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Field Evaluation of a Lighting Control System for Open-Plan Offices

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National Research Council Canada | Conseil national de recherches Canada

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Acknowledgement

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- Institute for Research in Construction (IRC) of the National Research Council of Canada (NRC)
- Program on Energy Research and Development (PERD)
- Public Works and Government Services Canada (PWGSC)
- BC Hydro Power Smart
- Ledalite Architectural Products

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Test-site Description

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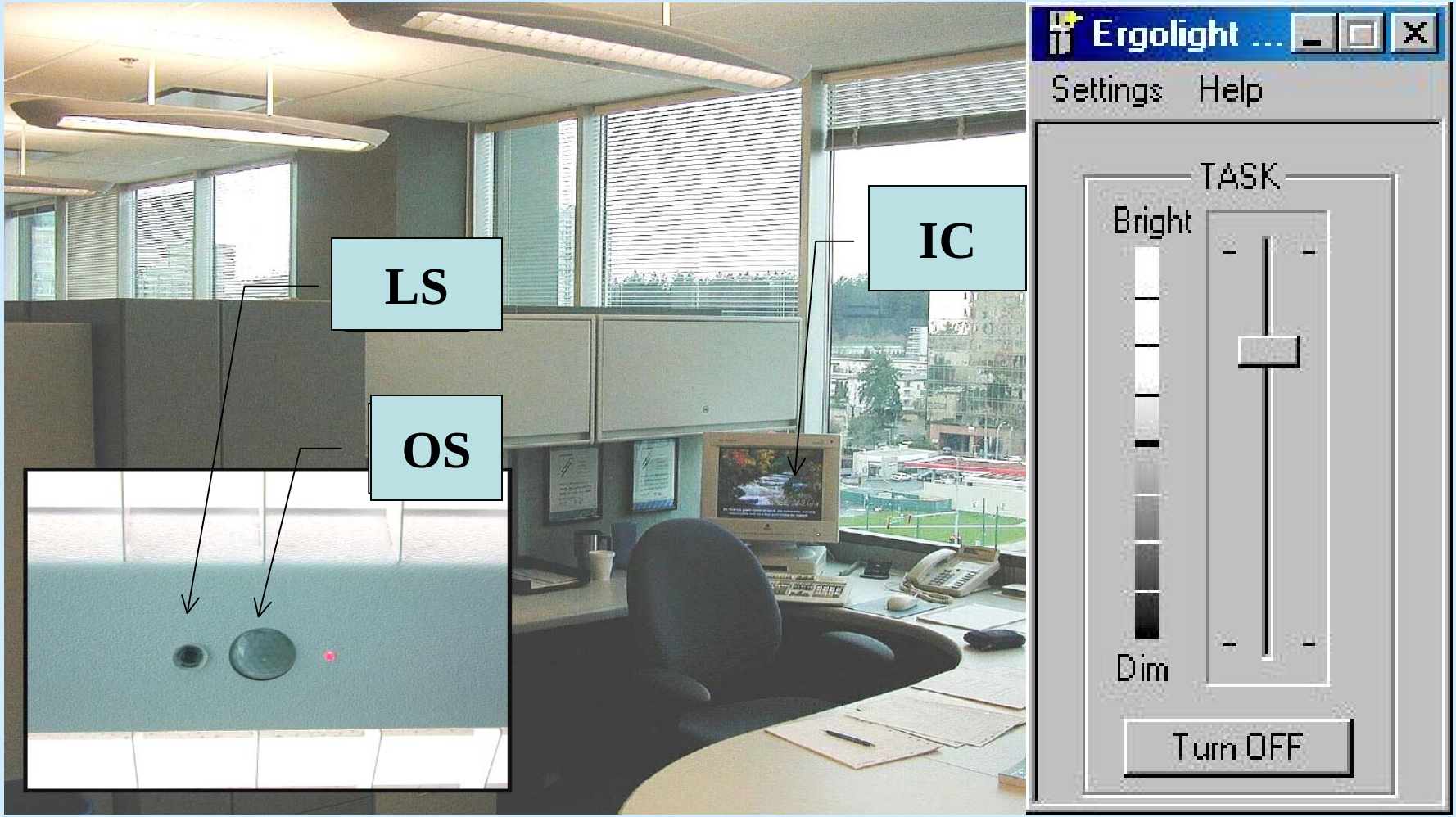
Lighting System Description



