



MEDICINAL CANNABIS ENVIRONMENT

15.12.20



Richel Medicinal Cannabis Webinar



Welcome to the Richel Medicinal Cannabis Webinar



A lot of unclear information concerning climate management



Review of scientific publications

soinnaire

01

Temperature, light and photosynthesis

Global effects of temperature and light on cannabis photosynthesis

02

Temperature, light and transpiration

How evolve transpiration under different temperature and light guidelines for multiple cannabis cultivars?

03

CO₂ supply

How does cannabis react in a CO₂ enriched environment?

04

Estimate your profitability

How to use physiological behavior to estimate your project profitability?



Temperature, light and photosynthesis

Global effects of temperature and light on cannabis
photosynthesis

01



01 Temperature, light and photosynthesis

UNITS REMINDER



Net photosynthesis

CO₂ consumption of the plant

$\mu\text{mol}(\text{CO}_2).\text{m}^{-2}.\text{s}^{-1}$



Photosynthetic Photon Flux Density

Instantaneous light usable by the plants

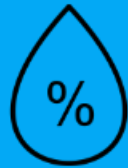
$\mu\text{mol}.\text{m}^{-2}.\text{s}^{-1}$



Daily Light Integral

Daily light usable by the plants

$\text{mol}.\text{d}^{-1}$



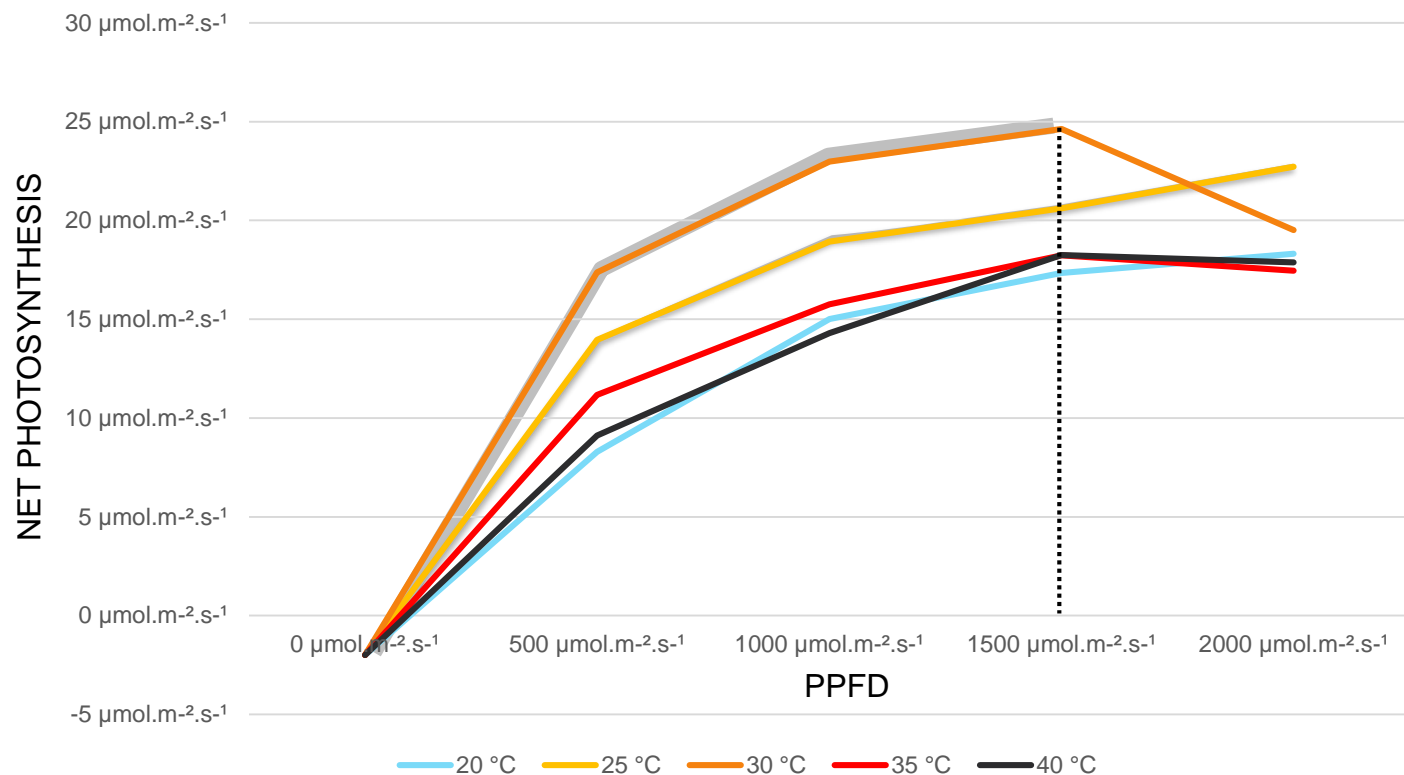
01 Temperature, light and photosynthesis

PHOTOSYNTHESIS ACTIVITY OF ONE CULTIVAR UNDER DIFFERENT TEMPERATURE AND PPFD GUIDELINES

1500 $\mu\text{mol.m}^{-2}.\text{s}^{-1}$ seems optimal

PPFD is continuously valorized at 25°C

Photosynthesis is maximal at 30°C but decrease under high PPFD

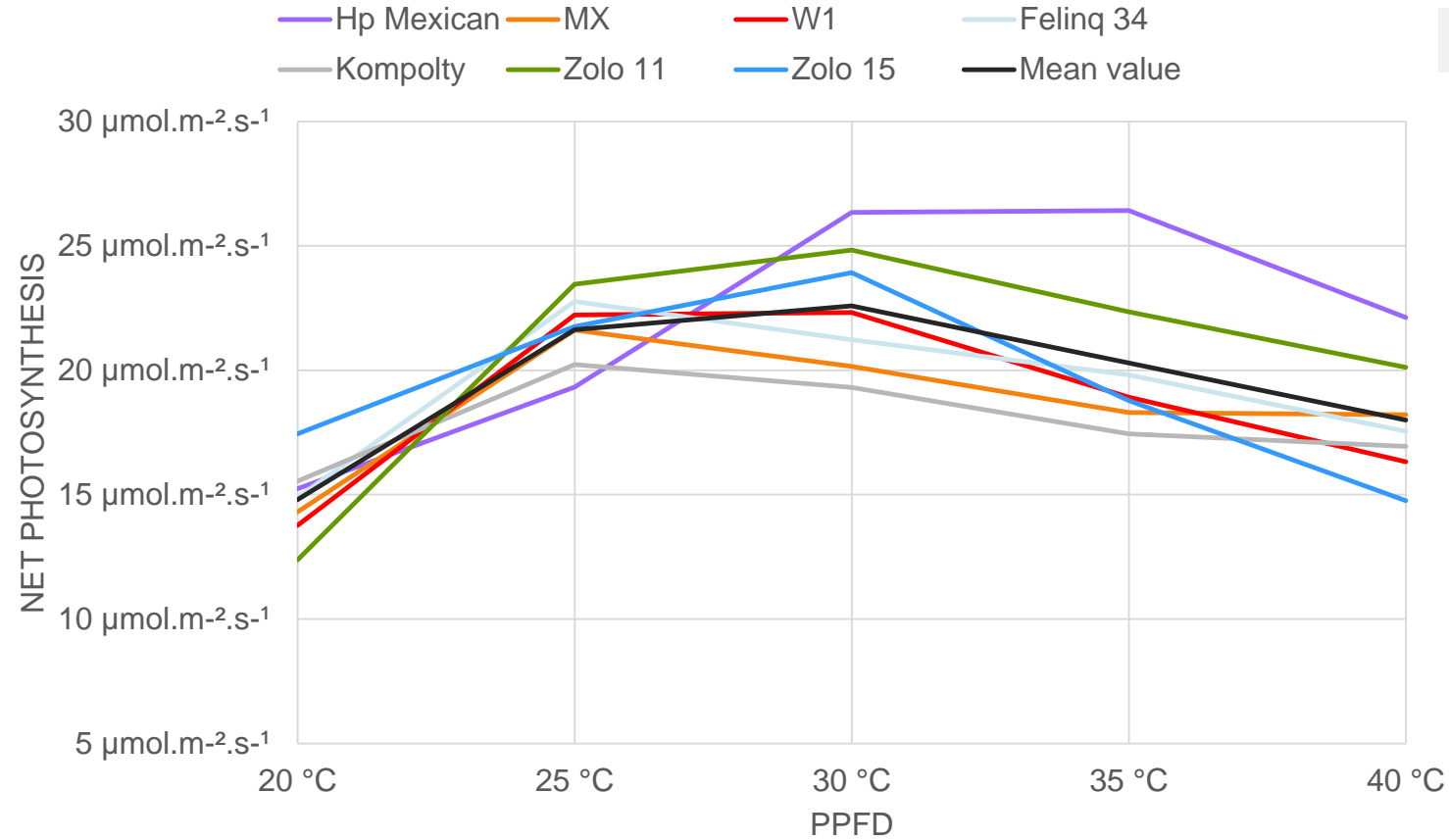


[1] CHANDRA, Suman, LATA, Hemant, KHAN, Ikhlas A. and ELSOHLI, Mahmoud A., 2008. Photosynthetic response of Cannabis sativa L. to variations in photosynthetic photon flux densities, temperature and CO₂ conditions. *Physiology and Molecular Biology of Plants*. October 2008. Vol. 14, no. 4, p. 299–306. DOI [10.1007/s12298-008-0027-x](https://doi.org/10.1007/s12298-008-0027-x).



01 Temperature, light and photosynthesis

PHOTOSYNTHESIS ACTIVITY OF MANY CULTIVARS UNDER DIFFERENT TEMPERATURE GUIDELINES AND 1500 $\mu\text{MOL.M}^{-2}.\text{S}^{-1}$



Intraspecific differences : difference between temperature for each cultivar

Cultivar	20 °C	25 °C	30 °C	35 °C	40 °C
HPM	d	cd	ab	a	bc
MX	b	a	a	ab	ab
W1	d	ab	a	bc	cd
F34	d	ab	bc	bc	cd
K	d	ab	bc	cd	cd
Z11	d	abc	a	ab	bc
Z15	cd	bc	ab	c	d

Analyse of photosynthesis variation for each cultivar

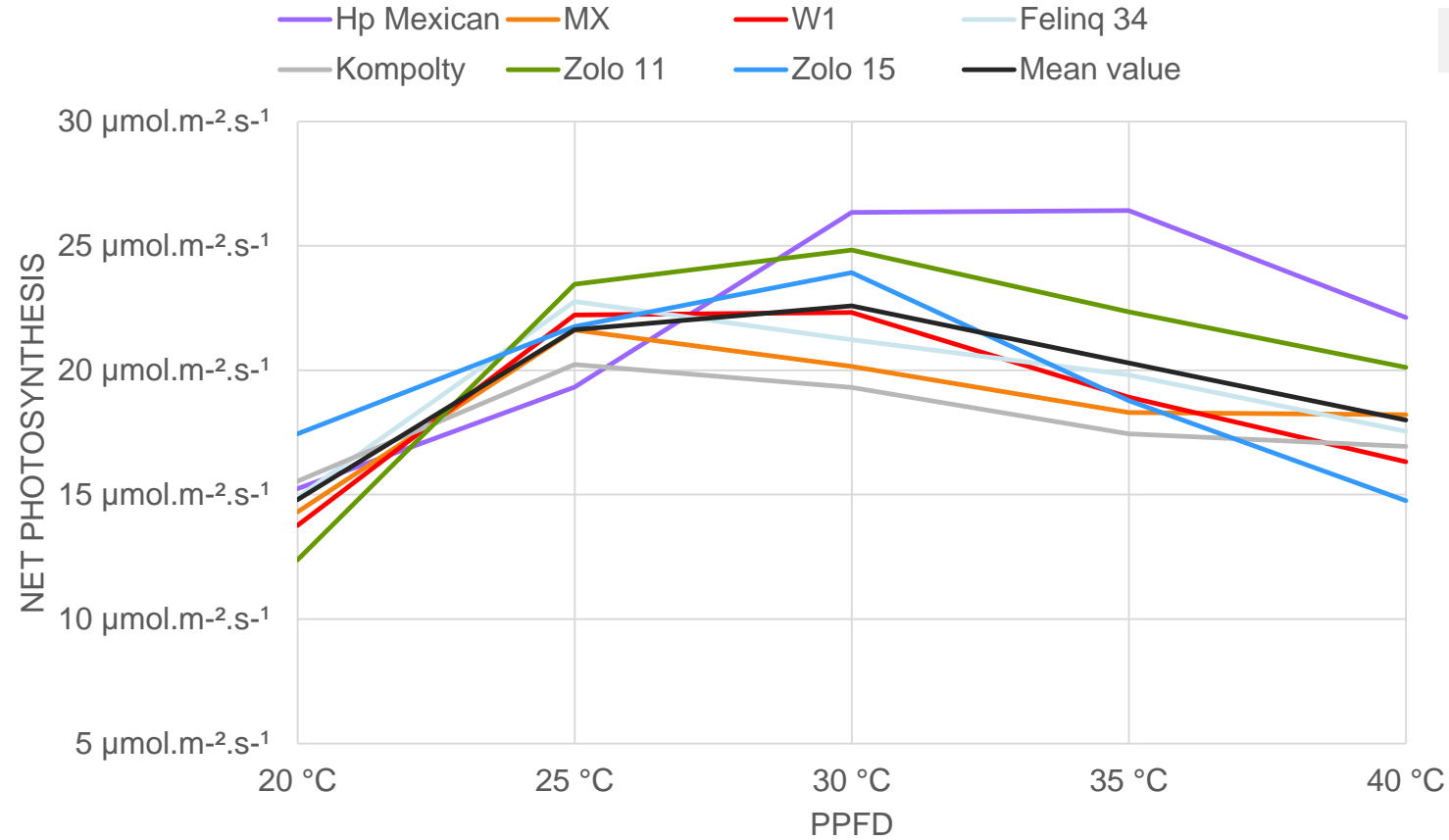
The closer the groups are to the « a », the more the plant photosynthesis

Same letter for different temperature means no statistical differences

[2] CHANDRA, Suman, LATA, Hemant, KHAN, Ikhlas A. and ELSOHLY, Mahmoud A., 2011. Temperature response of photosynthesis in different drug and fiber varieties of Cannabis sativa L. *Physiology and Molecular Biology of Plants*. July 2011. Vol. 17, no. 3, p. 297–303. DOI [10.1007/s12298-011-0068-4](https://doi.org/10.1007/s12298-011-0068-4).

