Seminar 2 - Delivering Positive Outcomes

Steven Beletich

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Who I am

- Steven Beletich
  - Phase out of incandescent lamps (Australia, China, Middle East)
  - NSW ESS architect (+VEET)
  - CBD tenancy lighting methodology
  - etc.

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Homework Solution from Last Session

- Write your answers on a piece of paper now
- Bring them to the front

Learning Objectives of this Session

- By the end of this session, you should:
  - Have a basic understanding of the objectives of lighting design
  - Have an understanding of the economics of lighting efficiency upgrades
  - Understand what constitutes an effective business case
  - Be engaged !!
  - Be empowered !!

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Contents

- Recap of session 1
- Overview of lighting design
- Case study
- Building a successful business case
- A few words about LED lighting
- Context = primarily office space

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Recap of Session 1

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Terminology

Luminaire	Entire light fitting
Lamp	
Ballast / Transformer	
Power (Watts)	Energy per second

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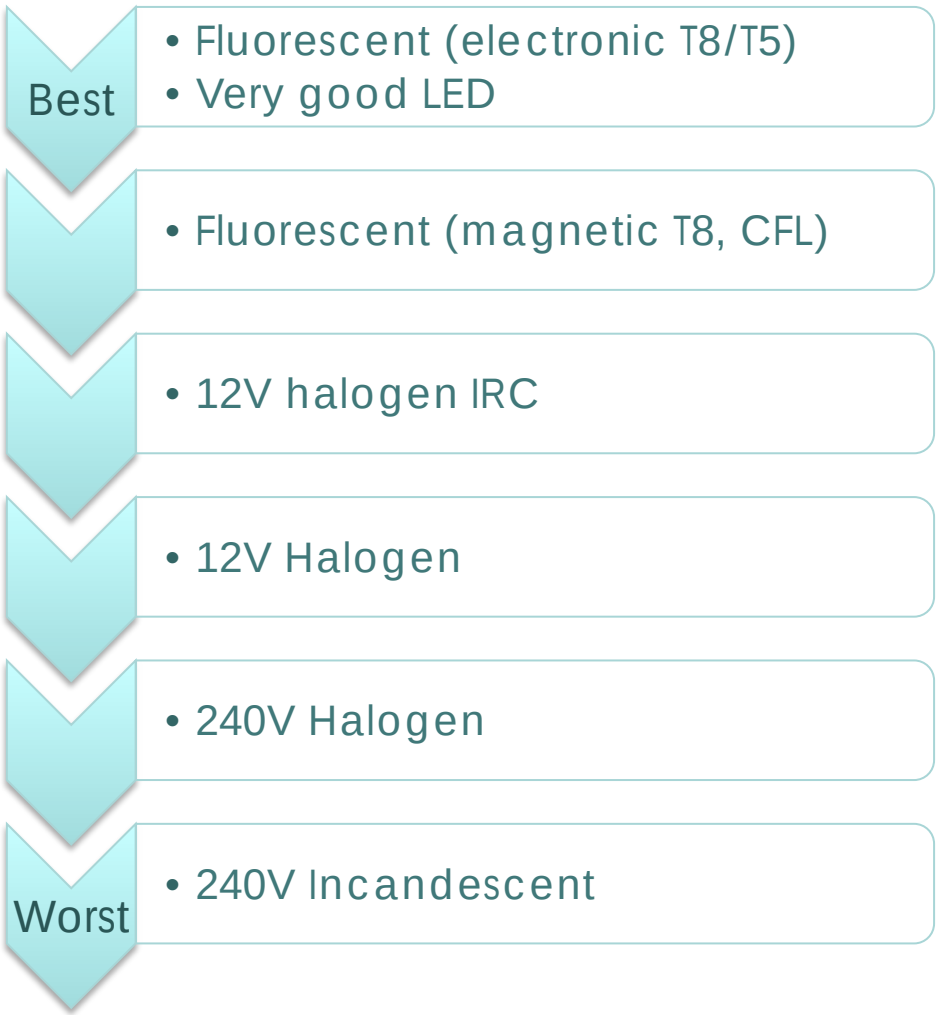
Lamp Types (Ranked by Efficiency)



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Ballast Technology

- Magnetic
  - Typically have starter
  - Lights typically flicker on startup
  - Ballast losses ~8W per lamp
- Electronic
  - No starter
  - No flicker – fast ramp up
  - Losses ~1W per lamp
  - Will actually drive the lamp to produce ~10% more light

Lighting Power Density

- Lighting power density =
  - Total luminaire power ÷ floor area

- Best practice is <7 Watts/m^2 (office)
- Any lower may cause light levels to suffer
- Does not take into account control systems (i.e. operating hours)

Solution to Interactive Exercise from Last Session

Assume floor area of 1500 square metres, fitted with:

- 275 fluorescent luminaries (twin 36W lamp and magnetic ballast)
- 50 halogen downlights (50W lamp and magnetic transformer)

1. Existing Lighting			
Total floor area (m^2)	G14	Given	1,500
a) Fluorescent Luminaires			
Number of fluorescent luminaires	G16	Given	275
Lamp power per lamp (Watts)	G17	Given	36
Number of lamps per luminaire	G18	Given	2
Ballast technology	G19	Given	Magnetic
Ballast losses (Watts)	G20	Magnetic=8, Electronic=1	8
Total power per luminaire (Watts)	G21	(G17+G20) * G18	88
Total power fluorescent luminiares (Watts)	G22	G21*G16	24,200
b) Halogen Downlights			
Number of halogen downlights	G25	Given	50
Lamp power per lamp (Watts)	G26	Given	50
Number of lamps per luminaire	G27	Given	1
Transformer technology	G28	Given	Magnetic
Transformer losses (Watts)	G29	Magnetic=12, Electronic=3	12
Total power per luminaire (Watts)	G30	(G26+G29) * G27	62
Total power for all halogen luminiares (Watts)	G31	G30*G25	3,100
Total lighting power for this space (Watts)	G33	G22 + G31	**27,300**
Energy cost p.a.	G34	G10*G11*G33/1000	**$18,018**
Lighting power density for this space (Watts/m^2)	G35	G33/G14	**18.2**

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Solution to Homework from Last Session

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Nabers rating calculator results

Premise type	Office				
Premise scope	Tenancy				
Building details	Homework, Solution,				
State and postcode	MELBOURNE 3000		**Hours of occupancy**	58	hrs/week
Area of office	1500	m^2	**Number of computers**	105	

Energy Star rating (Calculator version number: 10.0)

Average performance

Your office has average greenhouse performance.There is scope for significant improvement, and positive changes will have a noticeable impact on your performance.

Results for the 12 months rating period	**Nabers energy rating**		**Nabers energy rating without GreenPower**	
Star rating	2.5 stars		2.5 stars	
GreenPower included	0	%	0	%
Energy intensity	436	MJ/m^2	436	MJ/m^2
Total greenhouse gas emissions (Full fuel cycle - scope 1 & 2)	220099	kg CO_2-e p.a.	220099	kg CO_2-e p.a.
Total greenhouse gas emissions (Full fuel cycle - scope 1,2 & 3)	245565	kg CO_2-e p.a.	245565	kg CO_2-e p.a.
Greenhouse gas intensity (Scope 1 & 2)	147	kg CO_2-e/m^2p.a	147	kg CO_2-e/m^2p.a
Greenhouse gas intensity (Full fuel cycle - scope 1,2 & 3)	164	kg CO_2-e/m^2p.a	164	kg CO_2-e/m^2p.a
Benchmarking factor (previously known as Normalised Emissions)	119		119	

Your energy data source input

Fuel type	**Quantity**	**Unit**	**Emissions (Full fuel cycled - Scope 1,2 & 3)**		**GreenPower**	
Electricity	181900.0	kWh	245565	kg CO_2e p.a.	0	%

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Overview of Lighting Design

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What is Lighting Design?

