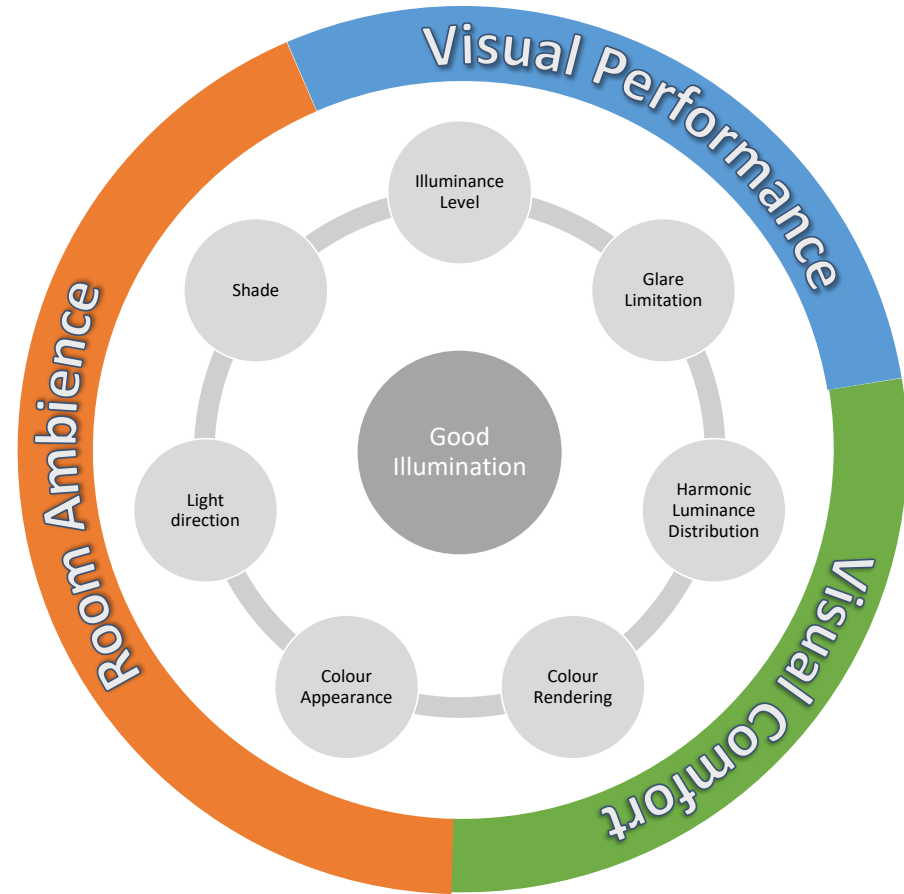


**Energy Savings** is **NOT always** **Energy Efficiency**

# Energy Efficient Lighting



THE COST CURVE PROVIDES A "MAP" OF ABATEMENT OPPORTUNITIES
Cost of abatement, 2030, €/tCO₂e*

**McKinsey and Vattenfall analysis**

Among the measures that have potential for CO2 reduction in buildings, energy efficient lighting comes first largest in developing countries, second largest in countries with their economies in transition, and third largest in the industrialized countries