01 Temperature, light and photosynthesis

PHOTOSYNTHESIS ACTIVITY OF MANY CULTIVARS UNDER DIFFERENT TEMPERATURE GUIDELINES AND 1500 μ MOL.M⁻².S⁻¹



Intraspecific differences : difference between temperature for each cultivar

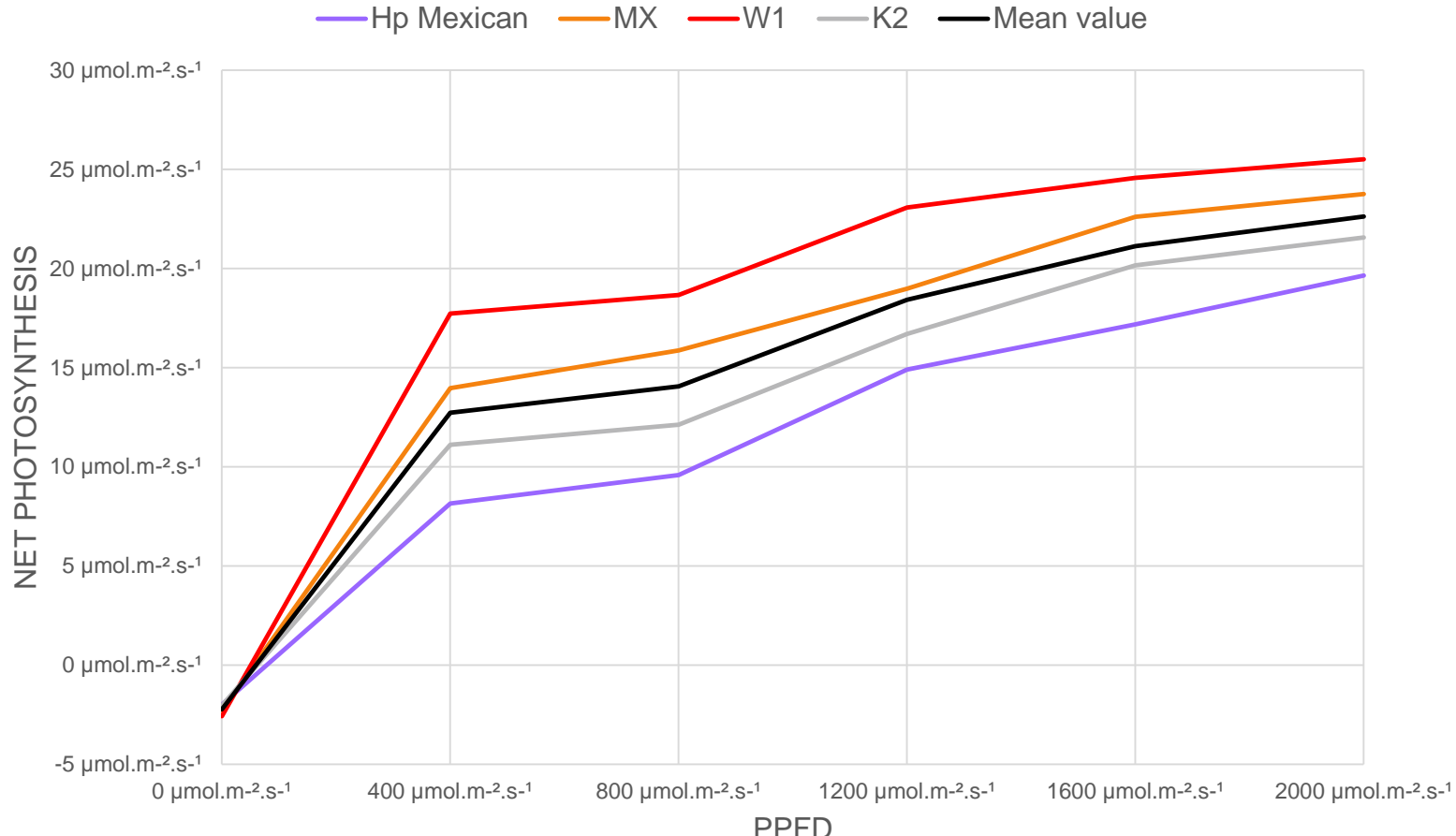
Cultivar	20 °C	25 °C	30 °C	35 °C	40 °C
HPM	d	cd	ab	a	bc
MX	b	a	a	ab	ab
W1	d	ab	a	bc	cd
F34	d	ab	bc	bc	cd
K	d	ab	bc	cd	cd
Z11	d	abc	a	ab	bc
Z15	cd	bc	ab	c	d

No difference between 25°C and 30°C

[2] CHANDRA, Suman, LATA, Hemant, KHAN, Ikhlas A. and ELISOHLY, Mahmoud A., 2011. Temperature response of photosynthesis in different drug and fiber varieties of Cannabis sativa L. *Physiology and Molecular Biology of Plants*. July 2011. Vol. 17, no. 3, p. 297–303. DOI [10.1007/s12298-011-0068-4](https://doi.org/10.1007/s12298-011-0068-4).

01 Temperature, light and photosynthesis

PHOTOSYNTHESIS ACTIVITY OF MANY CULTIVARS UNDER DIFFERENT PPFD GUIDELINES AND 25°C



No difference between 1600 and 2000 $\mu\text{mol.m}^{-2}\text{s}^{-1}$

1200 $\mu\text{mol.m}^{-2}\text{s}^{-1}$ is a good compromise

No difference between 400 and 800 $\mu\text{mol.m}^{-2}\text{s}^{-1}$

[3] CHANDRA, Suman, LATA, Hemant, MEHMEDIC, Zlatko, KHAN, Ikhlas A. and ELISOHLY, Mahmoud A., 2015. Light dependence of photosynthesis and water vapor exchange characteristics in different high Δ^9 -THC yielding varieties of *Cannabis sativa* L. *Journal of Applied Research on Medicinal and Aromatic Plants*. June 2015. Vol. 2, no. 2, p. 39–47. DOI [10.1016/j.jarmap.2015.03.002](https://doi.org/10.1016/j.jarmap.2015.03.002).

01 Temperature, light and photosynthesis

WHAT YOU MUST REMEMBER



**Maximum of photosynthesis at
25°C-30°C**

If you want to warm up : 25°C

If you want to cool down : 30°C



**Optimum PPFD near
1500 $\mu\text{mol.m}^{-2}.\text{s}^{-1}$**



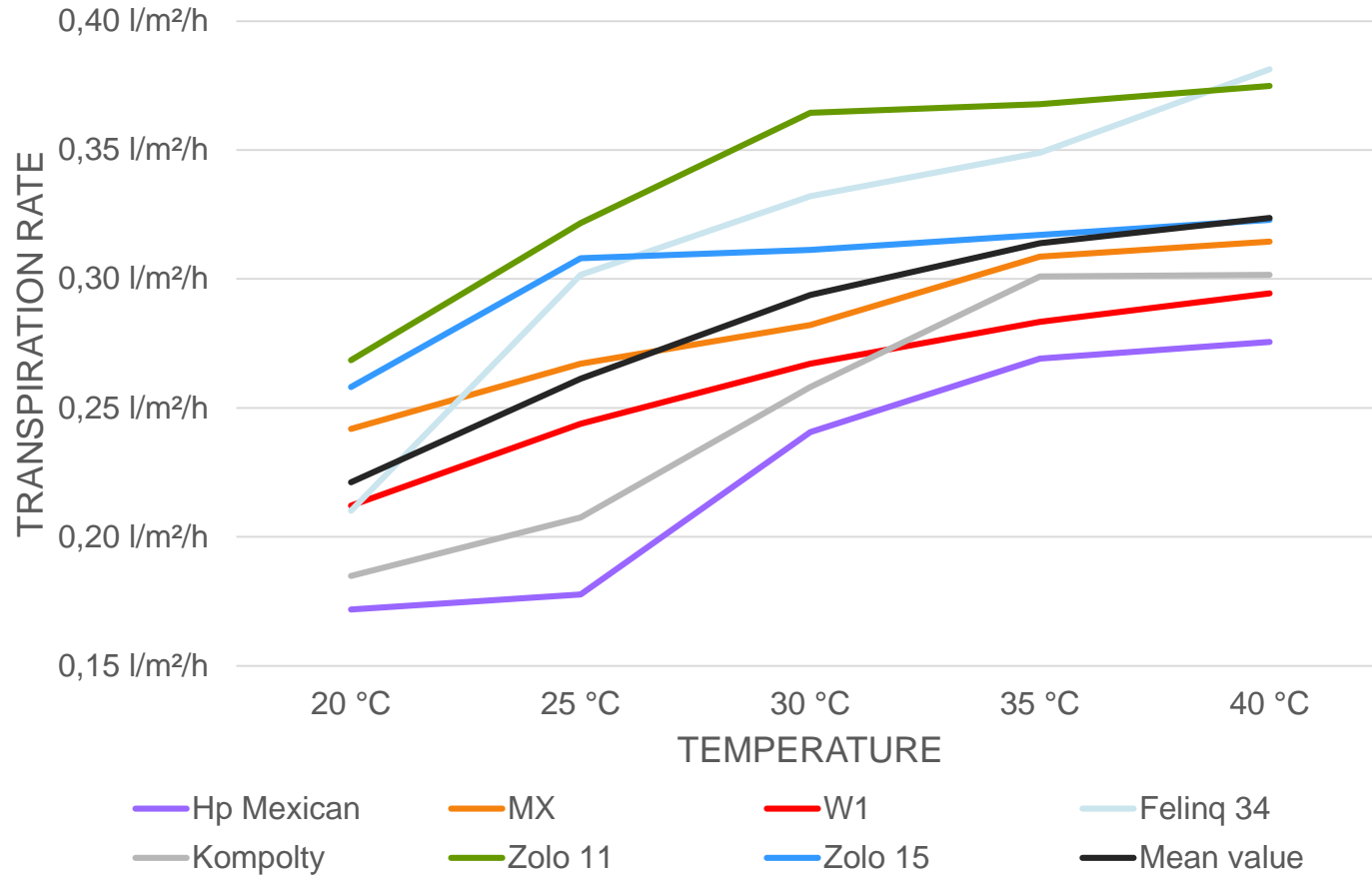
Temperature, light and transpiration

How evolve transpiration under different temperature and light guidelines for multiple cannabis cultivars?

02

02 Temperature, light and transpiration

TRANSPIRATION RATE OF MANY CULTIVARS UNDER DIFFERENT TEMPERATURE GUIDELINES AND $1500\mu\text{MOL.M}^{-2}.\text{S}^{-1}$



0,25 – 0,30 $\text{l/m}^2/\text{h}$ under guidelines temperature

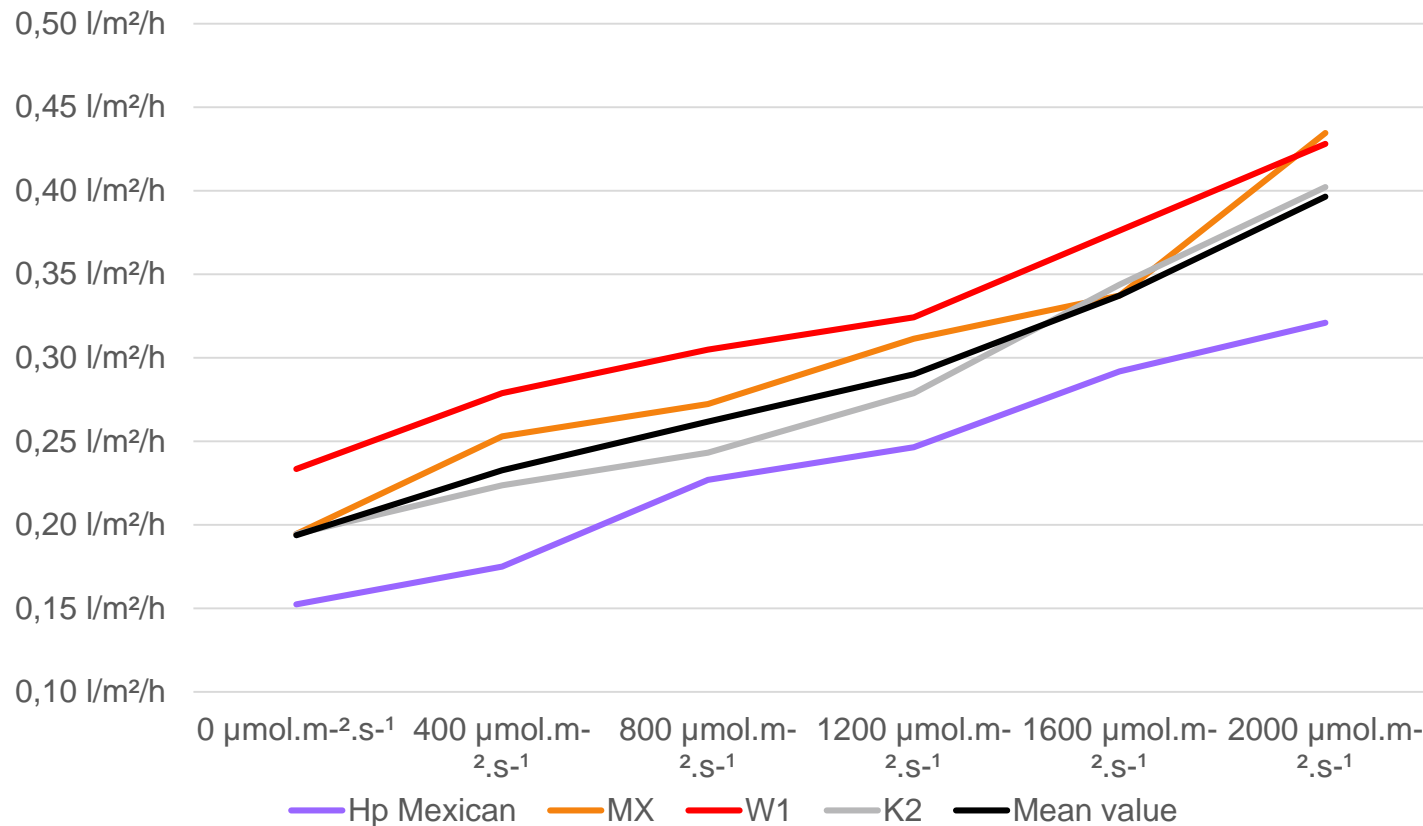
0,4 $\text{l/m}^2/\text{h}$ is the maximum transpiration rate under $1500\mu\text{mol}$

[2] CHANDRA, Suman, LATA, Hemant, KHAN, Ikhlas A. and ELSOHLY, Mahmoud A., 2011. Temperature response of photosynthesis in different drug and fiber varieties of *Cannabis sativa* L. *Physiology and Molecular Biology of Plants*. July 2011. Vol. 17, no. 3, p. 297–303. DOI [10.1007/s12298-011-0068-4](https://doi.org/10.1007/s12298-011-0068-4).