- Lighting is not rocket sience
- But is more difficult than some might think
- Much subjectivity
- Objectives of Lighting Design
  - Safety
  - Productivity
  - User enjoyment
  - Energy efficiency
  - Longevity

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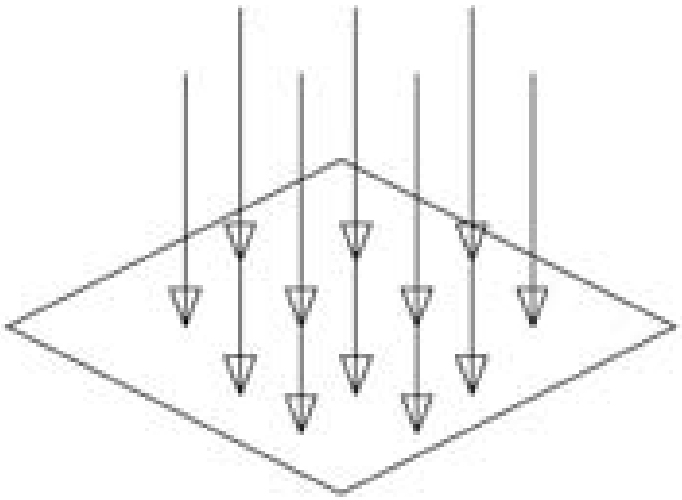
Lighting Design Standards

- Lighting should meet AS/NZS 1680
  - Av maintained lux
  - Uniformity of lux
  - Cut-off angle for luminaires (glare)
  - Lamp colour temperature
  - Lamp colour rendering
  - Glare index

Lux

- Lux = units of “illuminance”
- = total light output ÷ floor area
- Units = lumens/m^2 or “Lux”



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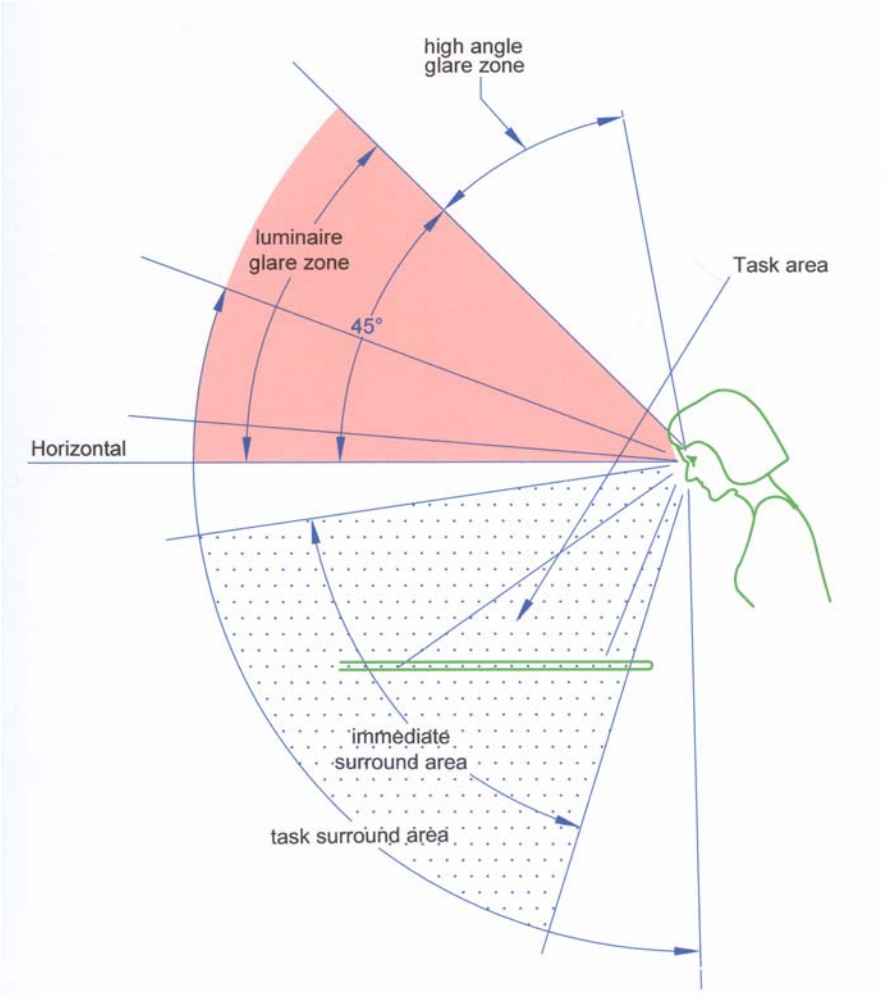
Average Maintained Lux

- Lighting designer must compensate for “lumen depreciation” of lights
  - Lamp depreciation
  - Accumulation of dust & dirt
- Build in a “maintenance factor” to account for this loss of light
  - Typically around 80%
    - (well maintained fluorescent)
  - Therefore must over-design by 25%

Uniformity of Lux

- The ratio of the minimum lux to the average lux
- Light levels should be relatively uniform throughout the space
- However work surfaces may be “task lit”

Cut Off Angle for Luminaires



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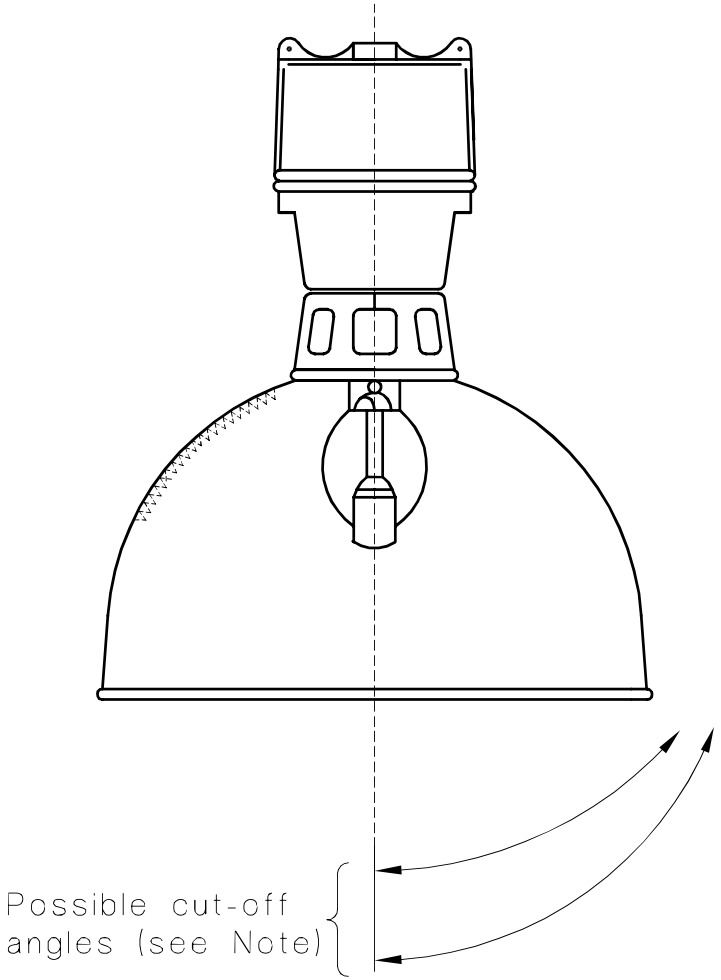
Cut Off Angle for Luminaires (cont)



(a) Clear lamp, exposed arc tube

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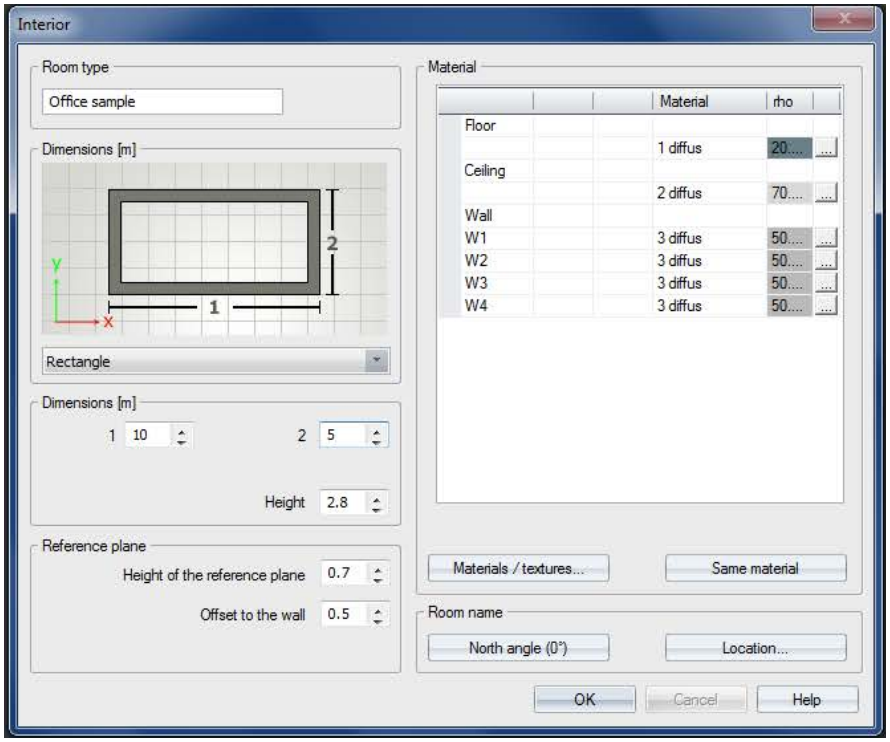
Lamp Colour Temperaure

- Warm white = 2700-3000K
  - Good for homes in cool climates
- Cool white = 4000K
  - Good for offices
- Daylight = 5000+K
  - Bluish light