# Parameters determining the energy demand for lighting
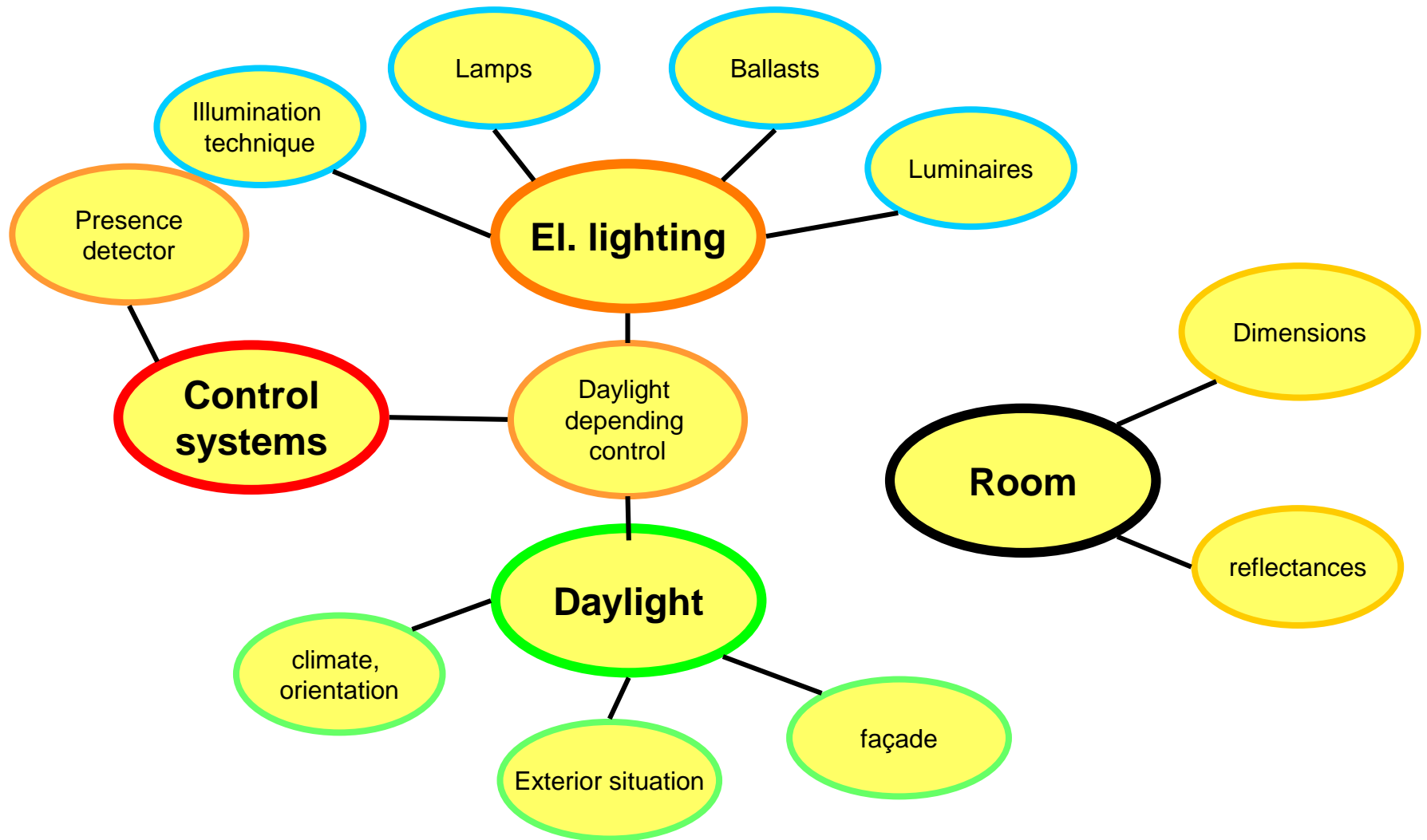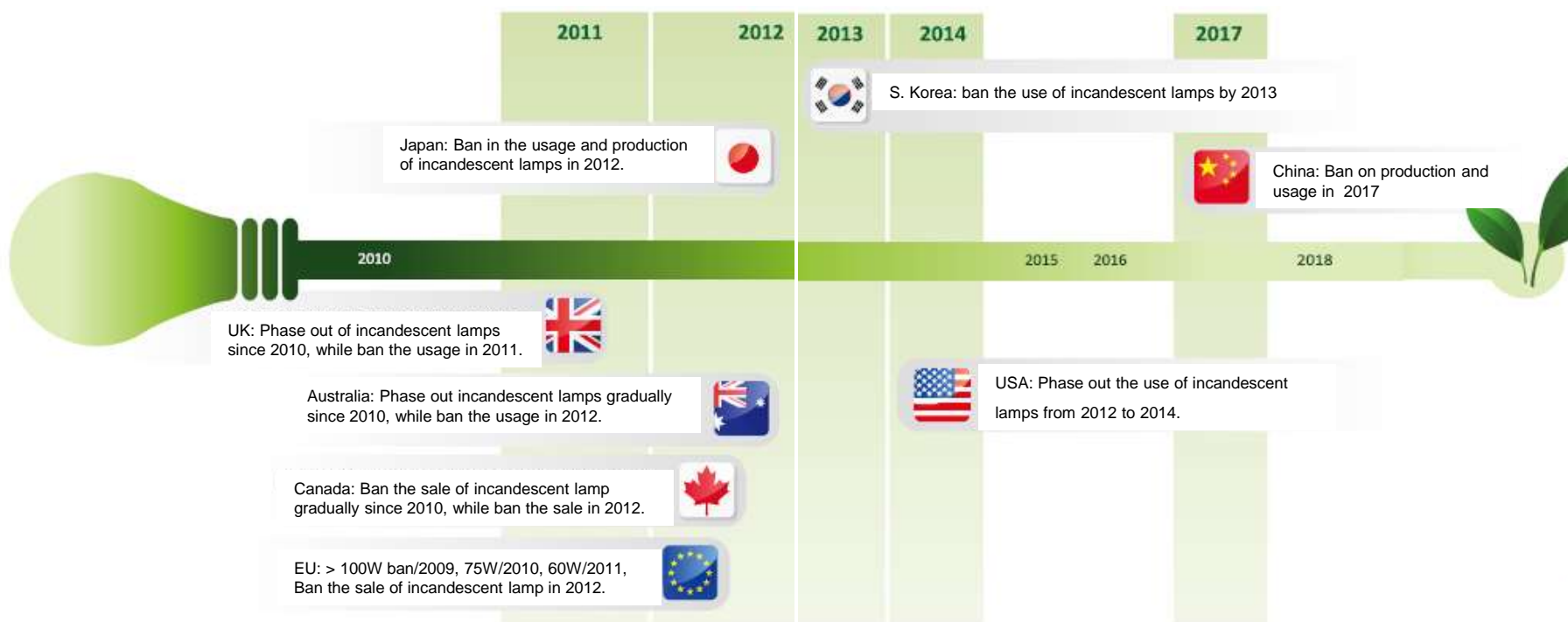
# Light Source Technology