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Project Objectives

1. Asses the overall long-term energy savings and power demand reductions of the installed lighting system compared to conventional ceiling-recessed fluorescent light fixtures (2x32 W-T8 lamps, static electronic ballast);
2. Separate the saving contributions from occupant control, occupancy sensors and daylight photosensors;
3. Investigate the effect on energy use of an intervention to the workplace believed to increase the energy savings (Awareness Campaign);

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Project Objectives

4. Evaluate the occupant satisfaction in the workplace featuring the lighting control system, a key factor towards increased acceptability rates, user support and market adoption;
5. Examine the effects of the lighting conditions created by the lighting control system on the occupant satisfaction with lighting, environmental satisfaction and job satisfaction;
6. Examine the Venetian blind use.

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Method

1. **Lighting system energy use and power demand study**: monitored lighting system, centrally and at the individual level, from January 18 to December 31, 2005;
2. **Environmental and job satisfaction study:** conducted 3 online occupant surveys;
3. **Venetian blinds study:** monitored Venetian blind use by occupants from October 2004 to April 2006.

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Energy Use & Power Demand

Data Collection:

- Every 15-minutes for each light fixture in the network
- Energy use
- Occupant use of the on-screen slider
- Status of occupancy sensors
- Status of daylight sensors

Data Access:

- Obtained formal consent from occupants to analyze data
- 86 fixtures used in the analyses (57-perimeter; 18-2nd row; 11-interior)

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Characteristics of Lighting System Operation

- **Phase 1: Jan 18-Mar 11, 2005 (39 workdays)**
  - No LS control
  - System controlled by IC and OS only
  - OS set to 8 min time delay + 7 minutes dimming to shut-off
- **Phase 2: Mar 12-Oct 2, 2005 (140 workdays)**
  - All three controls enabled
  - OS set to 12 min time delay + 3 minutes dimming to shut-off
  - LS control restricted to 50% of downlight output

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Characteristics of Lighting System Operation

- **Phase 3: Oct 3-Dec 31, 2005 (61 workdays)**
  - Same as Phase 2 + Awareness Campaign
  - Monthly e-mail remainders were sent by management to employees to remind them about the availability of the lighting control system, and how to use it.

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Energy Use Calculations

Baseline scenarios:

- Energy used by the installed system in the absence of controls **from 7:30 AM to 5 PM**.
- Energy used by installed system in the absence of controls during **the total** workstation occupied hours (7:30 AM to 5 PM, plus additional occupancy time).
- Energy used by a conventional static system (the lighting system previously in place) in the absence of controls during the total workstation occupied hours.