Lamp Colour Rendering

- Colour Rendering Index
  - How well light can “render” colours
- Scale of 1-100
- Want CRI of at least 80 for homes and offices

Lighting Design Software



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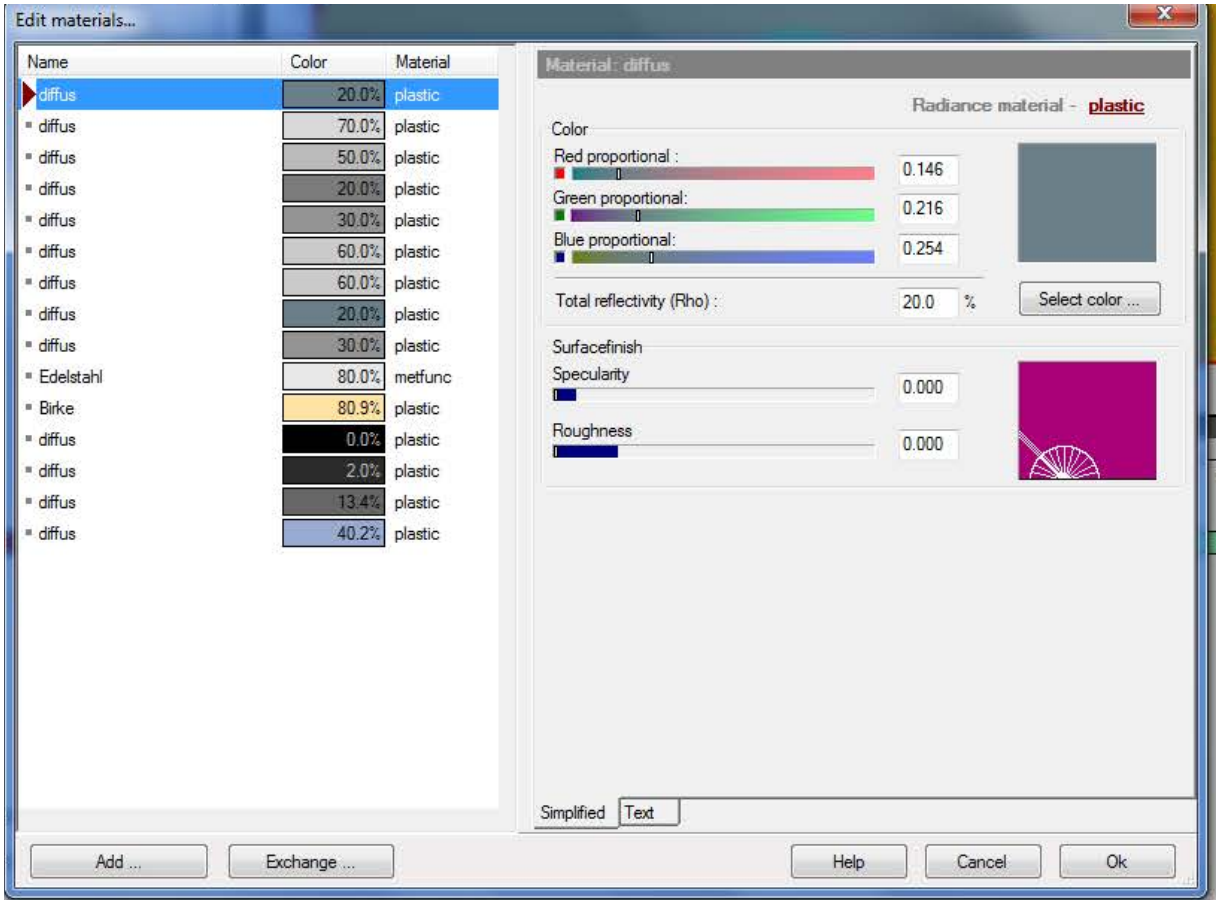

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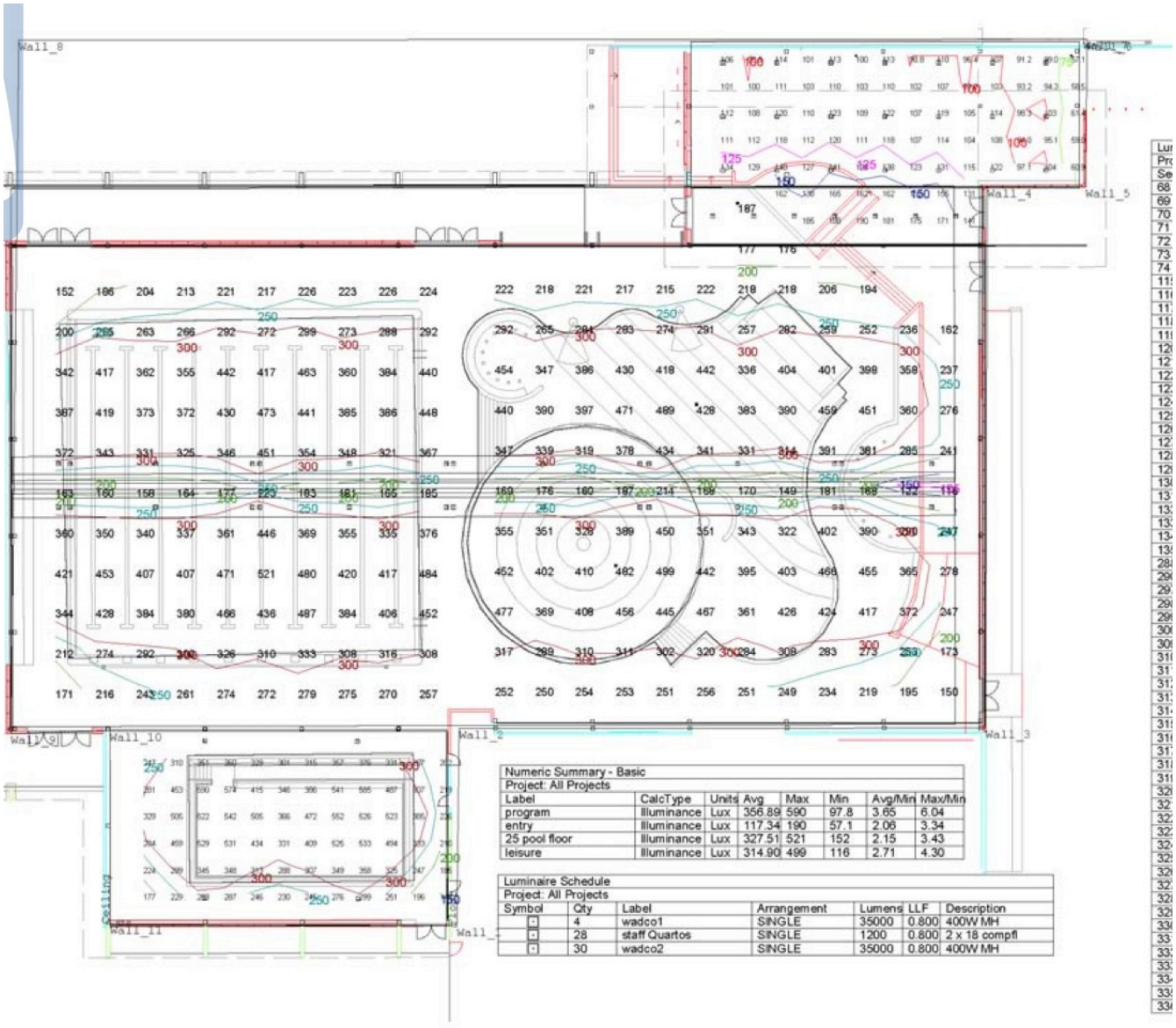

Numeric Summary - Basic							
Project: All Projects							
Label	CalcType	Units	Avg	Max	Min	Avg/Min	Max/Min
program	Illuminance	Lux	356.89	590	97.8	3.65	6.04
entry	Illuminance	Lux	117.34	190	57.1	2.06	3.34
25 pool floor	Illuminance	Lux	327.51	521	152	2.15	3.43
leisure	Illuminance	Lux	314.90	499	116	2.71	4.30

Luminaire Schedule						
Project: All Projects						
Symbol	Qty	Label	Arrangement	Lumens	LLF	Description
	4	wadco1	SINGLE	35000	0.800	400W MH
	28	staff Quartos	SINGLE	1200	0.800	2 x 18 compfl
	30	wadco2	SINGLE	35000	0.800	400W MH

General

Calculation algorithm used	Average indirect fraction
Height of evaluation surface	0.70 m
Height of luminaire plane	2.30 m
Maintenance factor	0.80
Total luminous flux of all lamps	34400 lm
Total power	418.4 W
Total power per area (50.00 m²)	8.37 W/m² (2.27 W/m²/100lx)