Source: OSRAM Opto Semiconductors
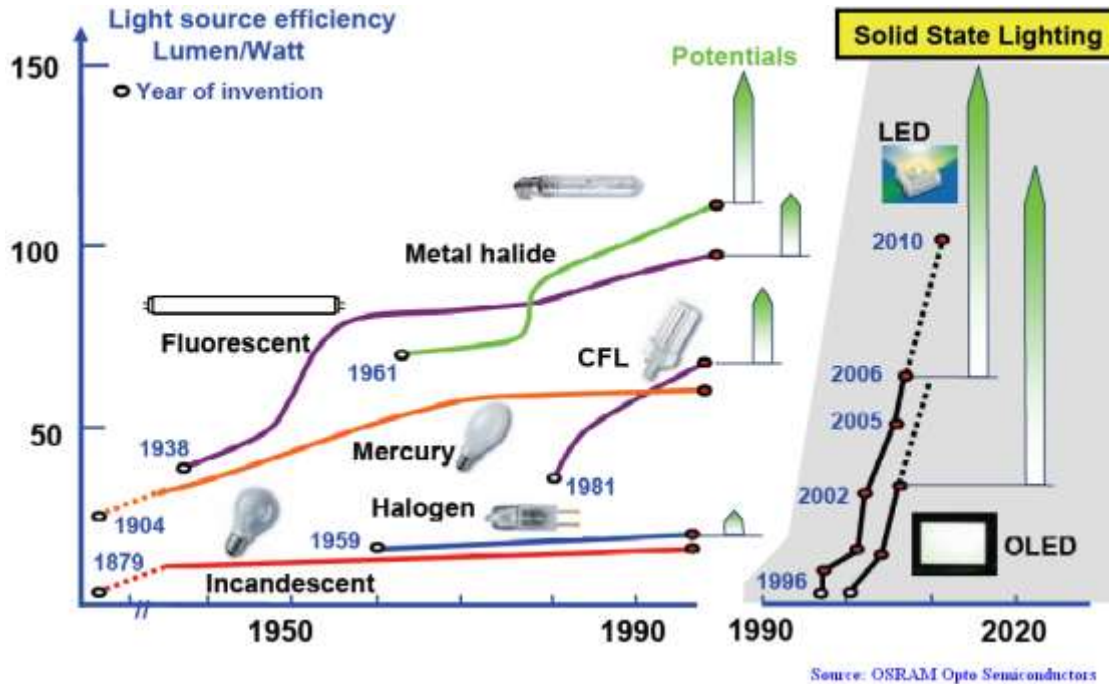
Laboratory record (CREE):