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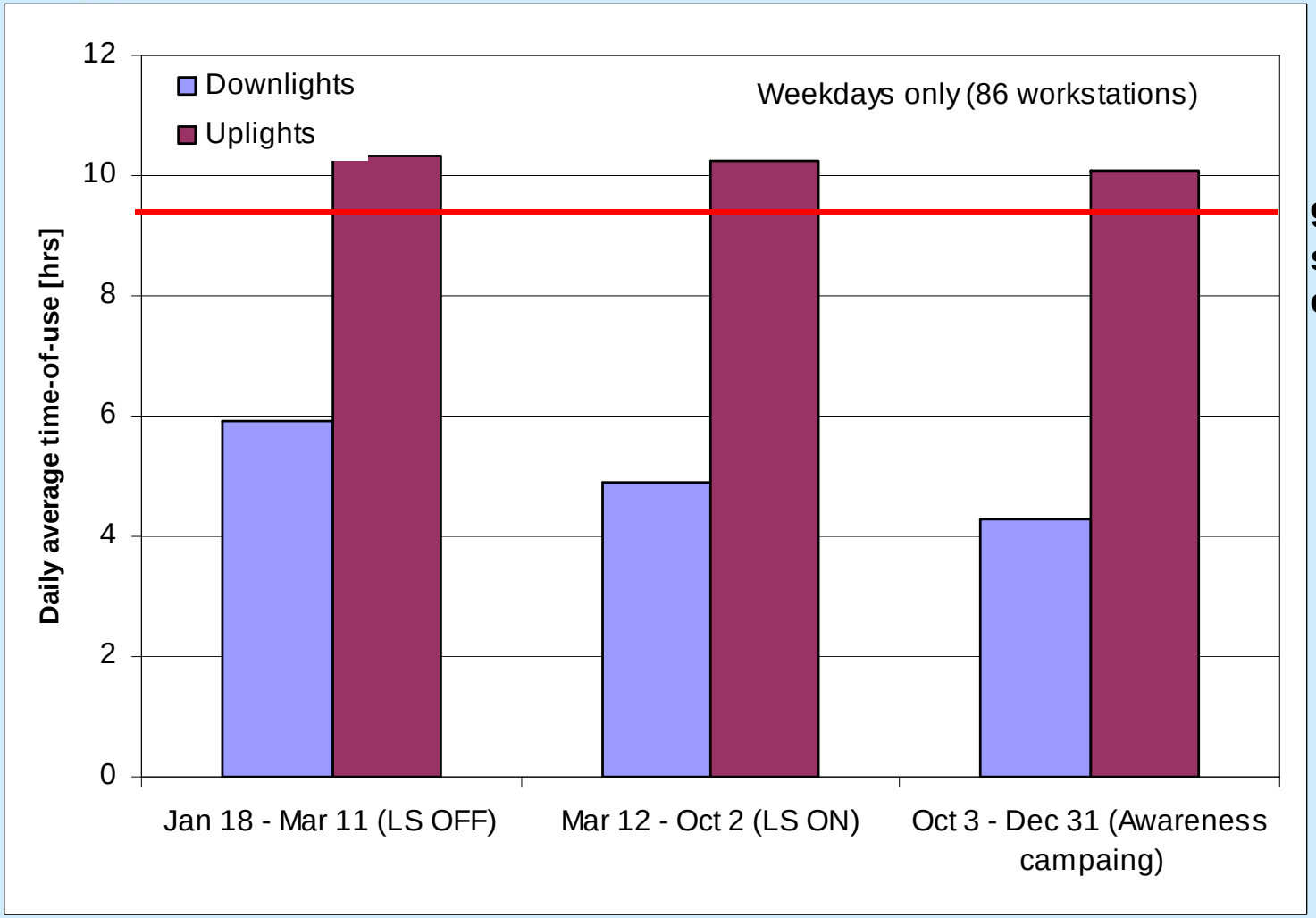
Average Daily Time-of-Use



9.5 hrs scheduled occupancy

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Energy Use Calculations

- **os** = downlights controlled by occupancy sensors only
- **ic** = downlights controlled by individual controls only
- **ls** = downlights controlled by light sensor control only
- **os+ic** = downlights controlled by occupancy sensor and individual control combined
- **os+ls** = downlights controlled by occupancy sensor and light sensor control combined
- **ic+ls** = downlights controlled by individual control and light sensor control combined
- **os+ic+ls (calculated)** = downlights controlled by all available controls combined
- **os+ic+ls (real)** = downlights controlled by all available controls combined