Illuminance

Average illuminance	Eav	369 lx
Minimum illuminance	Emin	300 lx
Maximum illuminance	Emax	448 lx
Uniformity g1	Emin/Em	1:1.23 (0.81)
Uniformity g2	Emin/Emax	1:1.49 (0.67)

Type No.\Make

1 8

Thorn

Order No.	: 96 202 394
Luminaire name	: DIFFUSALUX II G 1X49W HF PS OP [STD]
Equipment	: 1 x T16 49 W / 4300 lm

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Examples of Software Types

- Various free software packages
  - Relux
  - Dialux
  - OptiWin
  - Radiance
- Sophisticated packages
  - AGI32
  - Elum Tools
  - Optis
  - Visual 2.6

Where to Turn for Help

- Use an accredited lighting designer
- E.g. member of IESANZ
- Reputable equipment suppliers

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Case Study
Typical Office

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Existing Lighting

- Floor area 1500 m^2
- Existing lighting
- 275 fluorescent luminaries
  - Twin 36W lamp + magnetic ballast
- 50 halogen downlights
  - 50W lamp and magnetic transformer

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Existing Lighting (cont)

Data	Cell Ref	Formula	Answer
Energy cost per kWh	G10	Given	$0.22
Lighting hours per annum	G11	Given	3,000
1. Existing Lighting			
Total floor area (m^2)	G14	Given	1,500
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New Lighting

- Upgrade fluorescent luminaires to
  - High performance luminaire
  - Single 28W T5 lamp
  - T5 electronic ballast
  - 29 Watts total luminaire power
  - Suitable for majority of offices
  - 88W ➔ 29W
- Upgrade halogen downlights to LED
  - 62W ➔ 9W

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New Lighting (cont)

2. New Lighting

a) Upgrade fluorescent luminaires to high performance, single 28W lamp, T5 electronic

Total power per luminaire (Watts)	G39	Given	29
Total power for all luminaires of this type (Watts)	G40	G39*G16	7,975
b) Upgrade halogen downlights to 9W LED			
Total power per luminaire (Watts)	G42	Given	9
Total power for all luminaires of this type (Watts)	G43	G42*G25	450
New total lighting power for this space (Watts)	G44	G40+G43	**8,425**
Energy cost p.a.	G45	G10*G11*G33/1000	**$5,561**
New lighting power density for this space (Watts/m^2)	G46	G44/G14	**5.6**

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Business Case

3. Simple Business Case

Total cost to install each new fluorescent luminaire	G49	Given	$125
Total cost to install each new downlight	G50	Given	$40
Total Capex	G51	G49*G16+G50*G25	**$36,375**
Energy Savings p.a.	G52	G34-G45	**$12,458**
Simple Payback (years)	G53	G51/G52	**2.9**

4. Business Case with VEECs

Energy cost escalation p.a. (nominal)	G55	Given	0.0%
VEEC net value (per MWh certificate)	G56	Given	$20
VEECs generated (10 years)		(G33-G44)*G11*10/1000000	566
VEET net value (total)	G58	G57*G56	$11,325
Capex net of VEET savings	G59	G51-G58	**$25,050**
Simple Payback (years)	G60	G59/G52	**2.0**

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Building a Successful Business Case

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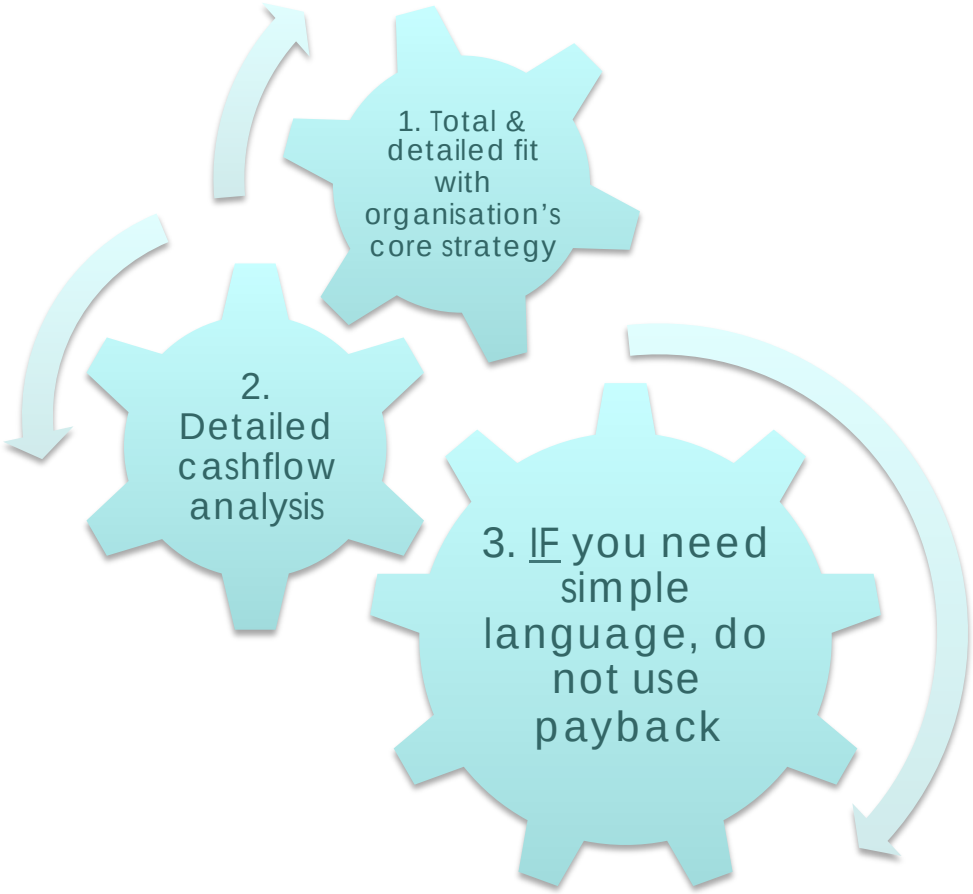
3 Steps to a Turn Business Case into a Bankable Project



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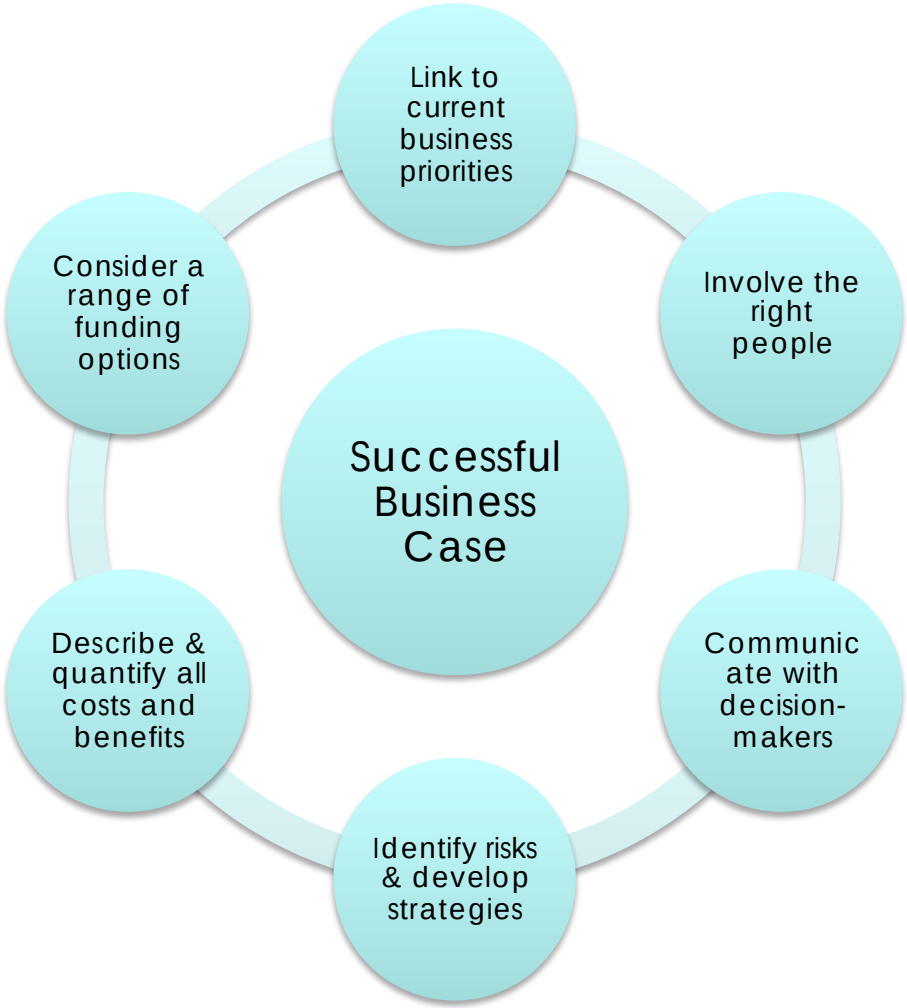
1. Business Case = Detailed Fit with Organisation's Core Strategy