02

Temperature, light and transpiration

TRANSPIRATION RATE OF MANY CULTIVARS UNDER DIFFERENT PPFD GUIDELINES AND 25°C



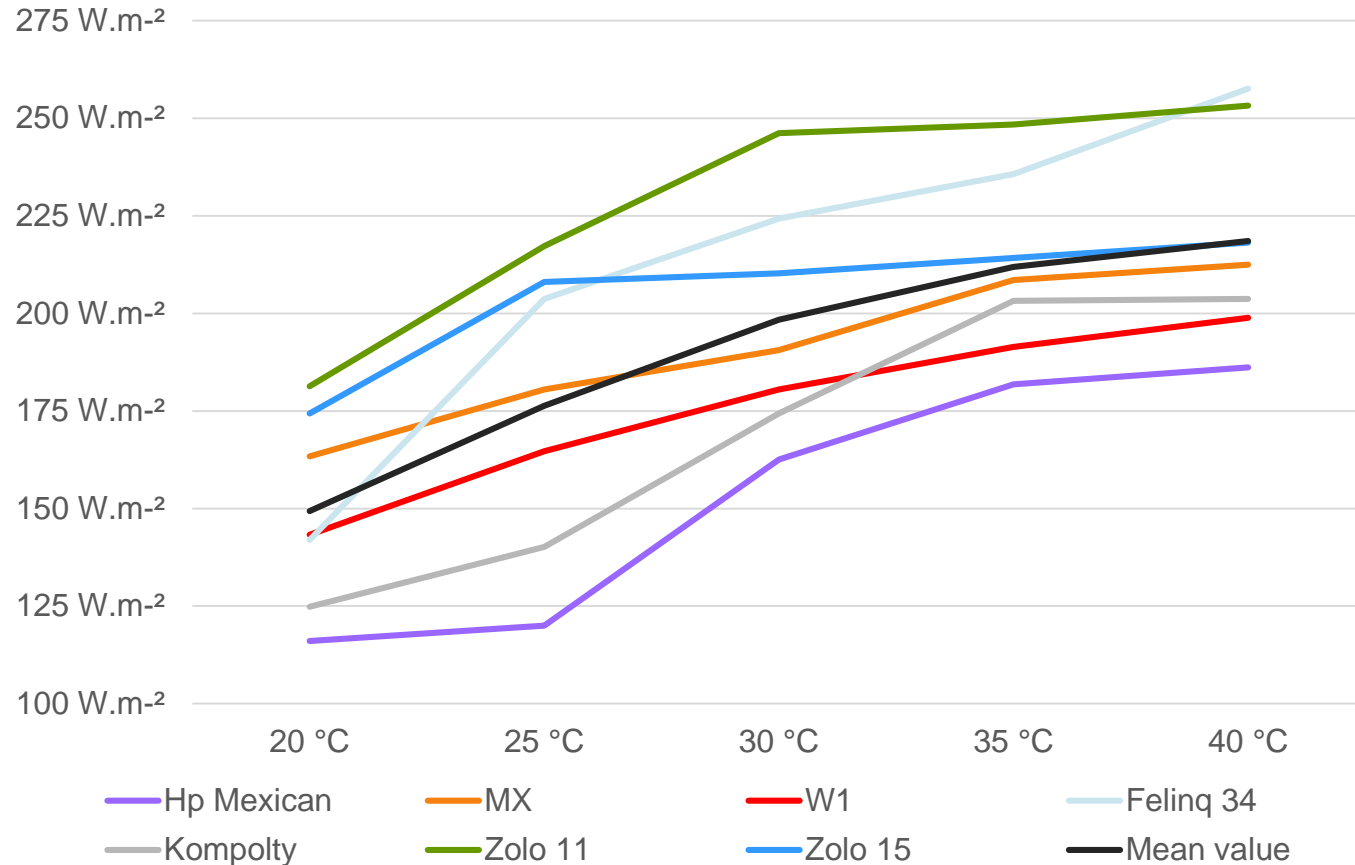
From 0,15 to 0,40 l/m²/h

Very strong correlation
between light and
transpiration

[3] CHANDRA, Suman, LATA, Hemant, MEHMEDIC, Zlatko, KHAN, Ikhlas A. and ELSOHLI, Mahmoud A., 2015. Light dependence of photosynthesis and water vapor exchange characteristics in different high Δ9-THC yielding varieties of Cannabis sativa L. *Journal of Applied Research on Medicinal and Aromatic Plants*. June 2015. Vol. 2, no. 2, p. 39–47. DOI [10.1016/j.jarmap.2015.03.002](https://doi.org/10.1016/j.jarmap.2015.03.002).

02 Temperature, light and transpiration

LATENT HEAT FLUX OF MANY CULTIVARS UNDER DIFFERENT TEMPERATURE GUIDELINES AND $1500\mu\text{MOL.M}^{-2}.\text{S}^{-1}$



$1500\mu\text{mol.m}^{-2}.\text{s}^{-1}$ of light \cong 315 W.m^{-2} of energy

Between 35% and 80% of the lighting energy is used for vaporization

[2] CHANDRA, Suman, LATA, Hemant, KHAN, Ikhlas A. and ELSOHLI, Mahmoud A., 2011. Temperature response of photosynthesis in different drug and fiber varieties of *Cannabis sativa* L. *Physiology and Molecular Biology of Plants*. July 2011. Vol. 17, no. 3, p. 297–303. DOI [10.1007/s12298-011-0068-4](https://doi.org/10.1007/s12298-011-0068-4).

02 Temperature, light and transpiration

WHAT YOU MUST REMEMBER



Transpiration increase with temperature rise

0,25 – 0,30l/m²/h under guidelines temperature

0,5l/m²/h under extreme conditions



Transpiration increase with light PPFD rise

35% to 80% of the lighting energy is used for transpiration under 1500μmol.m⁻².s⁻¹

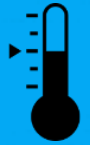


CO₂ supply

How does cannabis react in a CO₂ enriched environment?

03

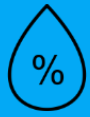




25°C



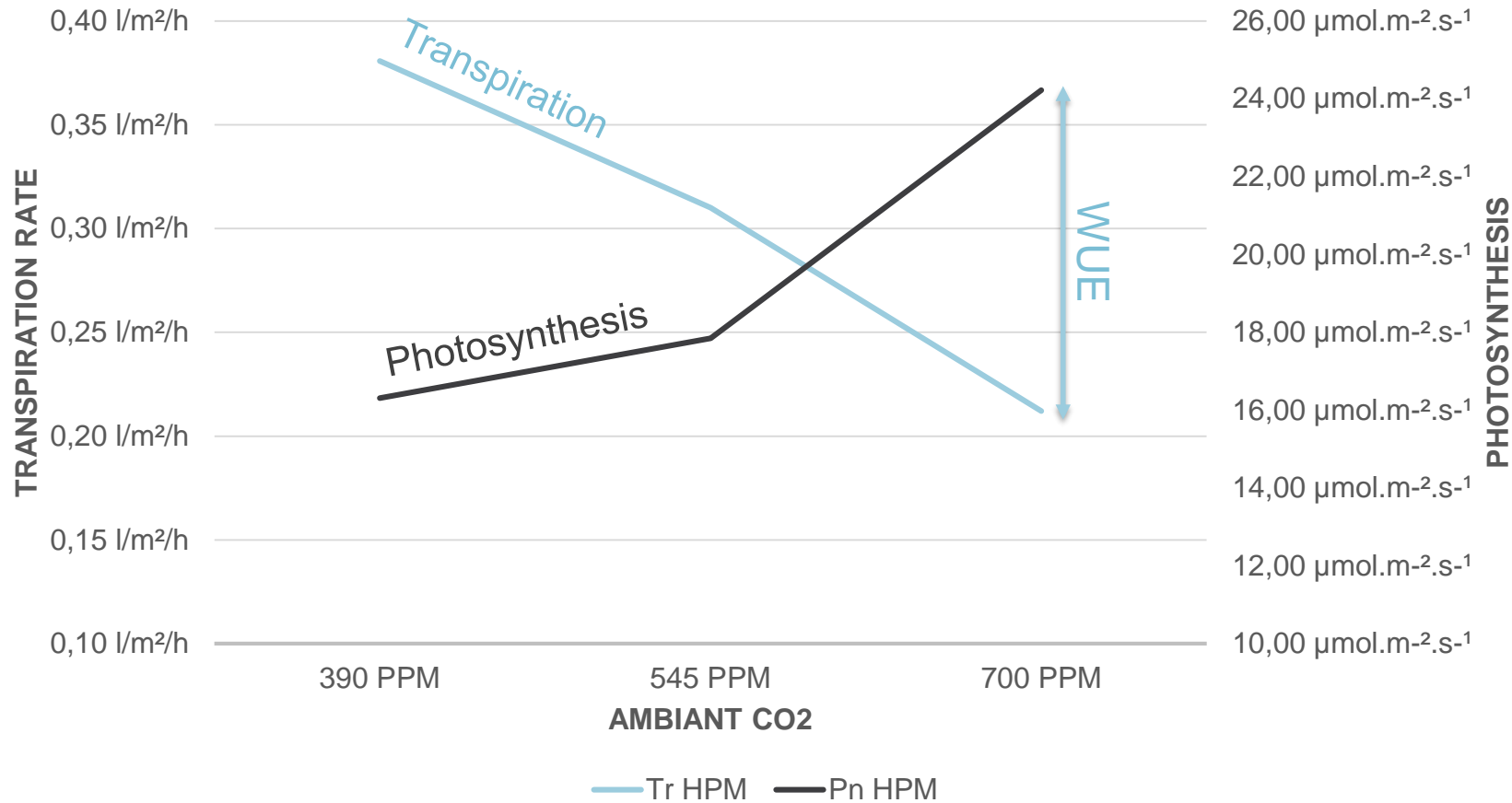
1500 PPFD



55%

03 CO₂ supply

TRANSPIRATION RATE OF MANY CULTIVARS UNDER DIFFERENT CO₂ GUIDELINES, 1500 μMOL.M⁻².S⁻¹ OF PPFD AND 25°C



Water Use Efficiency

$$\frac{Pn}{Tr}$$

The higher the better : less water loss for higher yield

[4] CHANDRA, Suman, LATA, Hemant, KHAN, Ikhlas A. and ELSOHLY, Mahmoud A., 2011. Photosynthetic response of Cannabis sativa L., an important medicinal plant, to elevated levels of CO₂. *Physiology and Molecular Biology of Plants*. July 2011. Vol. 17, no. 3, p. 291–295. DOI [10.1007/s12298-011-0066-6](https://doi.org/10.1007/s12298-011-0066-6).



Estimate your profitability

How to use physiological behavior to estimate your project profitability?

04



04 Estimate your profitability

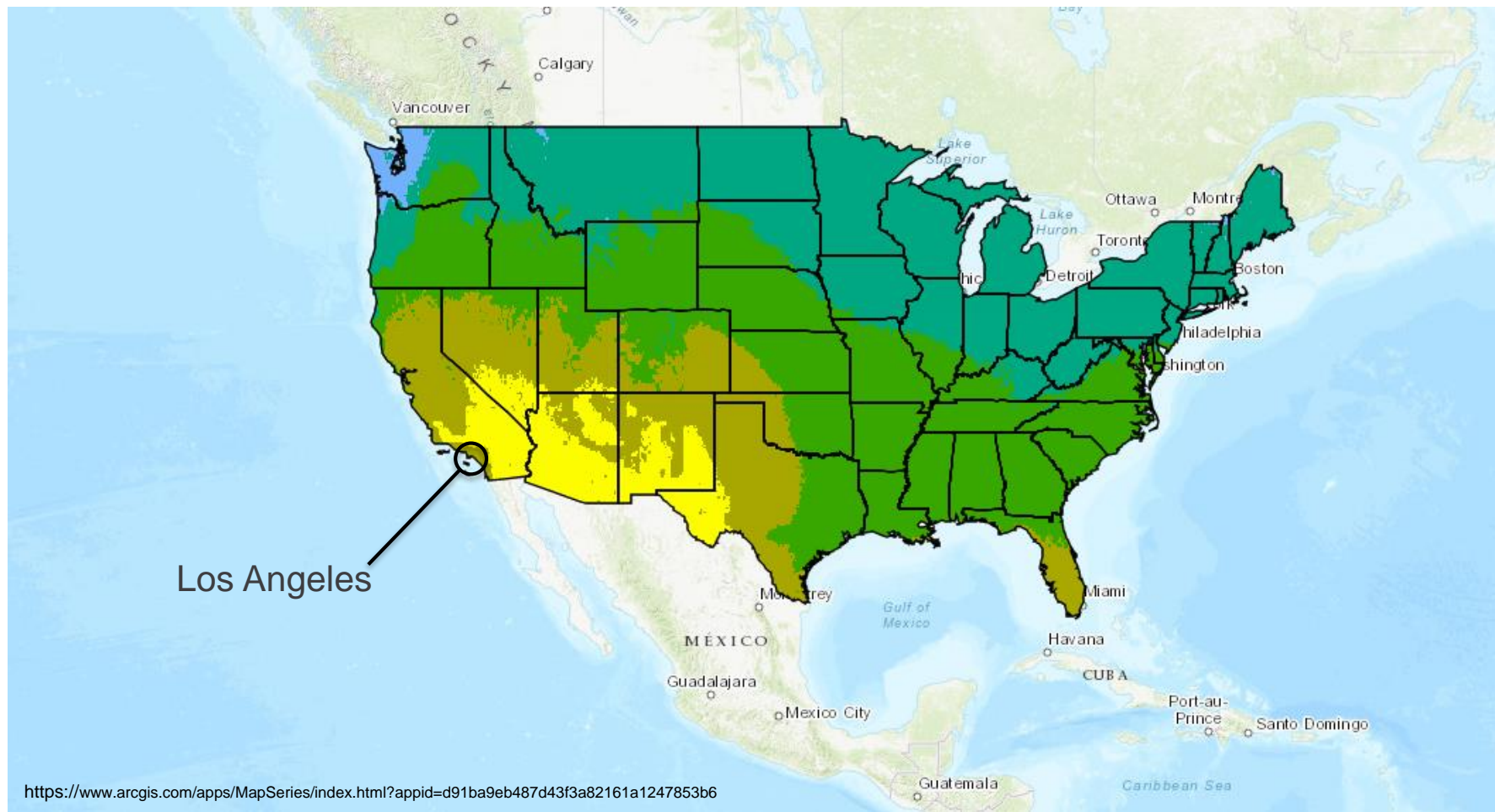
INCREASING LIGHT : FOR WHICH BENEFITS? FOR WHICH COSTS?