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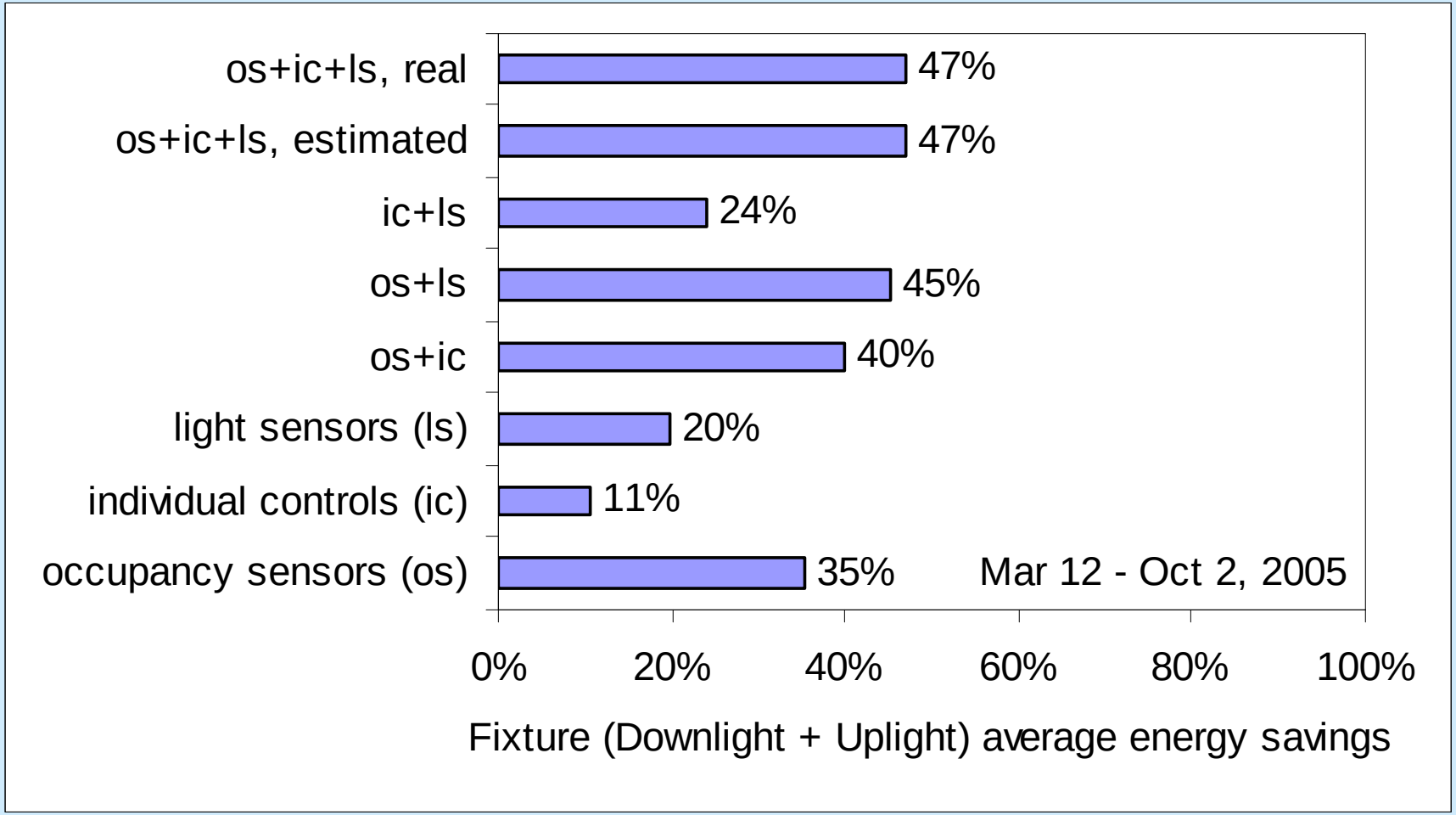
Average energy savings versus full lighting use of installed system