303 lm/W
(High Power)

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# Regulations on phasing out inefficient lamps

## Incandescent example



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# Quality control issues on light sources

**Light output**

- *Total flux*
- Light *distribution*

**Light Quality**

- *Color temperature & Duv*
- *Color rendering issues*
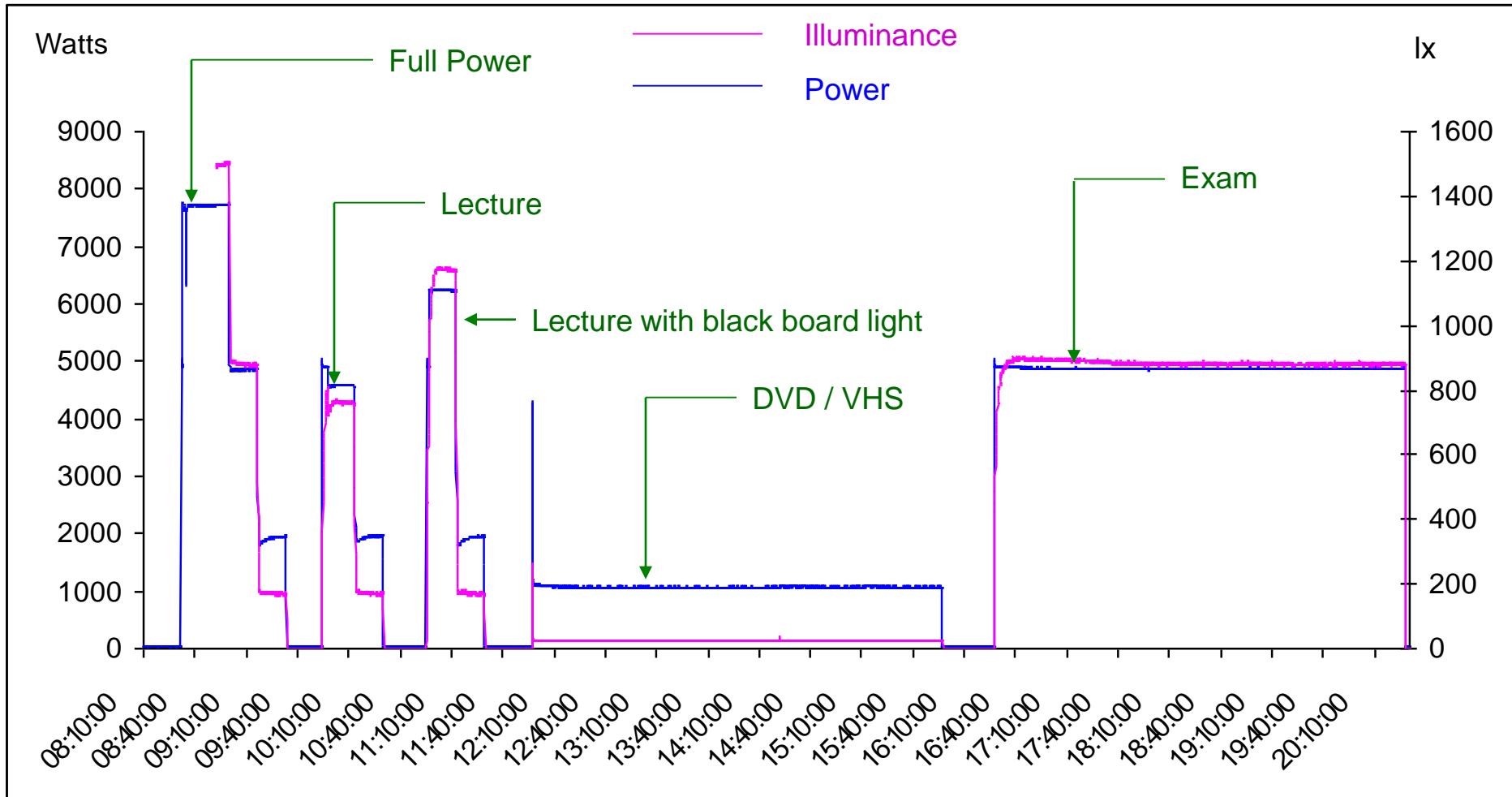- *Color Uniformity & maintenance*
- *Life time*