PPFD ($\mu\text{mol.m}^{-2}.\text{s}^{-1}$)	Photophase (h)	DLI (mol.d^{-1})
400	12	17
800	12	35
1200	12	52
1600	12	69
2000	12	86

For an equal DLI, PPFD can change depending on the day duration. PPFD can be expressed considering DLI and photophase

04 Estimate your profitability

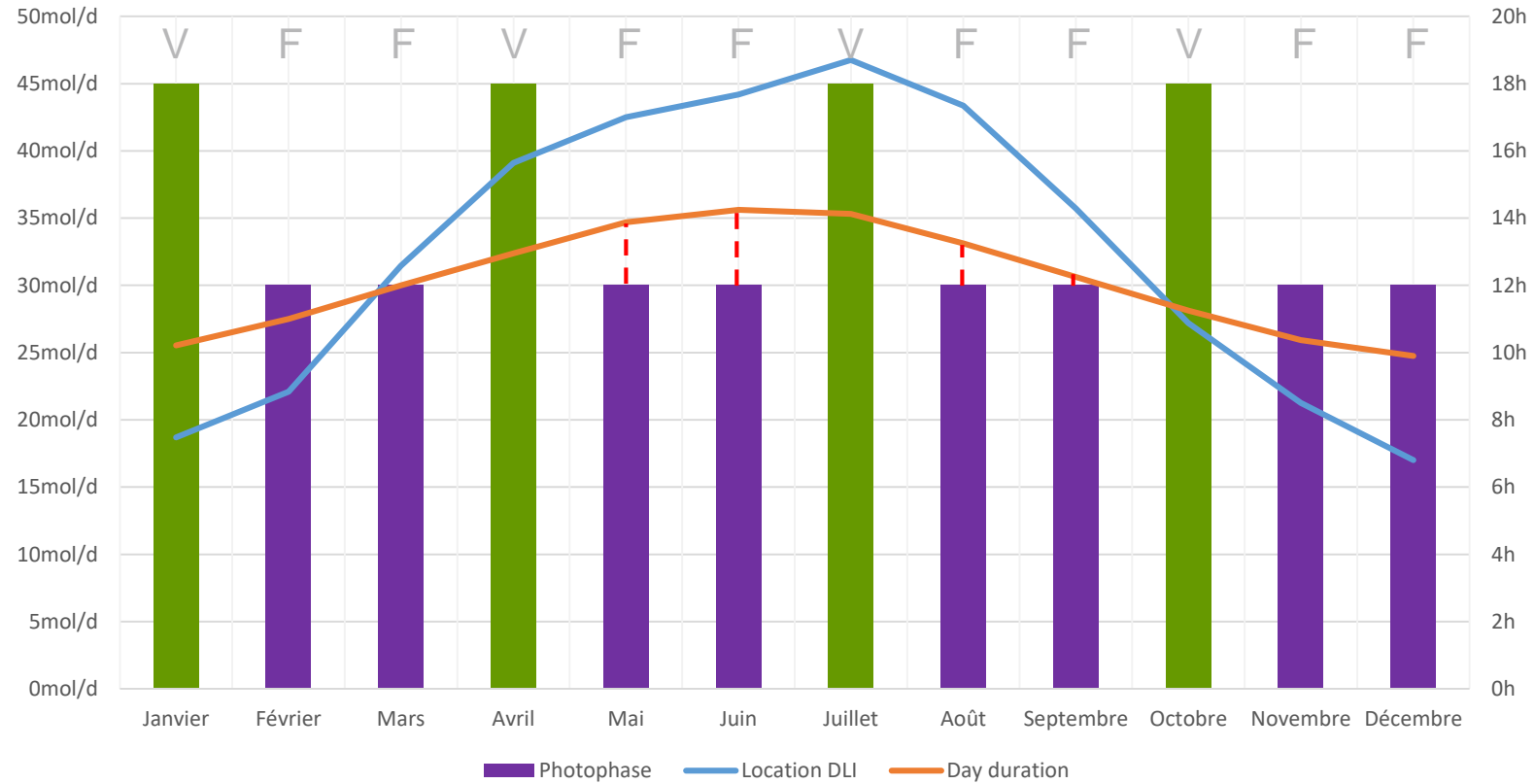
I. ANALYSIS OF LOCATION'S DATAS



04 Estimate your profitability

I. ANALYSIS OF LOCATION'S DATAS

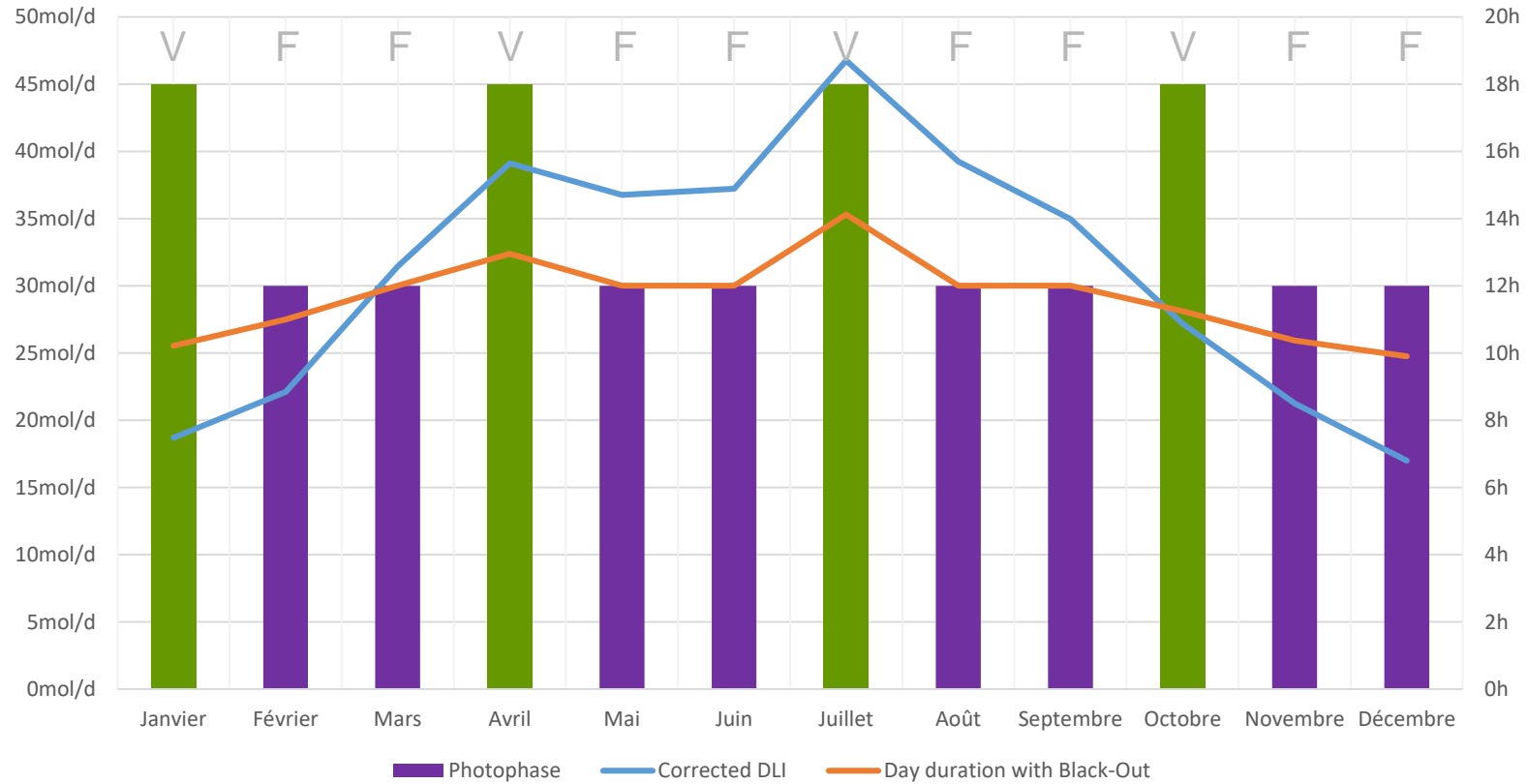
Los Angeles DLI and day duration with medicinal cannabis photophase



04 Estimate your profitability

I. ANALYSIS OF LOCATION'S DATAS

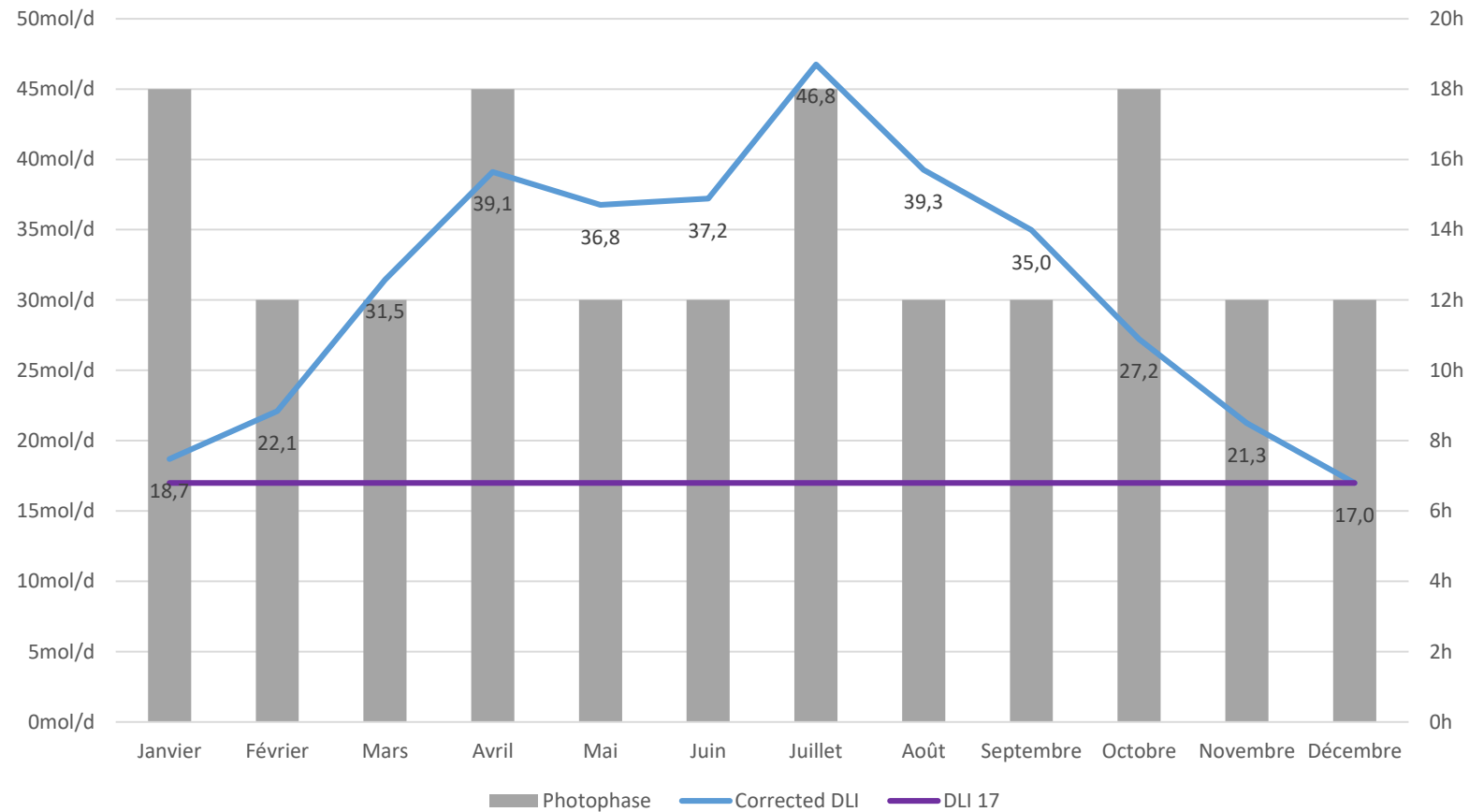
Los Angeles corrected DLI and day duration with medicinal cannabis photophase