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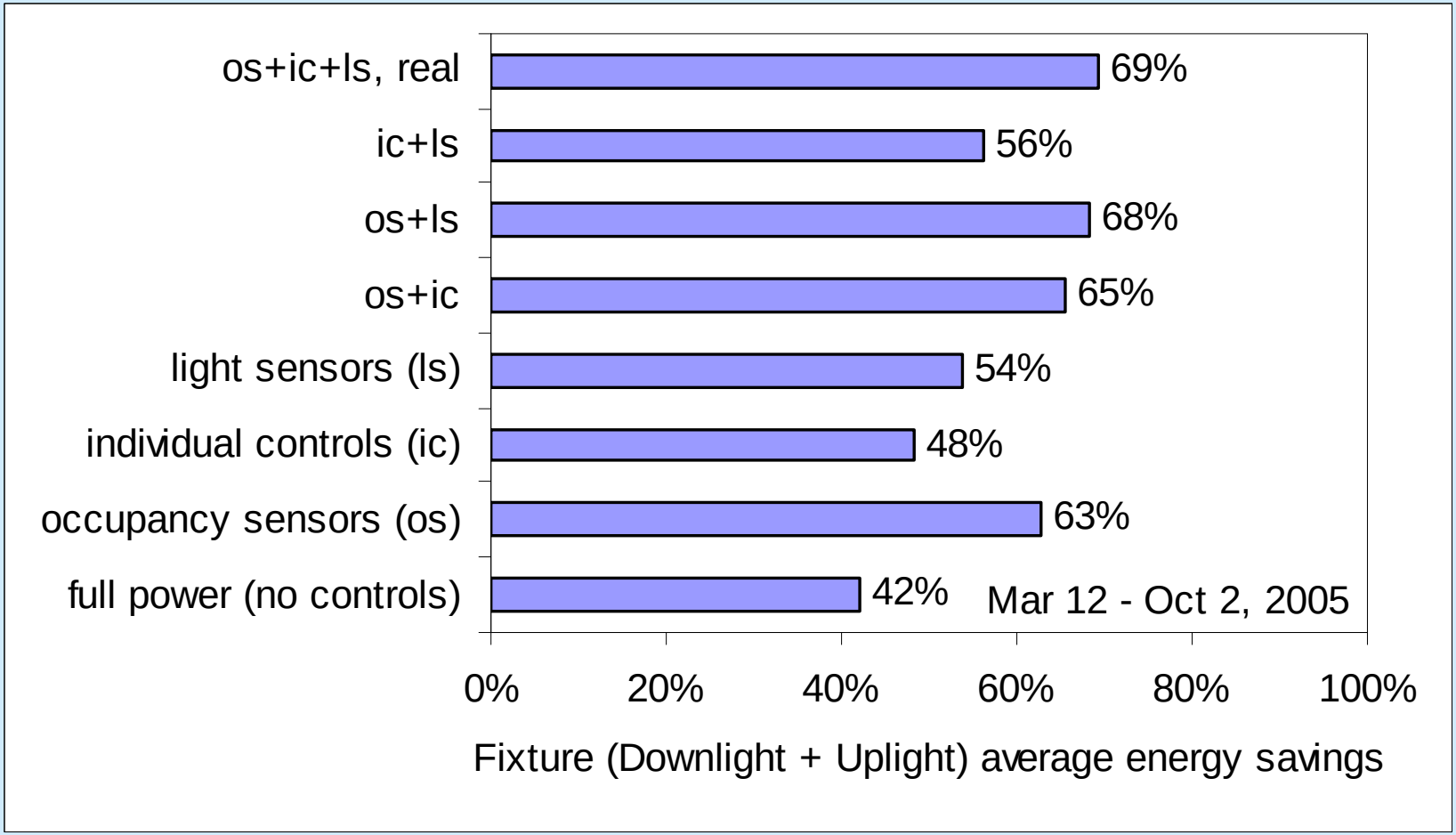
Average energy savings versus full use of conventional fluorescent static lighting