**Energy related issues**

- *Luminous efficacy*
- *Lumen maintenance*
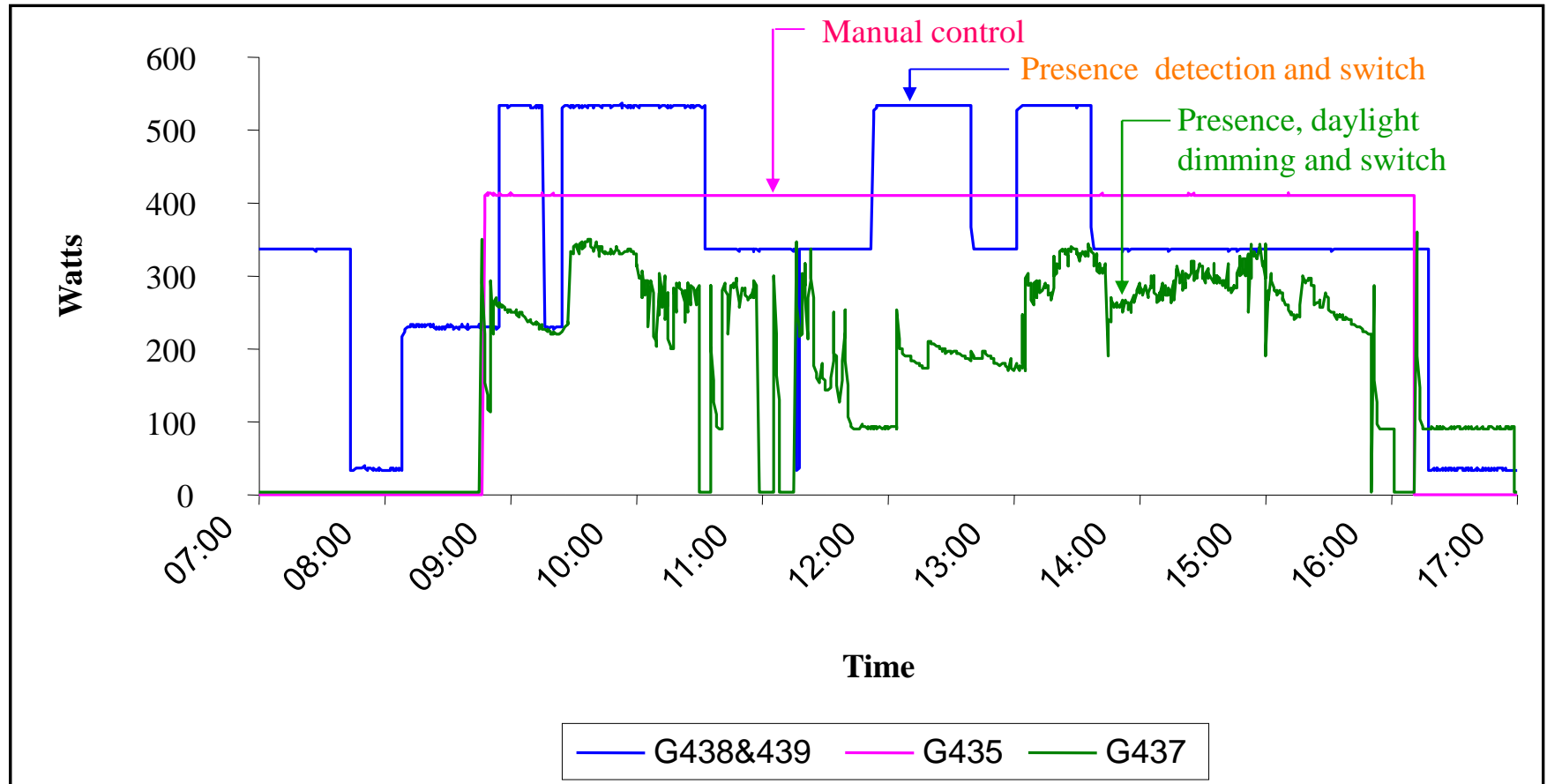- *Power factor*
- *Harmonic Distortion*