04 Estimate your profitability

II. COMPARISON TO GUIDELINES : 17MOL

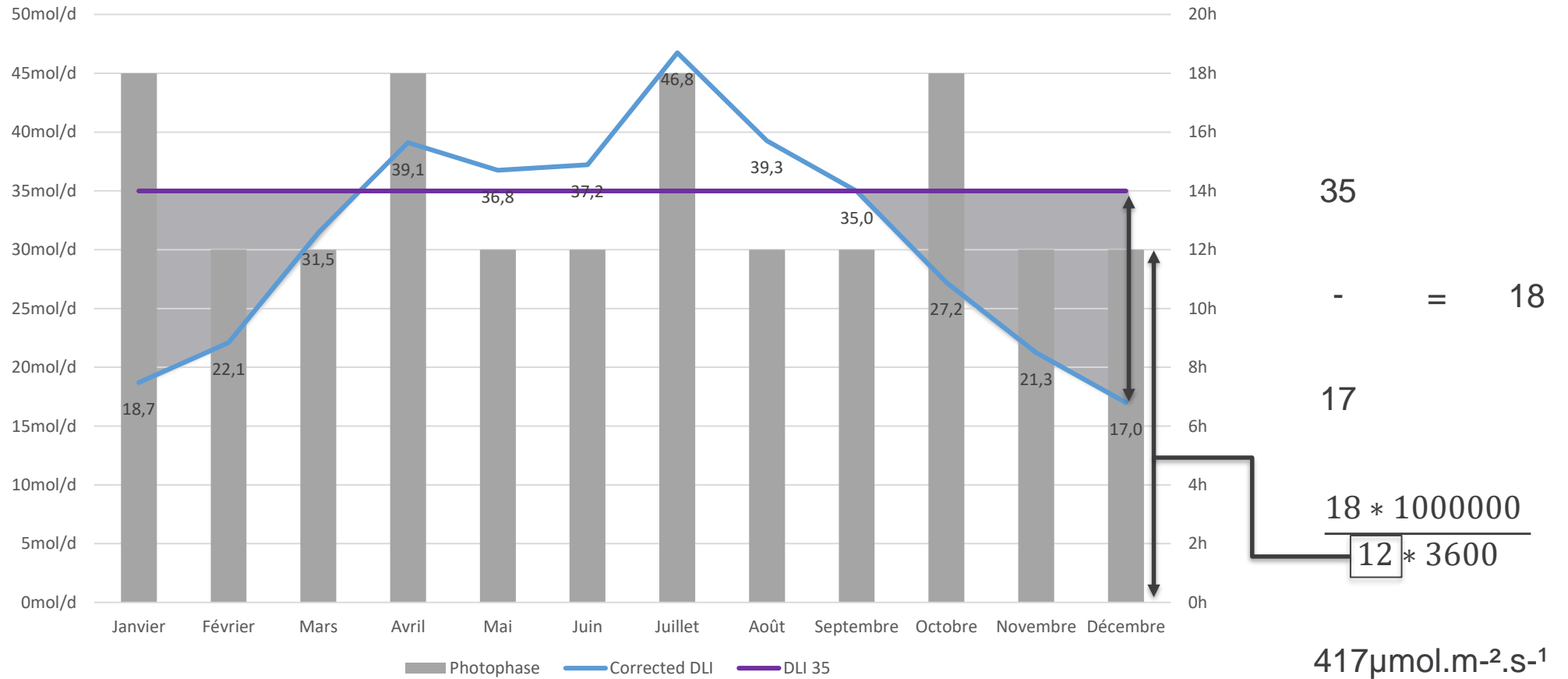
Los Angeles corrected DLI compared to a 17mol DLI needs (400 μ mol during 12h)



04 Estimate your profitability

III. COMPARISON TO GUIDELINES : 35MOL

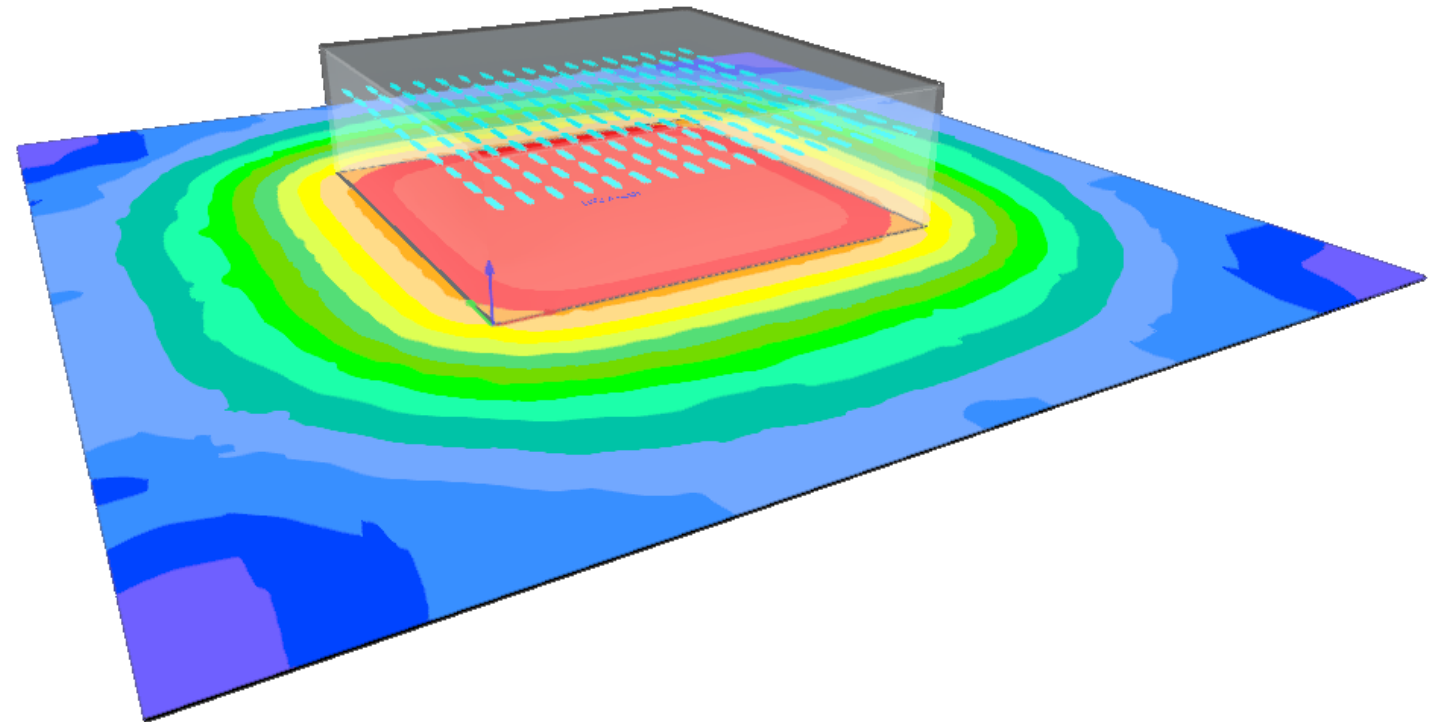
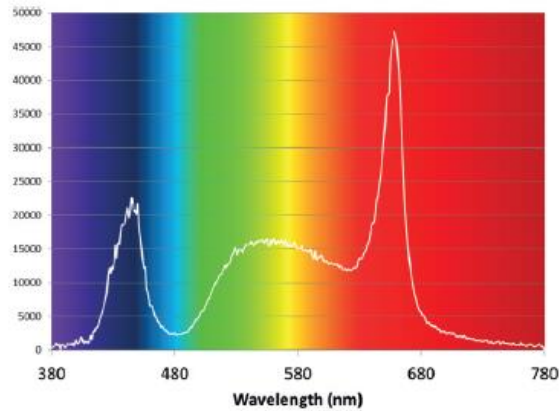
Los Angeles corrected DLI compared to a 35mol DLI needs (800μmol during 12h)



04 Estimate your profitability

III. COMPARISON TO GUIDELINES : 35MOL

Simulation in a 3D 400 m² glasshouse

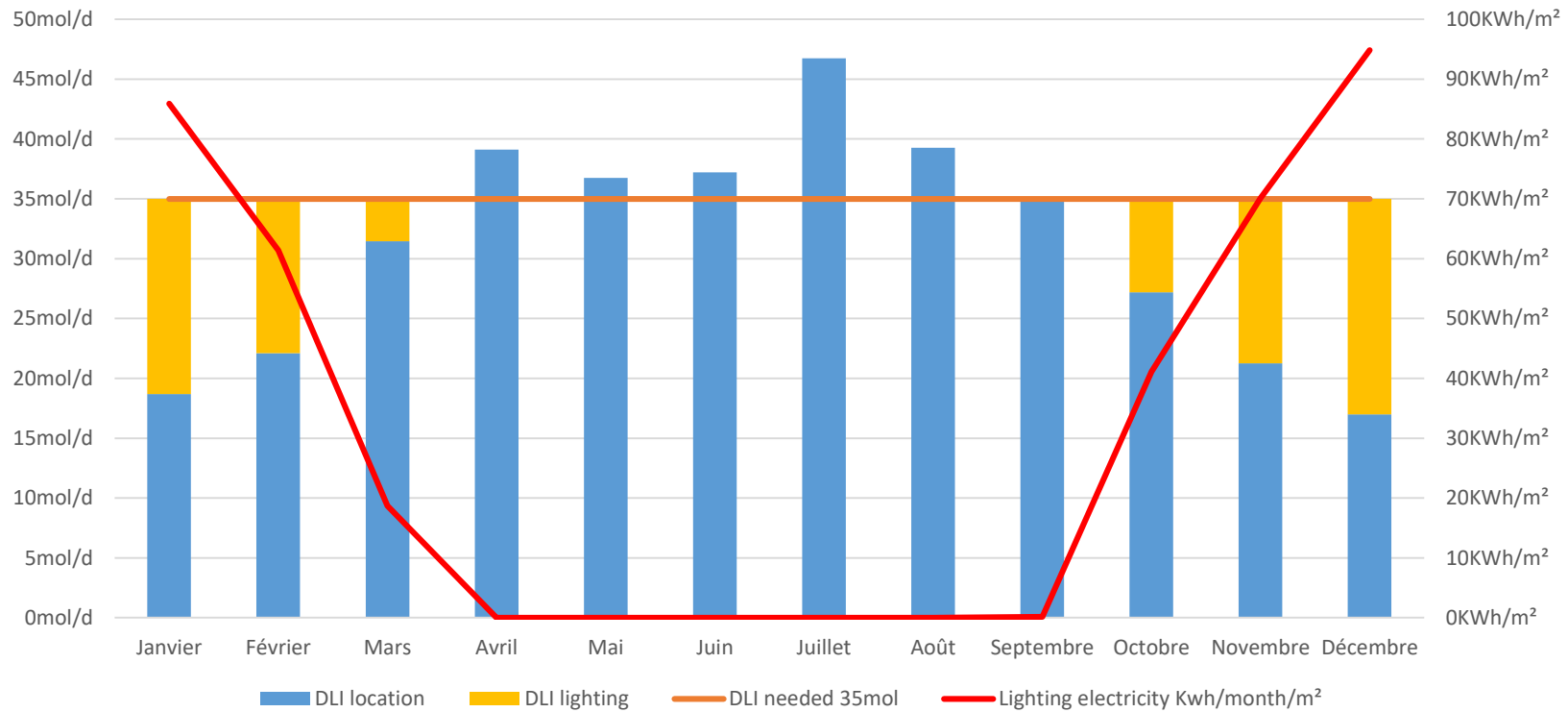


- LED Lamps (600W)
- Need of 170 lamps (0,43l/m²)
- 1175\$ per lamps (considering electricity raccordments) and 5 years of accounting depreciation

04 Estimate your profitability

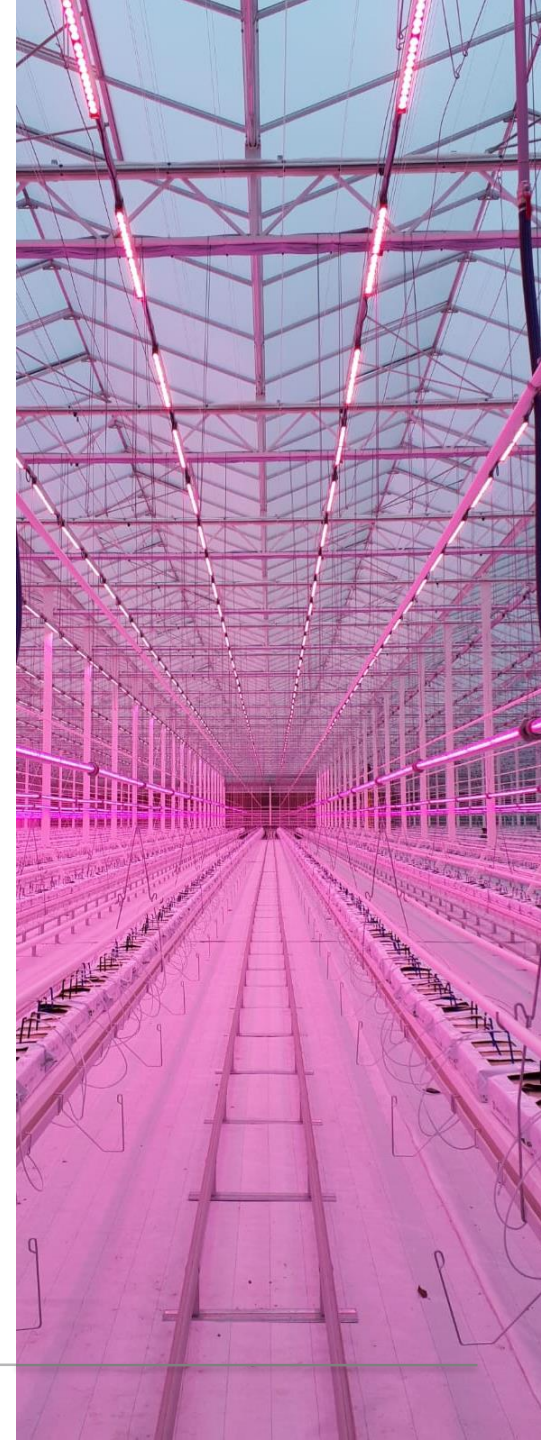
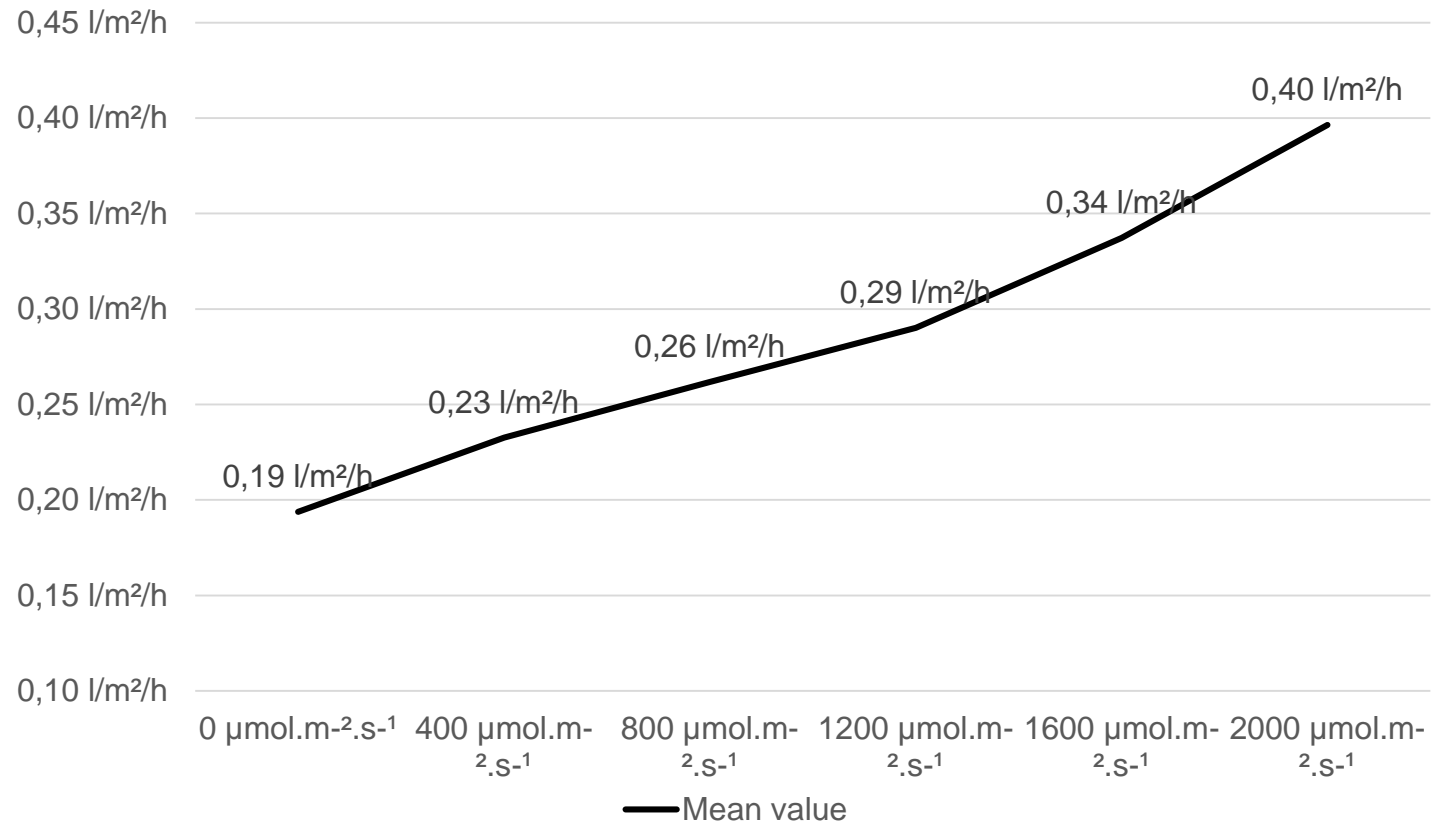
III. COMPARISON TO GUIDELINES : 35MOL