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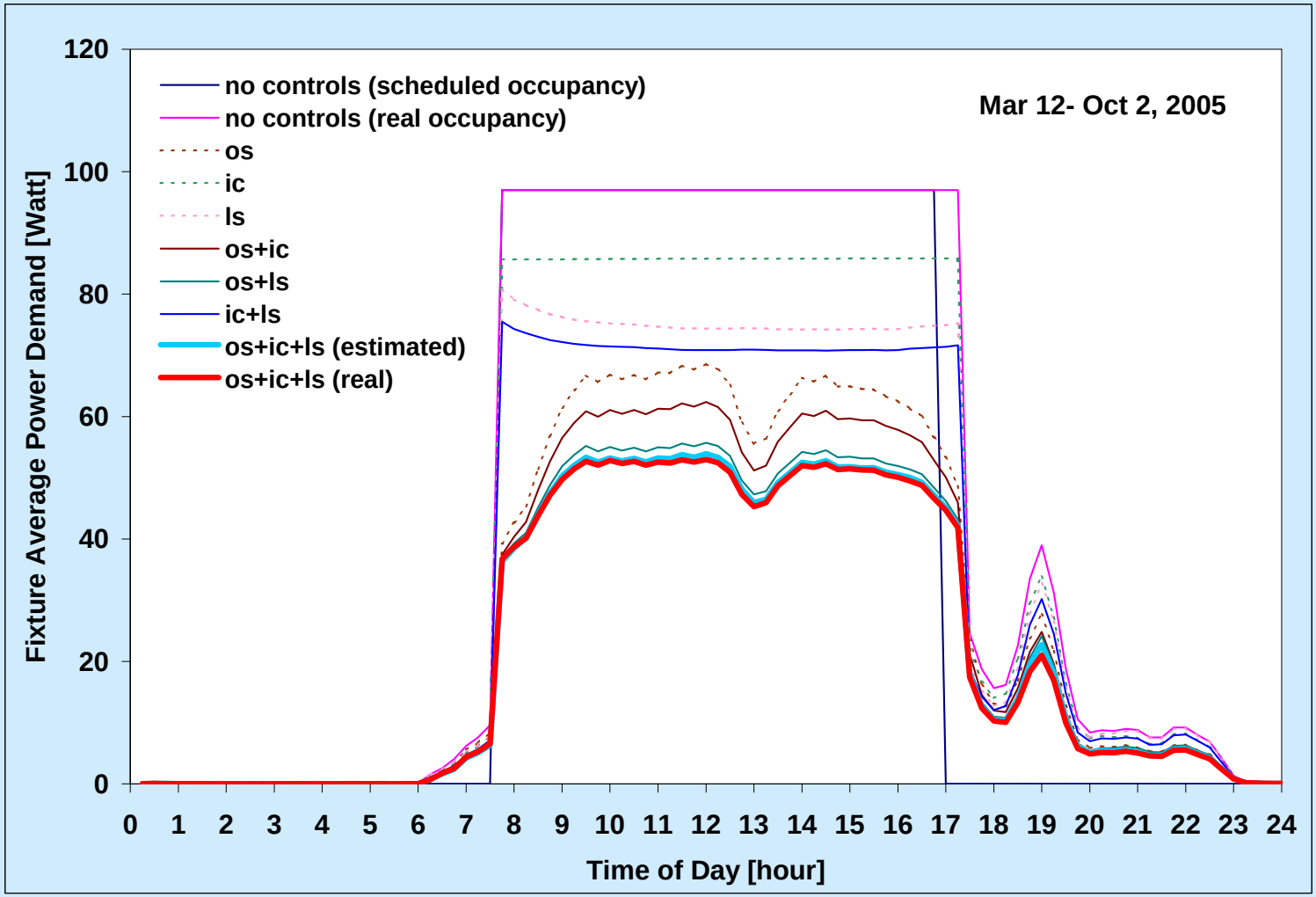
Fixture Average Daily Power Demand



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Individual Control Frequency-of-use

Number of active workstations (out of 86 WS)	Phase 1	Phase 2	Phase 3
No.of workstations with manual on/off adjustments	81	34	21
No.of workstations with manual dimming adjustments	81	52	44
IC adjustments across all 86 workstations			
Manual On/Off / day	3.72	0.61	1.79
Manual Dimming / day	5.26	0.99	2.5
Total manual control actions/day	8.98	1.6	4.29
Average manual control actions/WS/day	**0.10**	**0.02**	**0.05**

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Other design/operation options