## Awareness + Regulation

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# Lighting Control

# Lighting Control

# Smart road lighting control systems provide light …

AT RIGHT TIME

AT RIGHT PLACE

IN RIGHT DIRECTION

AT RIGHT AMOUNT

# Excessive and Inappropriate Light



- Temporal disturbances of sleep
- Circadian disruption
- Hormonal perturbations



- Discomfort
- Visual fatigue
- Temporal visual acuity losses
- Lower visual performance



40% Birds
10% glare
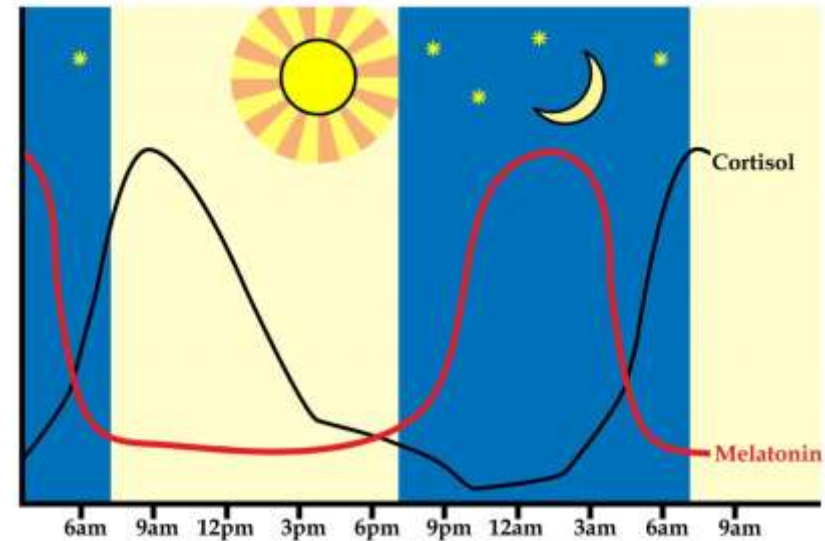50% useful

# Rethinking Light Beyond Vision

Light quantity and colour change during daytime



The concentration of melatonin and cortisol depend on the variation of light

A lot of light
High colour temperature
Uniform light

Less light
Low colour temperature
Non-uniform distribution



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# Lighting should be designed carefully

## Man masters light....

.....too little light in daytime

.....too much light by night

### consequences

- circadian misentrainment
  problems with body clock, similar to jet-lag
- problems with sleep & alertness
- compromised mood, functioning, well-being and health....