Artificial lighting DLI and electricity consumption per square meter for a 35mol/day guideline



04 Estimate your profitability

III. COMPARISON TO GUIDELINES : 35MOL



04 Estimate your profitability

III. COMPARISON TO GUIDELINES : 35MOL

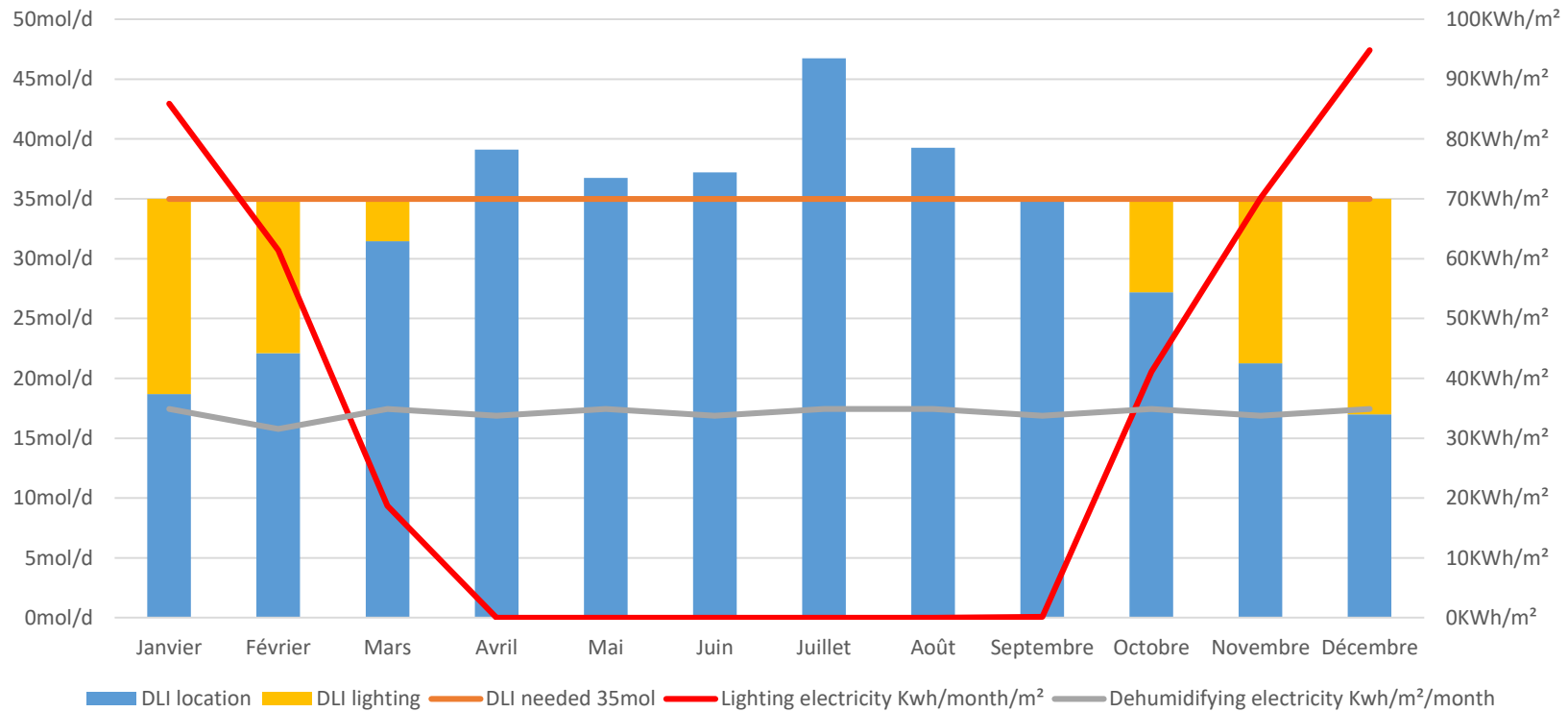


DLI (mol.d ⁻¹)	17	35	52	69	86
Transpiration (l.m ⁻² .h ⁻¹)	0,23	0,26	0,29	0,34	0,4
Dehumidification capacity (l.h ⁻¹)	12	12	12	12	12
Area (m ²)	400	400	400	400	400
Number of units (n)	8	9	10	11	13
Consumption (W)	4170	4170	4170	4170	4170
Price (\$)	7795	7795	7795	7795	7795
Equipment price (\$)	53600	60300	67000	73700	87100
Accounting depreciation (y)	5	5	5	5	5

04 Estimate your profitability

III. COMPARISON TO GUIDELINES : 35MOL

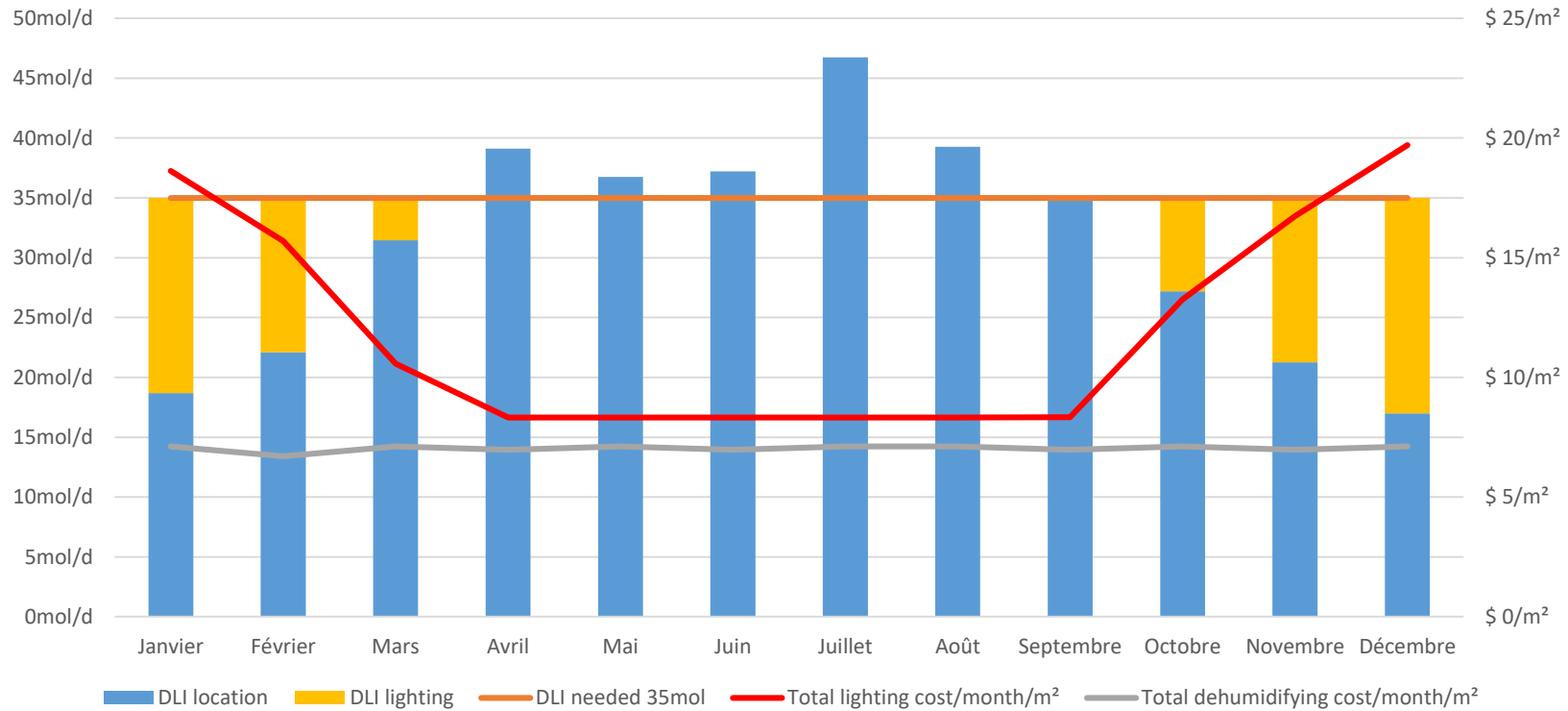
Artificial lighting DLI and electricity consumption per square meter for a 35mol/day guideline



04 Estimate your profitability

III. COMPARISON TO GUIDELINES : 35MOL

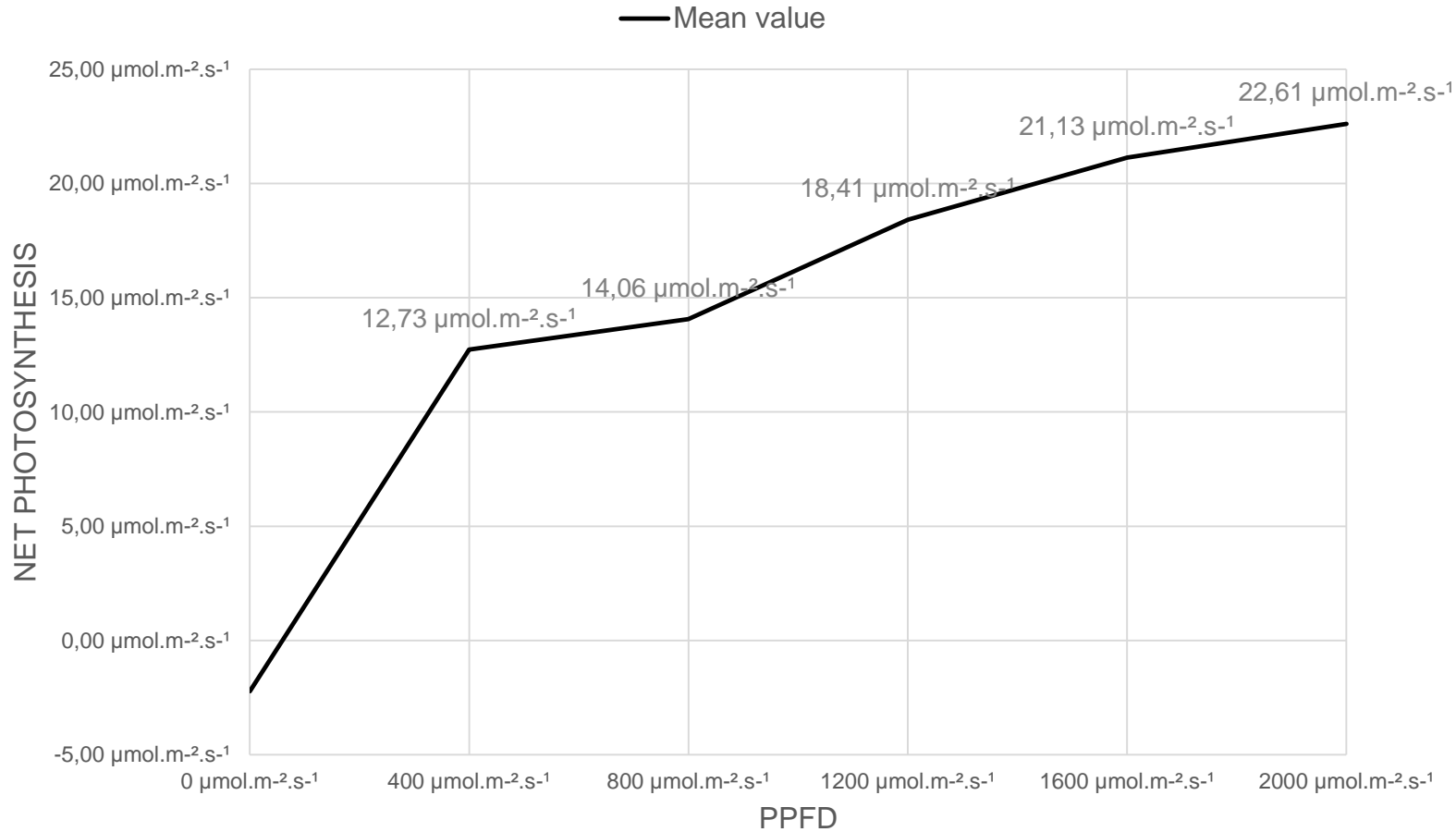
Artificial lighting DLI and total lighting cost (investment and electricity consumption) per square meter for a 35mol/day guideline