Source: The Business Case and Beyond, eex.gov.au (DRET), January 2012

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2. Detailed Cashflow Analysis

Inputs	
Project duration	10
Discount rate	5.0%
Energy price escalation p.a.	0.0%
CapEx	-$36,375
Annual energy savings (without escalation)	$12,458
Outputs (Nominal)	
Simple Payback (no energy price escalation)	2.9
Return on investment	2.4
"Times Money"	3.4
Outputs (Discounted)	
IRR	32%
NPV	$60,000
Benefit : cost ratio	164%

Year	0	1	2	3	4	5	6	7	8	9	10
Nominal Values											
CapEx	-$36,375										
Energy savings		$12,458	$12,458	$12,458	$12,458	$12,458	$12,458	$12,458	$12,458	$12,458	$12,458
Net cashlow	-$36,375	$12,458	$12,458	$12,458	$12,458	$12,458	$12,458	$12,458	$12,458	$12,458	$12,458
Cumulative cashflow	-$36,375	-$23,918	-$11,460	$998	$13,455	$25,913	$38,370	$50,828	$63,285	$75,743	$88,200
Disccounted Values											
Net cashlow	-$36,375	$11,864	$11,299	$10,761	$10,249	$9,761	$9,296	$8,853	$8,432	$8,030	$7,648

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3. IF You Need Simple Language

- e.g. for non-financial person
- Do not use payback
- Use either
  - IRR = “Interest Rate”
    - Comes from cashflow analysis
  - “Times Money”
    - How many times do you get your money back?

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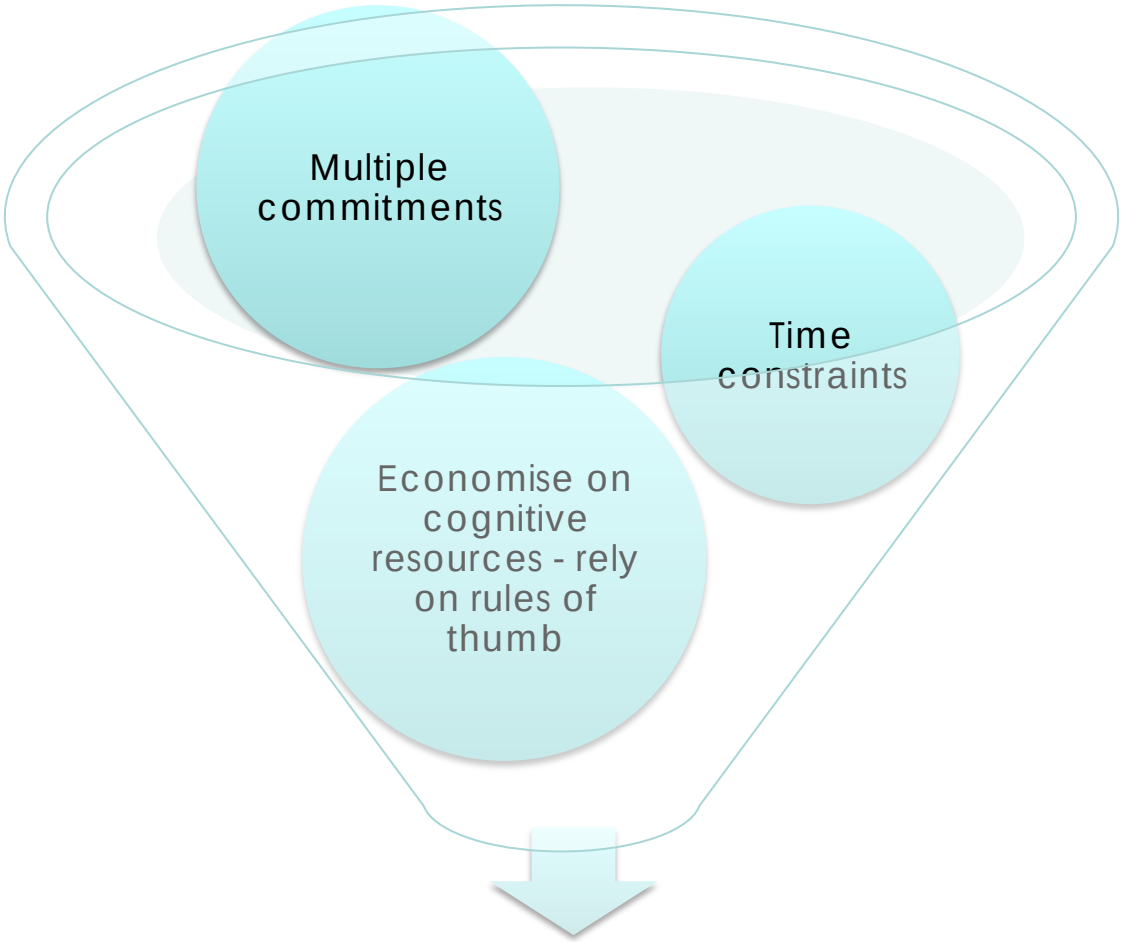
Why do We Use Payback?

- Very commonly used
- Simple to calculate:
  - CapEx ÷ annual benefit
  - Energy efficiency industry is technical, not financial
  - Appeals to other non-financial persons, e.g. engineers & building managers

Theory of “Bounded Rationality”



Source: Barriers to industrial energy efficiency - a literature review, United Nations Industrial Development Organization, Vienna 2011

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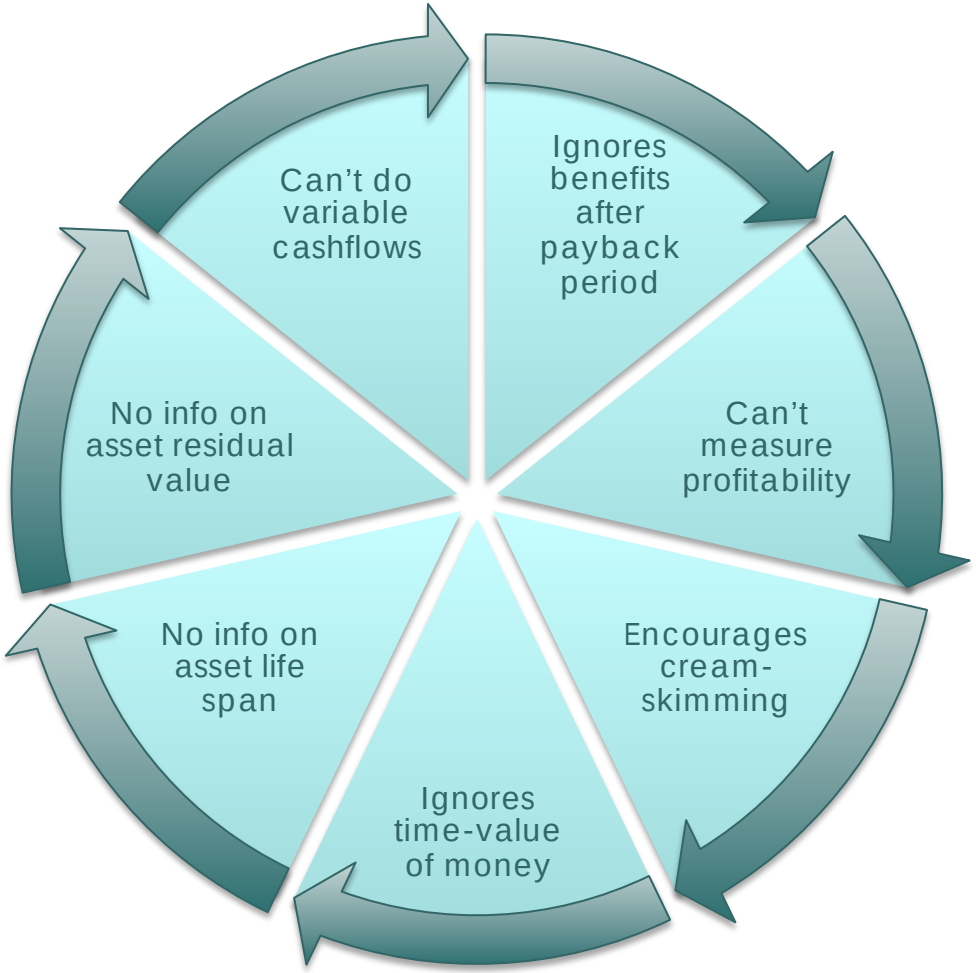
Problem with Payback #1: Lack of Detail



Source: Commonwealth of Massachusetts Executive Office of Energy and Environmental Affairs, Department Of Energy Resources, Energy Management Services Guide V. 2.1: Providing Energy Savings Through Energy Performance Contracting