## BETTER LIGHT HYGIENE,
## the right light at the right time & place

# Example: Domestic Lighting

- In the evening, blue-enriched light
  - Alerts
  - Compromises sleep: longer sleep-onset, less deep sleep and sleep quality
- In the (early) morning, dawn simulation (bedroom):
  - beneficial effects on sleep inertia & daytime well-being and cognitive performance



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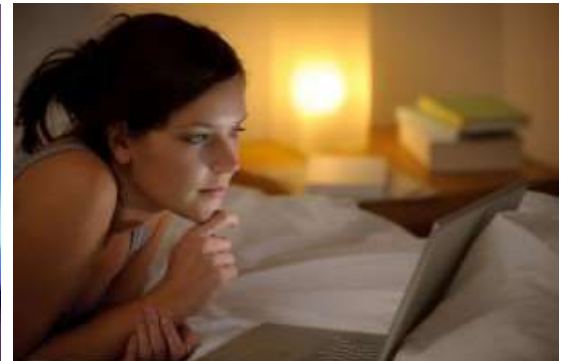
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- Design opportunities
  - Apply light in the early morning and late evening (best sensitivity)
  - During daytime use cooler color temperatures (i.e., blue-rich light) in rooms with little/no natural light entrance
  - Intelligent, dynamic light solutions: simulate dawn and dusk, automated photoperiod of about 12 hours of sufficient brightness and 12 hours of reduced light (relatively dim, blue-deprived light or dark)

# Other applications: Plant lighting
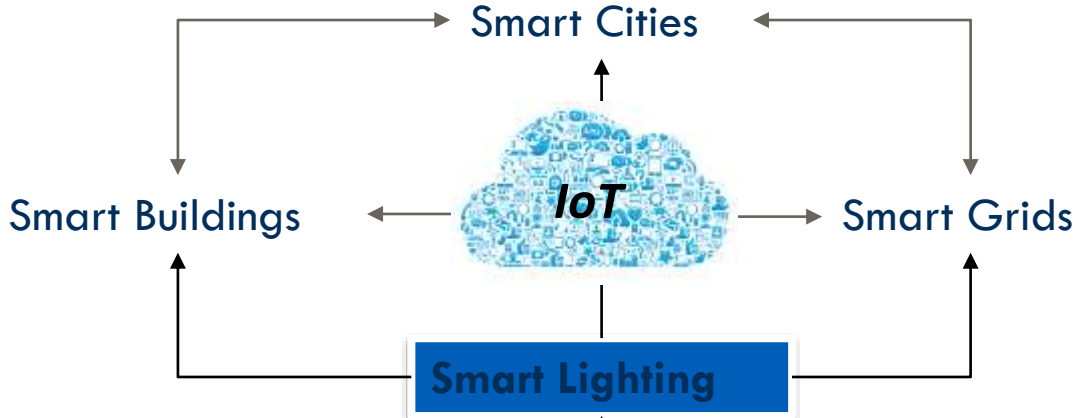
**Horticultural lighting main goals**

- Efficient use of energy

- Growth control and optimization (e.g. morphogenesis, germination, flowering and nutritional value)

- Increase crop productivity

- Implement versatile lighting tailored for specific crops



LED 1     HPS

# Environment friendly Fishing ?

# What's next ?



Smart Cities

IoT

Smart Buildings → ← Smart Grids

**Smart Lighting**

- Light as a Service
- Data as product
- VLC/LiFi

Interacting

Human Centric Lighting

Connected Lighting

Energy Efficient Lighting

Human Factors

Light-up

Technology

Sensing

Connecting

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