0,12\$/KWh
 Price of lamps and dehumidifying units divided by number of months of the accounting depreciation

04 Estimate your profitability

III. COMPARISON TO GUIDELINES : 35MOL



04 Estimate your profitability

III. COMPARISON TO GUIDELINES : 35MOL

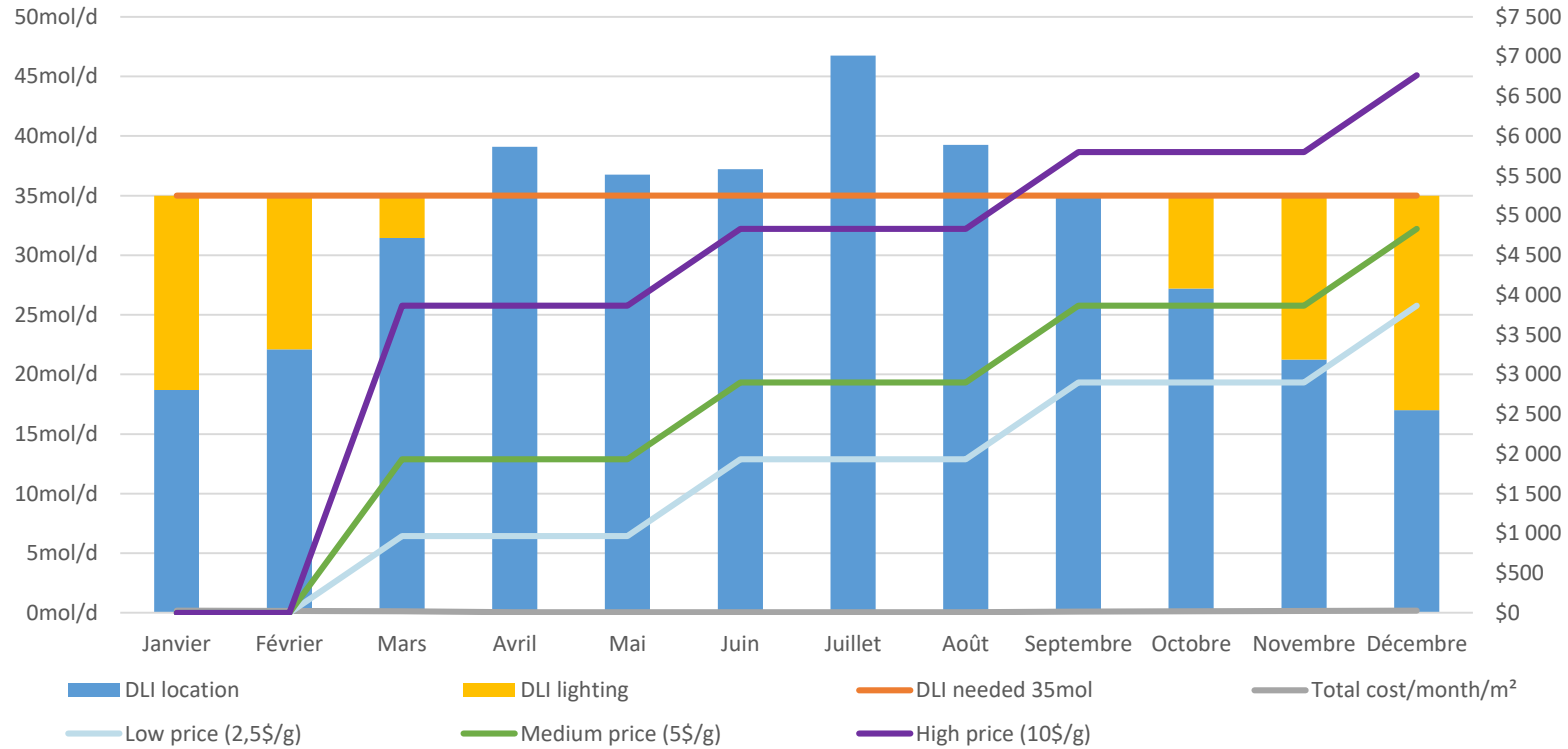
DLI (mol.d ⁻¹)	17	35	52	69	86
Photosynthesis (mmol.m ⁻² .s ⁻¹)	12,73	14,06	18,41	21,13	22,61
Evolution of photosynthesis (%)		+10%	+31%	+15%	+7%
Yield (g.m ⁻²)	350	387	506	581	622
Low price - 2,5\$/g	875\$	966\$	1265\$	1452\$	1554\$
Medium price - 5\$/g	1750\$	1933\$	2531\$	2905\$	3108\$
High price - 10\$/g	3500\$	3866\$	5062\$	5810\$	6216\$



04 Estimate your profitability

III. COMPARISON TO GUIDELINES : 35MOL

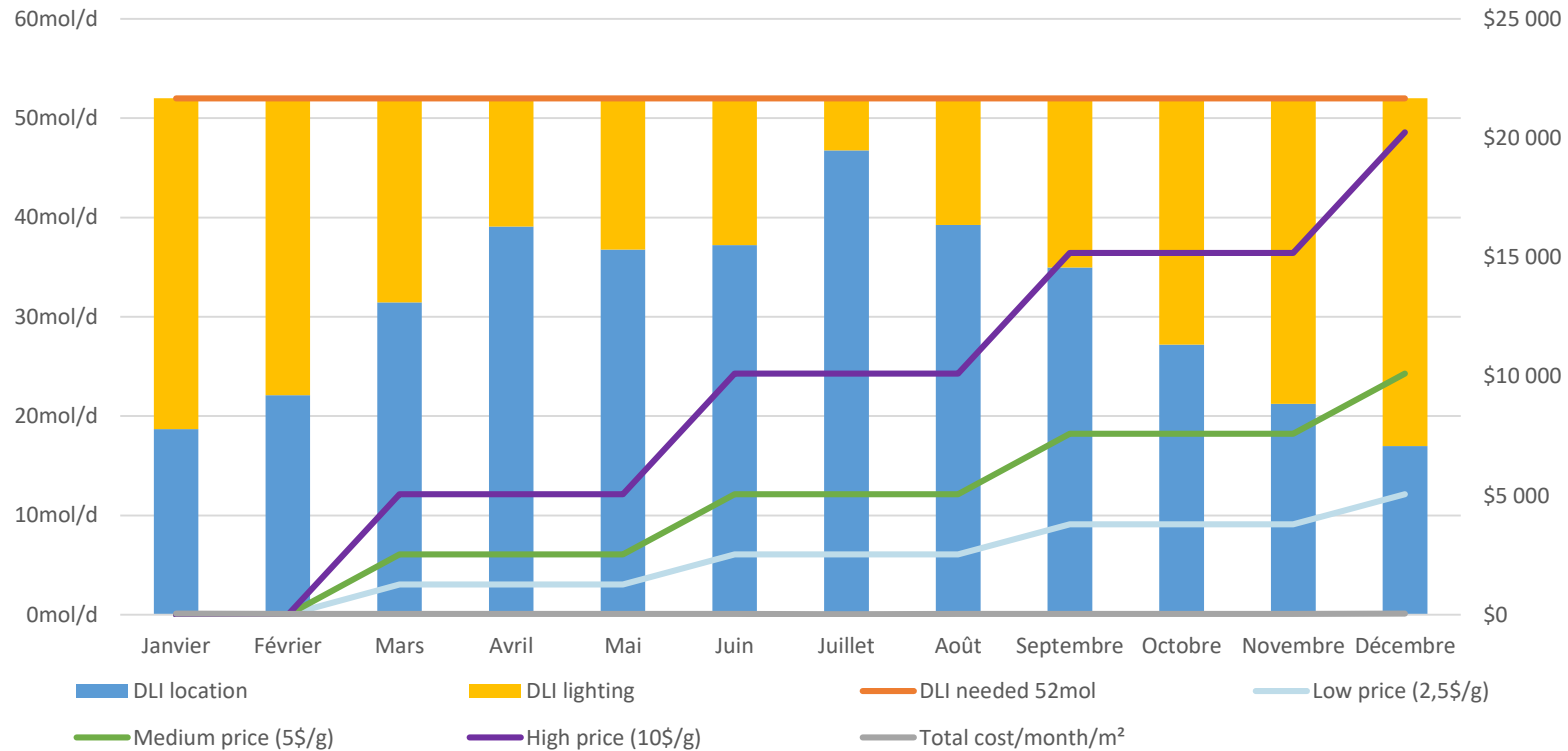
Comparison of potential turnover for three price ranges cannabis yield and total lighting cost per square meter for a 35mol/day guideline



04 Estimate your profitability

IV. COMPARISON TO GUIDELINES : 52MOL

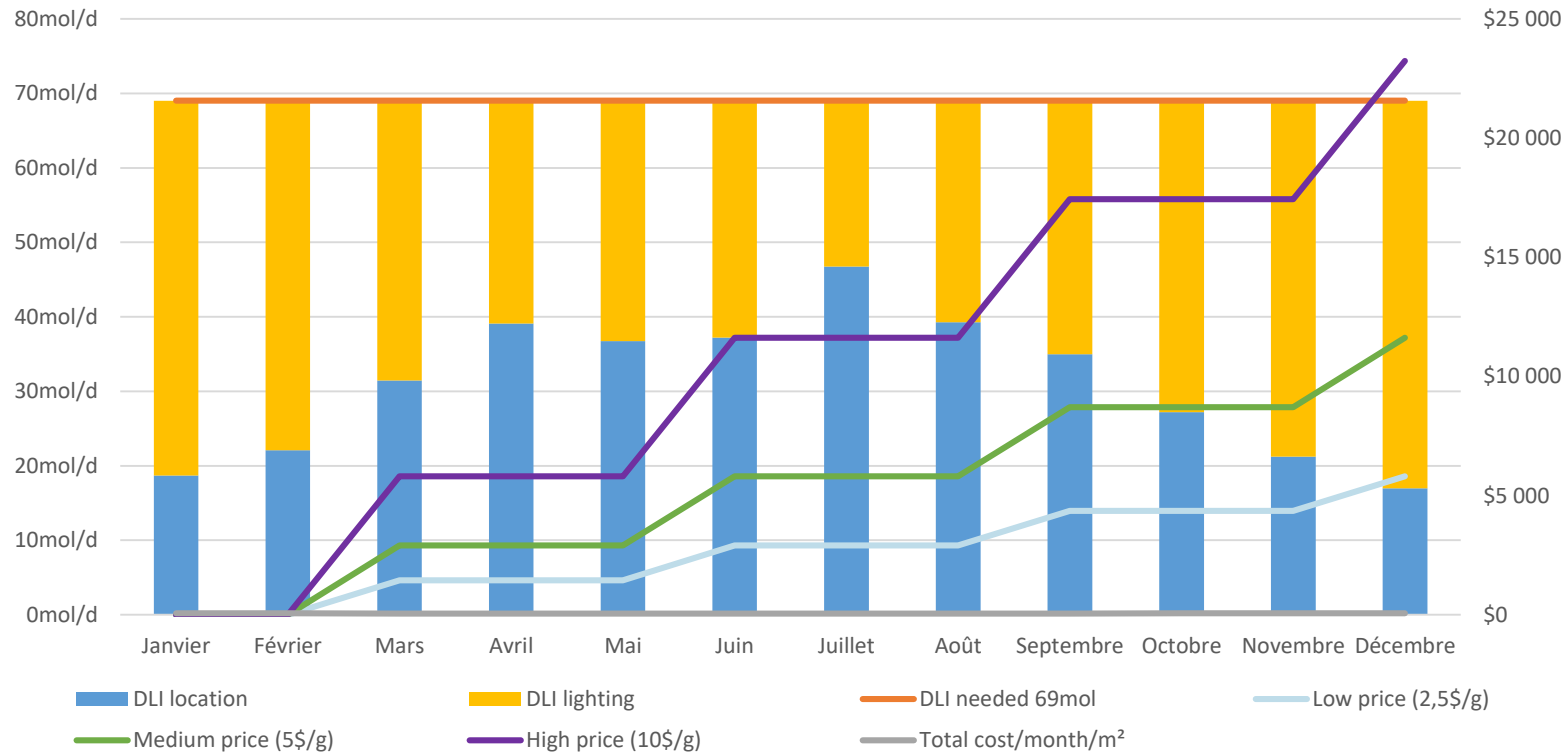
Comparison of potential turnover for three price ranges cannabis yield and total lighting cost per square meter for a 52mol/day guideline



04 Estimate your profitability

V. COMPARISON TO GUIDELINES : 69MOL

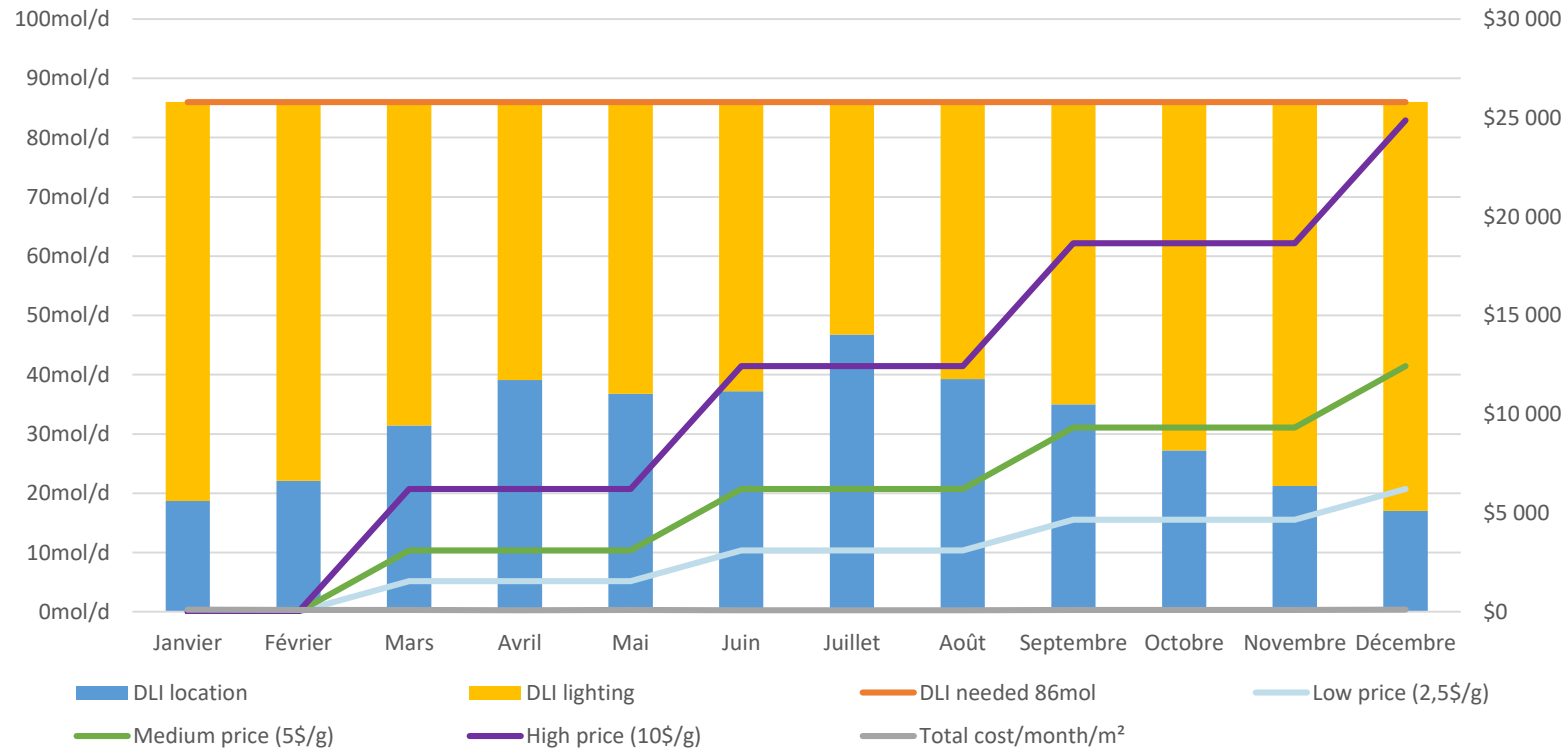
Comparison of potential turnover for three price ranges cannabis yield and total lighting cost per square meter for a 69mol/day guideline