	As Installed			Option 1		Option 2	
	Phase 1	Phase 2	Phase 3	Phase 2	Phase 3	Phase 2	Phase 3
	Jan18-Mar11	Mar12-Oct2	Oct3-Dec 31	Mar12-Oct2	Oct3-Dec 31	Mar12-Oct2	Oct3-Dec 31
Fixture Average Energy Savings	%	%	%	%	%	%	%
os	29	35	38	n/a	n/a	38	40
ic	20	11	5	n/a	n/a	n/a	n/a
ls	n/a	**20**	**11**	**32**	**16**	**34**	**18**
os+ic	40	40	39	n/a	n/a	43	42
os+ls	n/a	**45**	**44**	**51**	**46**	**55**	**49**
ic+ls	n/a	**24**	**14**	**34**	**19**	**37**	**21**
os+ic+ls (estimated)	40	**47**	**44**	**52**	**47**	**56**	**50**
os+ic+ls (real)	39	47	42	n/a	n/a	n/a	n/a
Fixture Average Power Demand Reduction	%	%	%	%	%	%	%
os	31	36	38	n/a	n/a	39	41
ic	21	12	5	n/a	n/a	n/a	n/a
ls	n/a	**23**	**15**	**39**	**24**	**42**	**25**
os+ic	41	41	40	n/a	n/a	45	43
os+ls	n/a	**47**	**46**	**55**	**50**	**59**	**54**
ic+ls	n/a	**26**	**18**	**41**	**26**	**44**	**28**
os+ic+ls (estimated)	41	**48**	**46**	**55**	**50**	**59**	**54**
os+ic+ls (real)	40	49	43	n/a	n/a	n/a	n/a

Option 1 = Currently installed system if downlights were allowed to dim to zero on LS
Option 2 = System with static 25 watt uplights and downlights allowed maximum dimming on LS

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Other design/operation options

	As Installed			Option 3		Option 4	
	Phase 1	Phase 2	Phase 3	Phase 2	Phase 3	Phase 2	Phase 3
	Jan18-Mar11	Mar12-Oct2	Oct3-Dec 31	Mar12-Oct2	Oct3-Dec 31	Mar12-Oct2	Oct3-Dec 31
Fixture Average Energy Savings	%	%	%	%	%	%	%
os	29	35	38	52	54	52	54
ic	20	11	5	15	7	15	7
ls	n/a	20	11	29	16	47	24
os+ic	40	40	39	59	56	59	56
os+ls	n/a	45	44	66	62	75	66
ic+ls	n/a	24	14	35	20	51	27
os+ic+ls (estimated)	40	**47**	**44**	**69**	**64**	**76**	**67**
os+ic+ls (real)	39	47	42	n/a	n/a	n/a	n/a
Fixture Average Power Demand Reduction	%	%	%	%	%	%	%
os	31	36	38	54	57	54	57
ic	21	12	5	17	7	17	7
ls	n/a	23	15	34	23	59	35
os+ic	41	41	40	62	59	62	59
os+ls	n/a	47	46	70	68	82	74
ic+ls	n/a	26	18	39	26	61	38
os+ic+ls (estimated)	41	**48**	**46**	**72**	**69**	**82**	**75**
os+ic+ls (real)	40	49	43	n/a	n/a	n/a	n/a

Option 3 = System with dimmable uplights and downlights restricted at 50% lamp output
Option 4 = System with dimmable uplights and downlights allowed maximum dimming on LS

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Conclusions

- Lighting power density of installed system is 42% lower than that of a static conventional fluorescent lighting system;
- The three controls combined saved an additional 42-47% in lighting energy use compared to installed system used at full power; This translates into savings of 67-69 % compared to a conventional system;
- Average peak daily power demand was reduced by similar amounts;

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Conclusions

	Lighting power density **W/m^2**	Energy savings **%**	Peak load **W/workstation**
Conventional - full power	10	-	174
Installed system - full power	5.8	42	97
Installed system - effective	3	69	53

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Conclusions

If used on their own (versus same system at full power):

- Occupancy control average savings: 30-40%
- Light sensor average savings: 10-20%
- Individual control average savings: < 10%
- Frequency-of-use of the individual control averaged under 0.05 control actions/WS/day

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Conclusions

- The Awareness Campaign resulted in higher occupant selected light levels and decreased energy savings from individual control;
- Other design/operation alternatives could increase the energy savings, however, careful consideration should be given to not create uncomfortable conditions for the occupants (uneven light distribution on the ceiling, distracting light level transitions);

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Conclusions

- Overall, energy data suggests a satisfactory installation of the lighting system;
- Continuous calibration and correct maintenance throughout the life of the system is key to its energy saving potential.

More information:

- **LEUKOS, Journal of the IESNA, Vol.4, No.1, July 2007**
- **NRC-IRC Publications: http://irc.nrc-cnrc.gc.ca/pubs/index_e.html**