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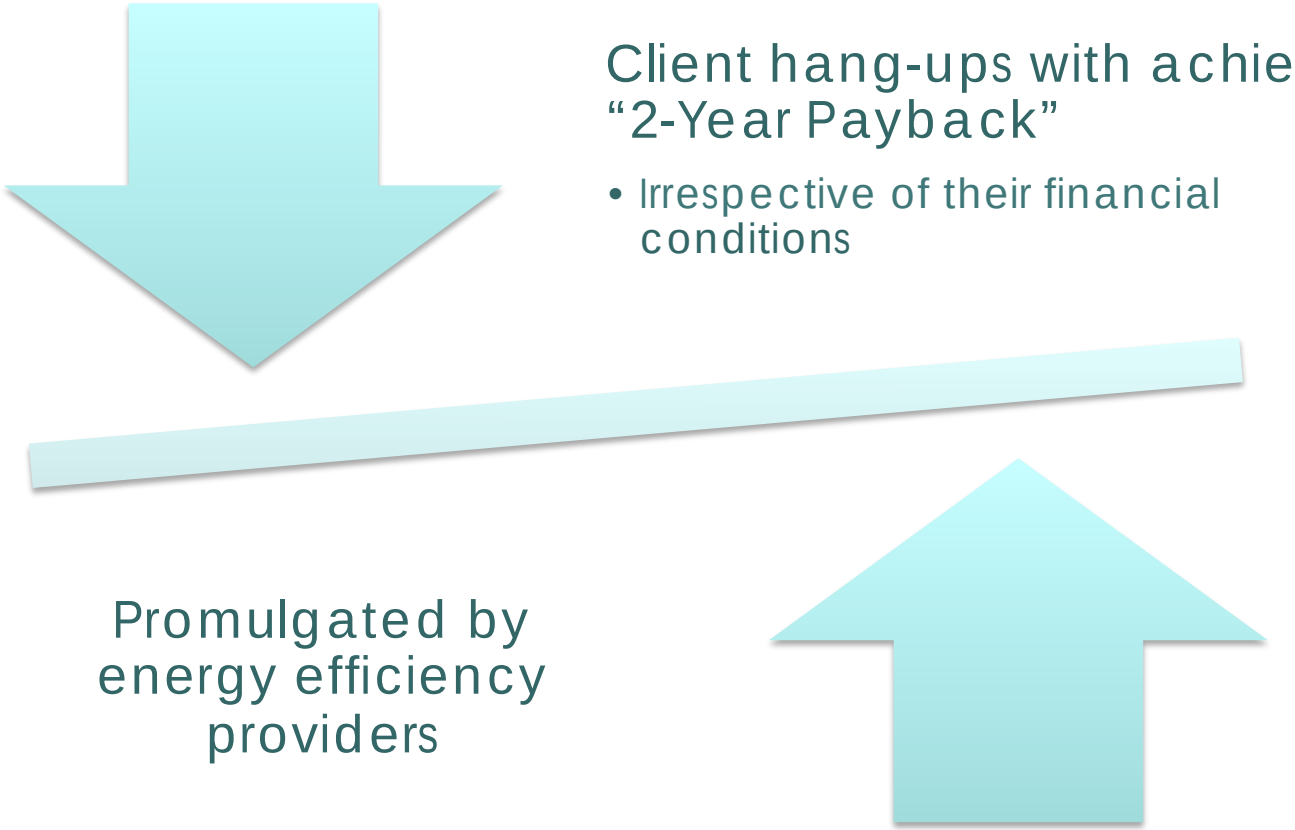
Problem with Payback #2: Psychology



Client hang-ups with achieving "2-Year Payback"

- Irrespective of their financial conditions

Promulgated by energy efficiency providers

Source: The Problem with Payback, Robert C. Bishop Energy Solutions Ltd, New Zealand, C1997.

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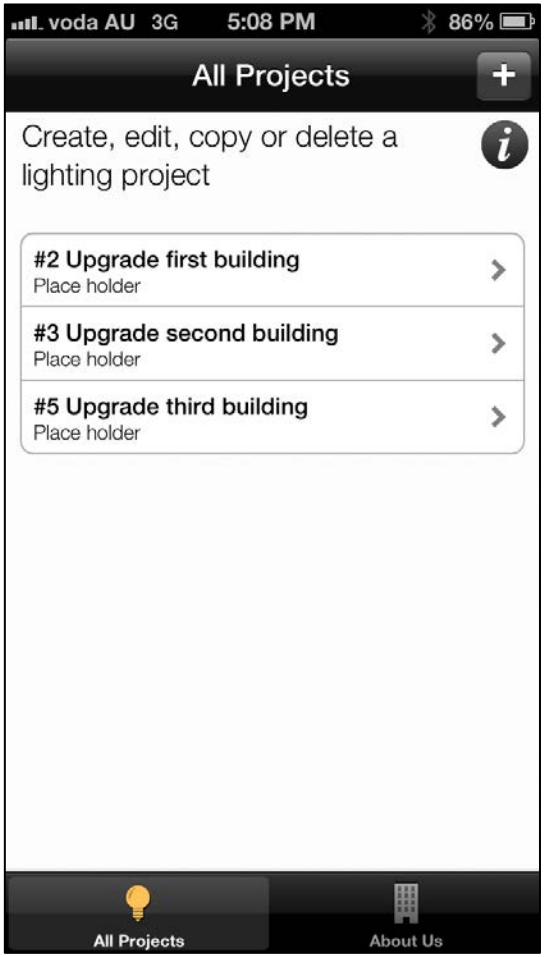
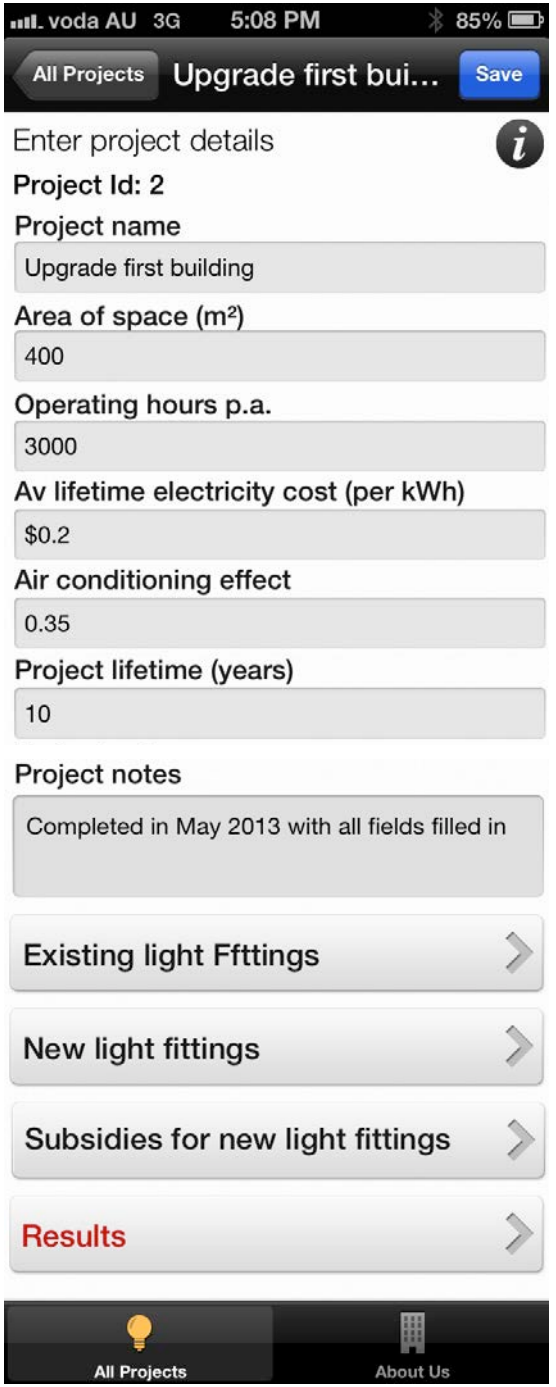
IRR = Internal Rate of Return

- Effectively the “interest rate” returned by the project
- = Discount rate that returns zero NPV
- IRR cannot be solved analytically
  - Only iteratively
  - Excel guesses (10%) then cycles through until result accurate within 0.00001%
  - Excel gives up after 20 attempts

Source: http://office.microsoft.com/en-au/excel-help/irr-HP005209146.aspx

Calculation of IRR without Excel





Calculation of IRR without Excel (regular cashflows) – Annuity Table

Project life (yrs):	**10**
Simple payback ratio:	**3.30**
IRR:	**28.0%**

	Years										
IRR	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
35.5%	0.7380	1.2827	1.6846	1.9813	2.2002	2.3618	2.4810	2.5690	2.6340	2.6819	2.7173
35.0%	0.7407	1.2894	1.6959	1.9969	2.2200	2.3852	2.5075	2.5982	2.6653	2.7150	2.7519
34.5%	0.7435	1.2963	1.7073	2.0128	2.2400	2.4089	2.5345	2.6279	2.6973	2.7489	2.7873
34.0%	0.7463	1.3032	1.7188	2.0290	2.2604	2.4331	2.5620	2.6582	2.7300	2.7836	2.8236
33.5%	0.7491	1.3102	1.7305	2.0453	2.2811	2.4578	2.5901	2.6892	2.7634	2.8191	2.8607
33.0%	0.7519	1.3172	1.7423	2.0618	2.3021	2.4828	2.6187	2.7208	2.7976	2.8553	2.8987
32.5%	0.7547	1.3243	1.7542	2.0786	2.3235	2.5083	2.6478	2.7530	2.8325	2.8924	2.9377
32.0%	0.7576	1.3315	1.7663	2.0957	2.3452	2.5342	2.6775	2.7860	2.8681	2.9304	2.9776
31.5%	0.7605	1.3388	1.7785	2.1129	2.3673	2.5607	2.7077	2.8196	2.9046	2.9693	3.0185
31.0%	0.7634	1.3461	1.7909	2.1305	2.3897	2.5875	2.7386	2.8539	2.9419	3.0091	3.0604
30.5%	0.7663	1.3535	1.8034	2.1482	2.4124	2.6149	2.7700	2.8889	2.9800	3.0498	3.1033
30.0%	0.7692	1.3609	1.8161	2.1662	2.4356	2.6427	2.8021	2.9247	3.0190	3.0915	3.1473
29.5%	0.7722	1.3685	1.8290	2.1845	2.4591	2.6711	2.8348	2.9613	3.0589	3.1343	3.1925
29.0%	0.7752	1.3761	1.8420	2.2031	2.4830	2.7000	2.8682	2.9986	3.0997	3.1781	3.2388
28.5%	0.7782	1.3838	1.8551	2.2219	2.5073	2.7294	2.9023	3.0368	3.1415	3.2229	3.2863
28.0%	0.7812	1.3916	1.8684	2.2410	2.5320	2.7594	2.9370	3.0758	3.1842	3.2689	3.3351
27.5%	0.7843	1.3995	1.8819	2.2603	2.5571	2.7899	2.9725	3.1157	3.2280	3.3161	3.3851
27.0%	0.7874	1.4074	1.8956	2.2800	2.5827	2.8210	3.0087	3.1564	3.2728	3.3644	3.4365
26.5%	0.7905	1.4154	1.9094	2.2999	2.6087	2.8527	3.0456	3.1981	3.3187	3.4140	3.4893
26.0%	0.7937	1.4235	1.9234	2.3202	2.6351	2.8850	3.0833	3.2407	3.3657	3.4648	3.5435
25.5%	0.7968	1.4317	1.9376	2.3407	2.6619	2.9179	3.1218	3.2843	3.4138	3.5170	3.5992

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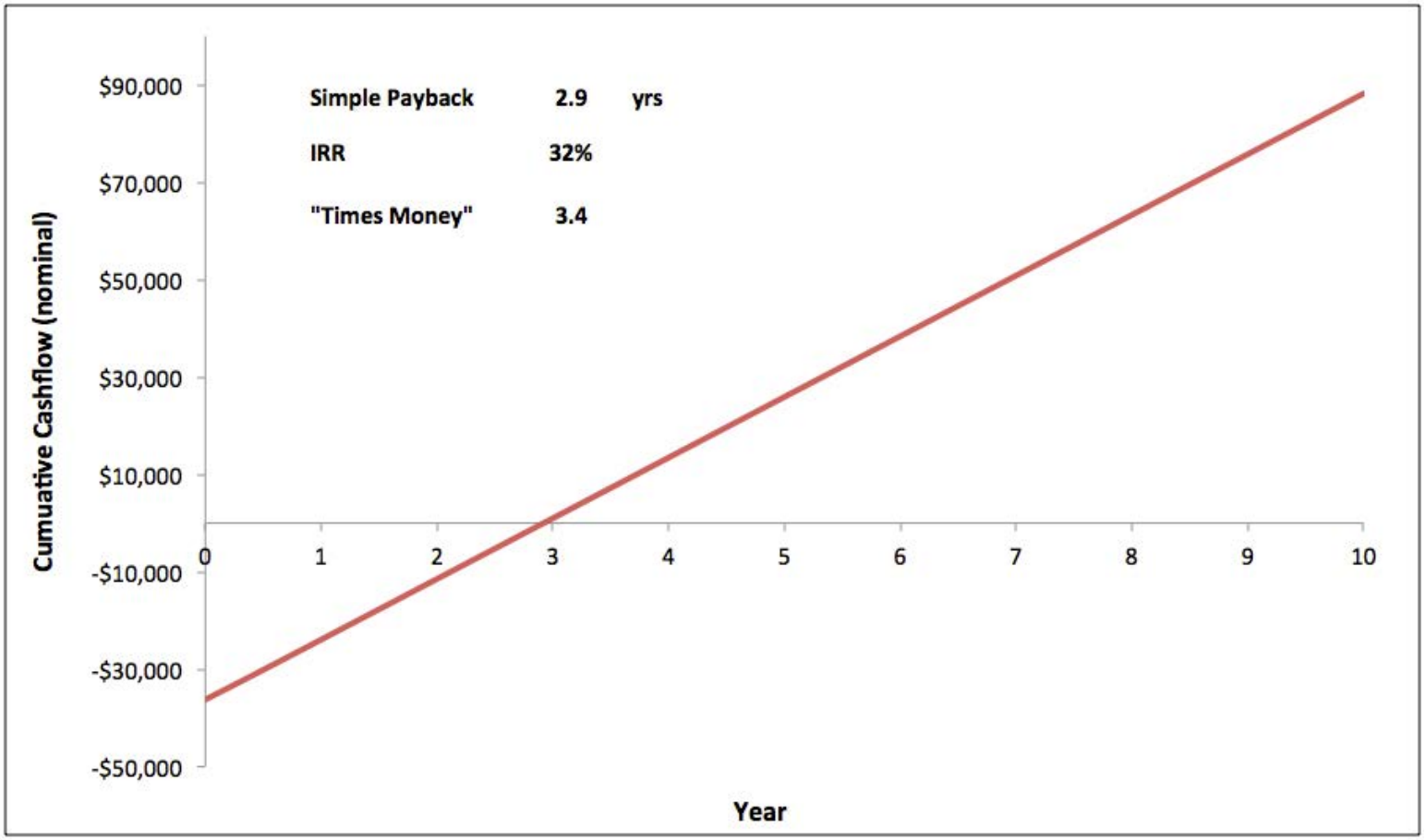
Times Money

- Over the life of the project, how many times do you get your money back?
- Conveys more information regarding duration
- Simple yet effective

Payback Case Study 1
10 Year Project



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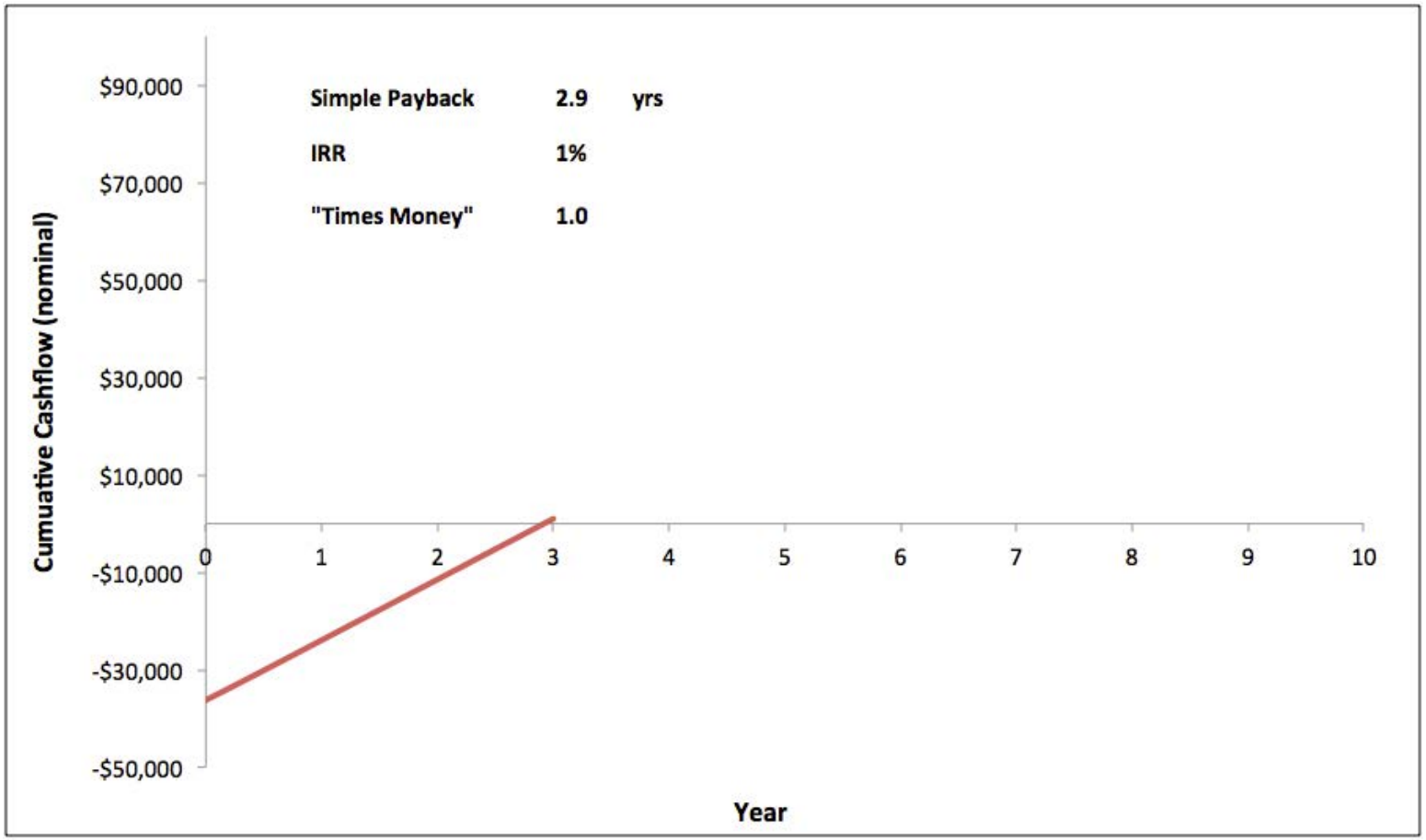
Payback Case Study 2
3 Year Project



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A Few Words About LED Lighting

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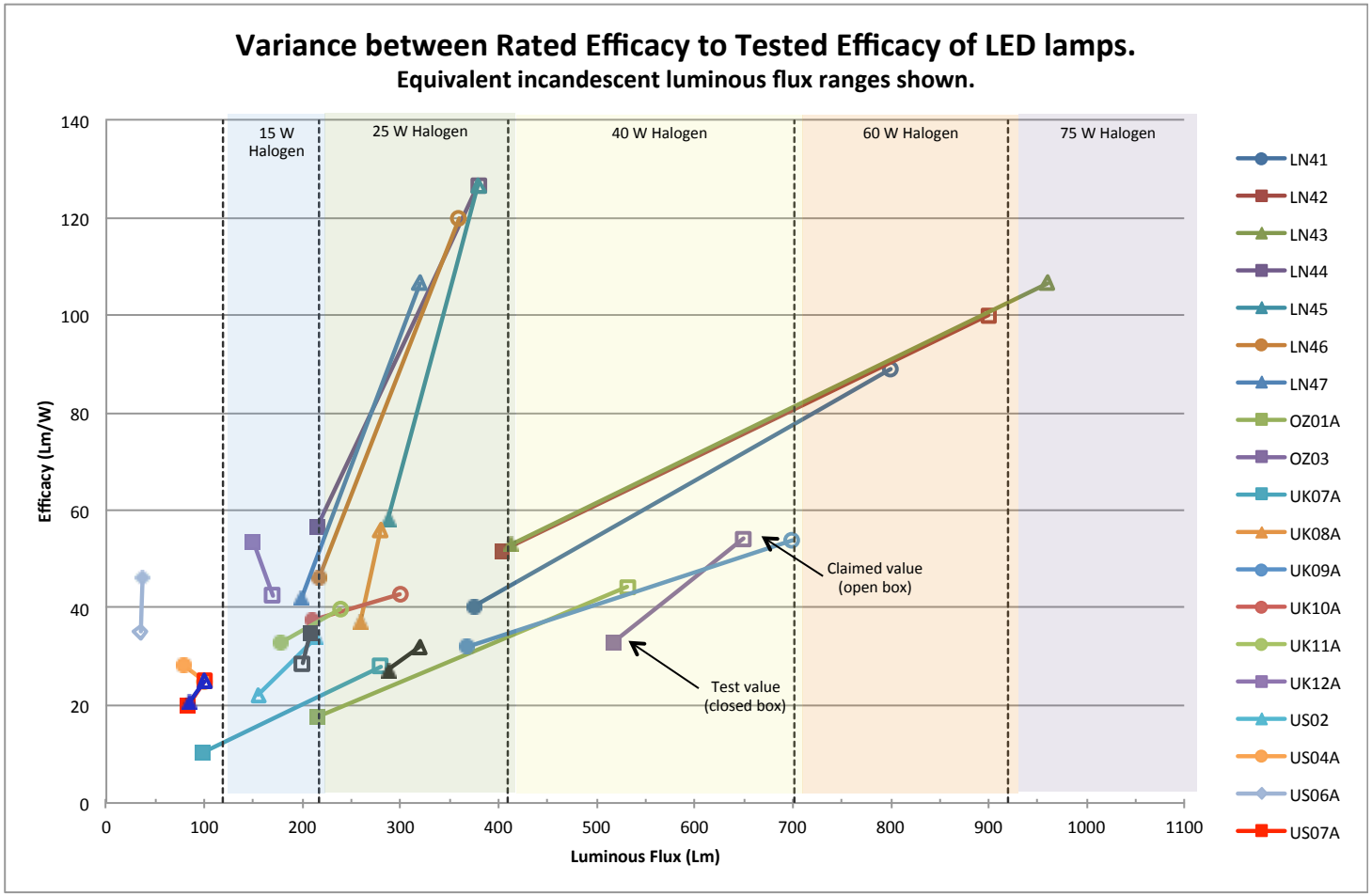
Over-Claimed Performance



Source: Australian DCCEE in 2010

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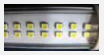
Caliper LED Tube Testing (2010)

Table 1b. CALiPER ROUND 11 SUMMARY –Troffers and High-Bay Luminaires

-- SSL testing following IESNA LM-79-08 -- 25ºC ambient temperature	DOE CALiPER TEST ID	Total Power (Watts)	Output (Initial Lumens)	Efficacy (lm/W)	CCT (K) [D_{uv}]	CRI	Photo
SSL Replacement Lamp (4' linear): Bare Lamp and Testing in Parabolic Louvered Troffer							
Bare Lamp	09-107C	22	1539	70	3548 [-0.002]	73	
*One lamp failed, no in situ**		--	--	--			
Bare Lamp	10-16	15	1368	93	5389 [-0.004]	77	
In situ (2 lamps in troffer)		29	2173	74			
Bare Lamp	10-17	19	1362	70	3249 *[0.007]*	65	
In situ (2 lamps in troffer)		39	2194	57			
Bare Lamp	10-18A	17	1533	91	5602 *[0.009]*	75	
*One lamp failed, no in situ**		--	--	--			
Bare Lamp	10-19	22	1887	86	5091 [0.008]	69	
In situ (2 lamps in troffer)		43	3247	75			
Bare Lamp	10-36	18	1628	90	4300 *[0.012]*	70	
In situ (2 lamps in troffer)		36	2785	78			
Fluorescent Benchmark (BK): Bare Lamp and Testing in High-Performance Lensed Troffers							
Bare Lamp (fluorescent)	BK10-34	32	3353	105	3387 [0.004]	82	
In situ (1 lamp troffer, Ballast Factor BF=1.18)		38	2708	71			
Bare Lamp (fluorescent)	Round 9 BK09-67	32	3247	101	3248 [0.002]	83	
In situ (2 lamp troffer, BF=1.18)		69	4767	69			
In situ (2 lamp troffer, retest, BF=0.88)		55	4045	74			

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Other Issues wrt LEDs

- LEDs hate heat
  - Light output decreases with temperature
- LED light output decreases over time
  - Significant
  - Difficult to test
- Compatibility
  - Heat
  - Electromagnetic interference
  - Light distribution pattern
  - Luminaire Warrantee

LEDs, In Short

- Now becoming more mature
- Beware claimed performance
  - Seek independent verification
- Ensure adequate light on the work surface !
- Compare maintained light levels
  - Apples with apples
- Compare linear LED with T5
- LED downlights have come a long way

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Learning Objectives of this Session

- By the end of this session, you should:
  - Have a basic understanding of the objectives of lighting design
  - Have an understanding of the economics of lighting efficiency upgrades
  - Understand what constitutes an effective business case
  - Be engaged !!
  - Be empowered !!

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Resources

- IESANZ Best Practice Program
  - http://www.iesanz.org/resources/best-practices-in-lighting/
- The Basics of Efficient Lighting
  - http://www.energyrating.gov.au/resources/program-publications/?viewPublicationID=1486
- Business cases
  - http://eex.gov.au/energy-management/the-business-case-and-beyond/

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Questions and Discussion

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