04 Estimate your profitability

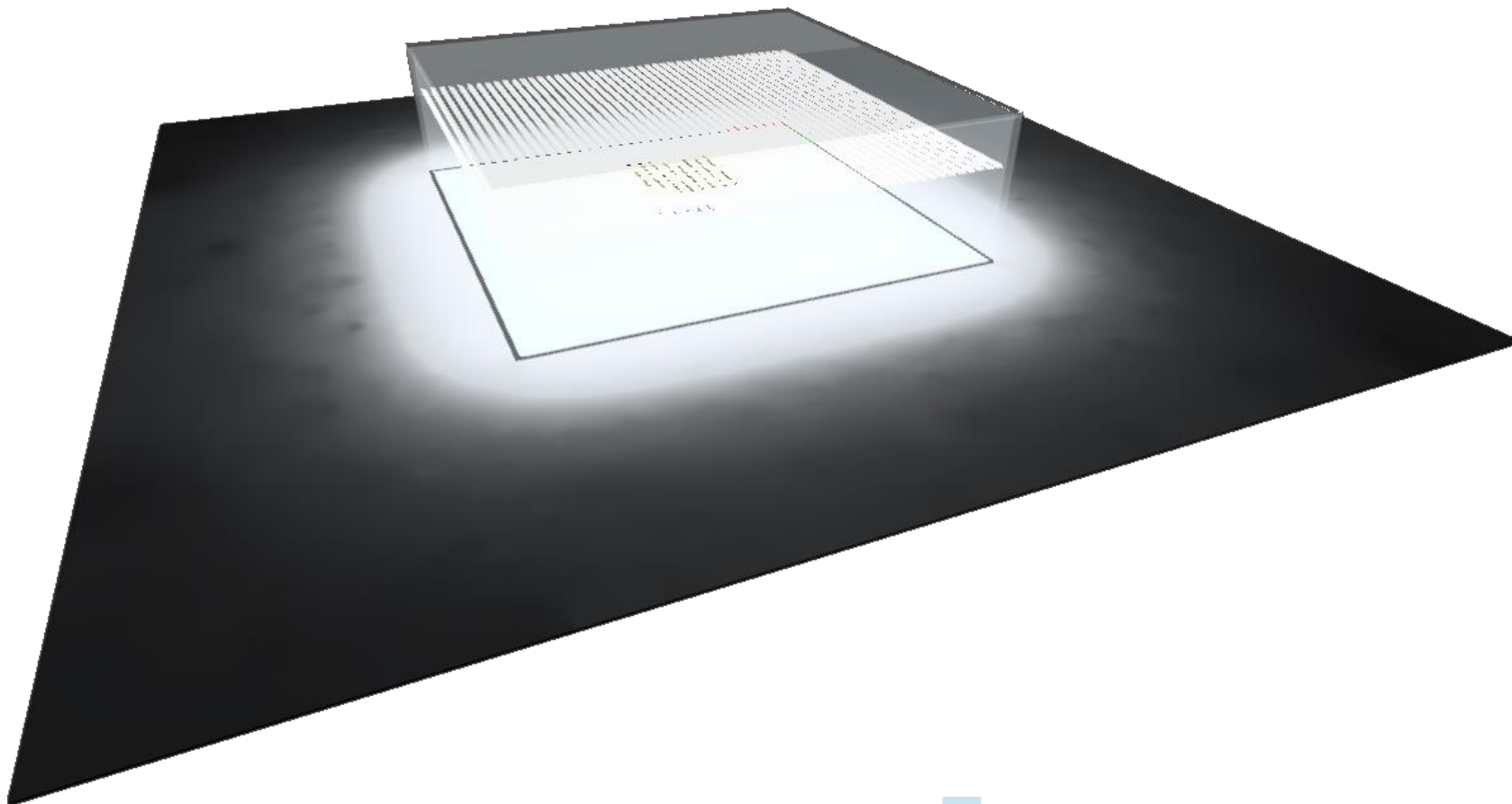
VI. COMPARISON TO GUIDELINES : 86MOL

Comparison of potential turnover for three price ranges cannabis yield and total lighting cost per square meter for a 86mol/day guideline



04 Estimate your profitability

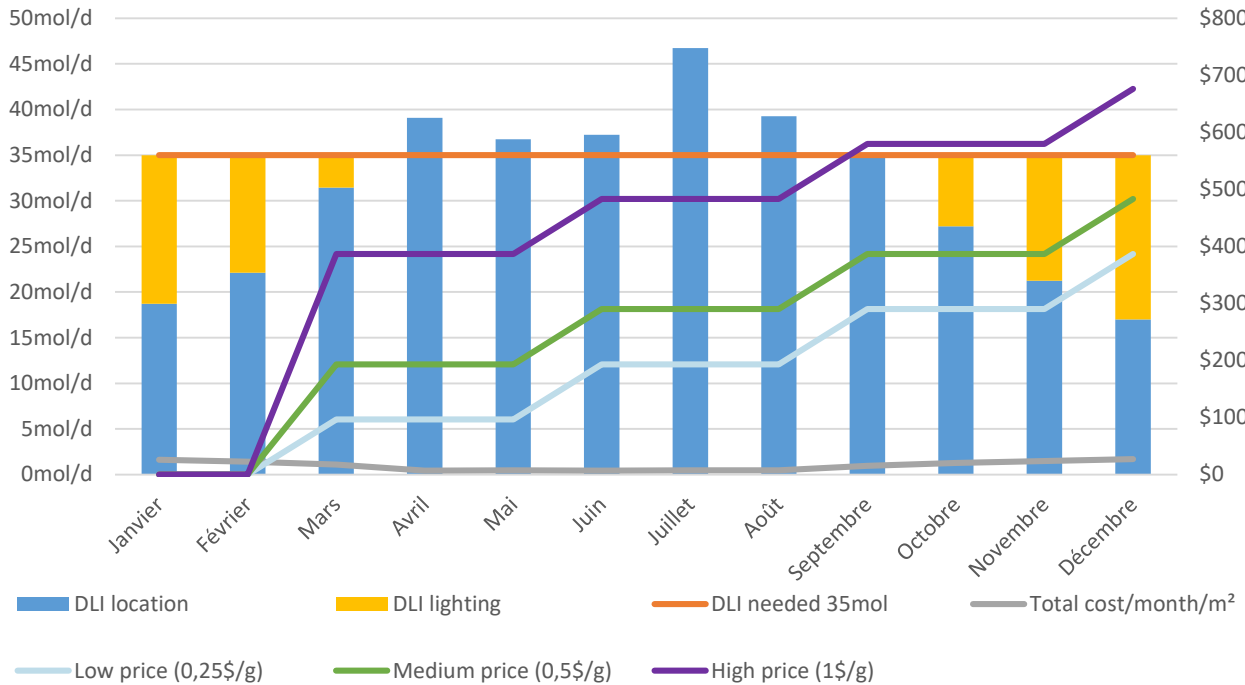
VI. COMPARISON TO GUIDELINES : 86MOL



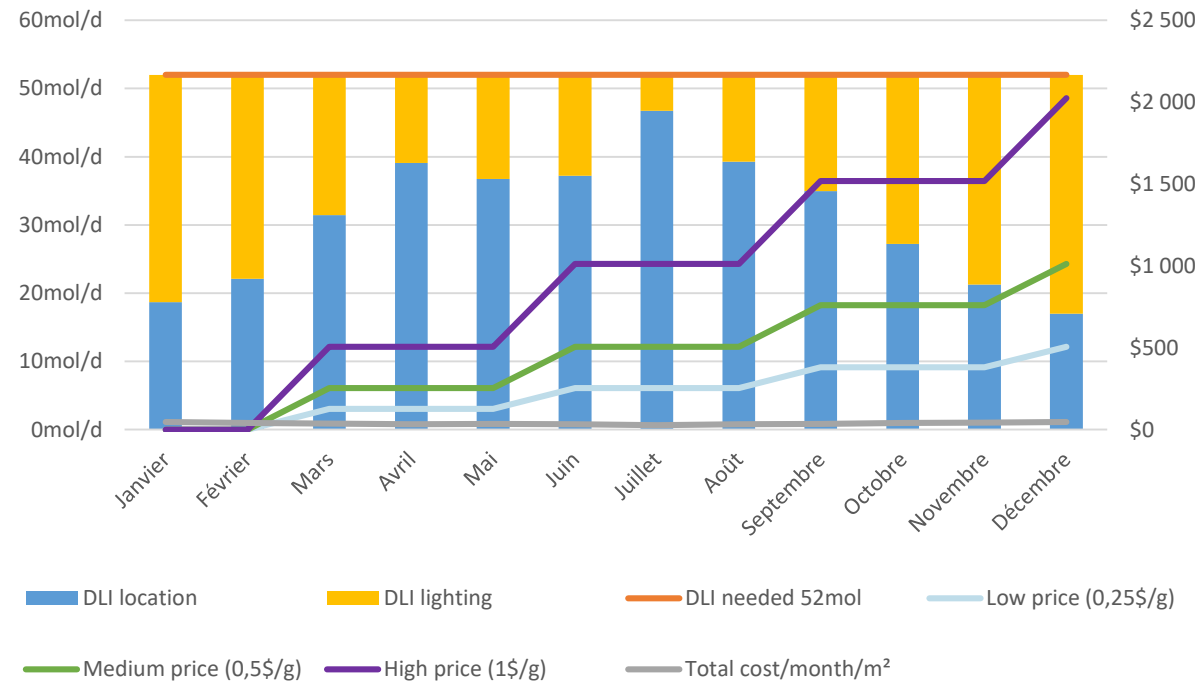
04 Estimate your profitability

VII. WHAT IF PRICES DECREASE?

Comparison of potential turnover for three price ranges cannabis yield and total lighting cost per square meter for a 35mol/day guideline



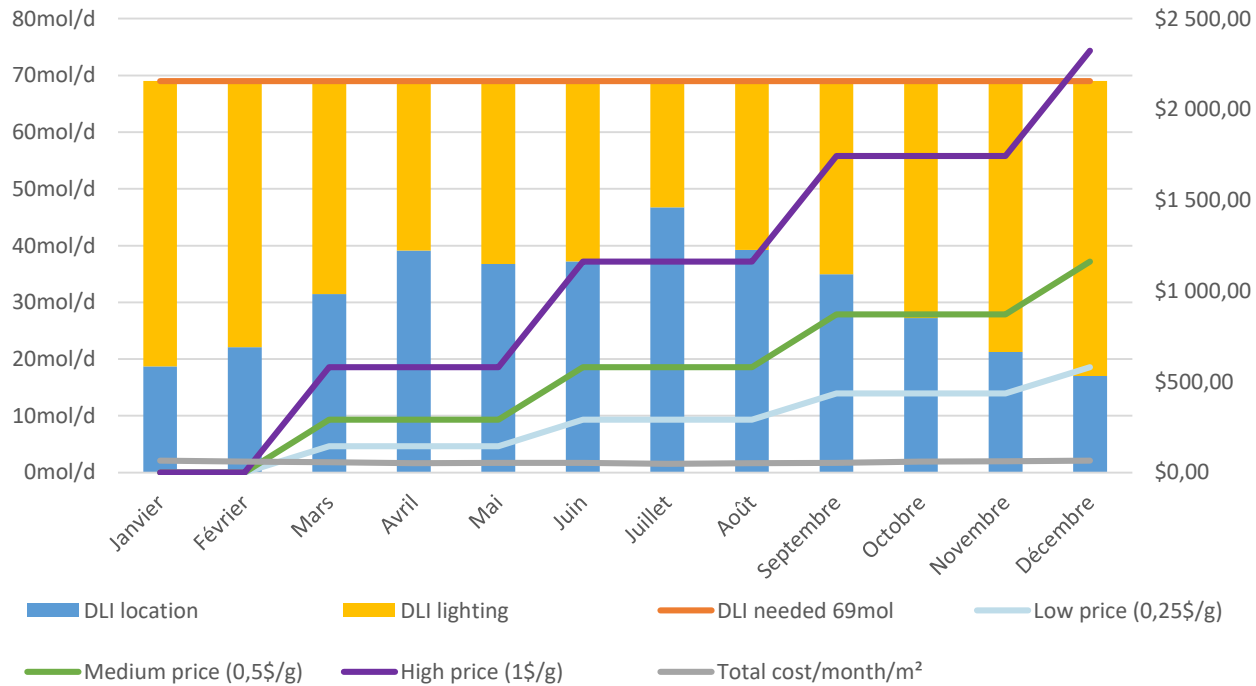
Comparison of potential turnover for three price ranges cannabis yield and total lighting cost per square meter for a 52mol/day guideline



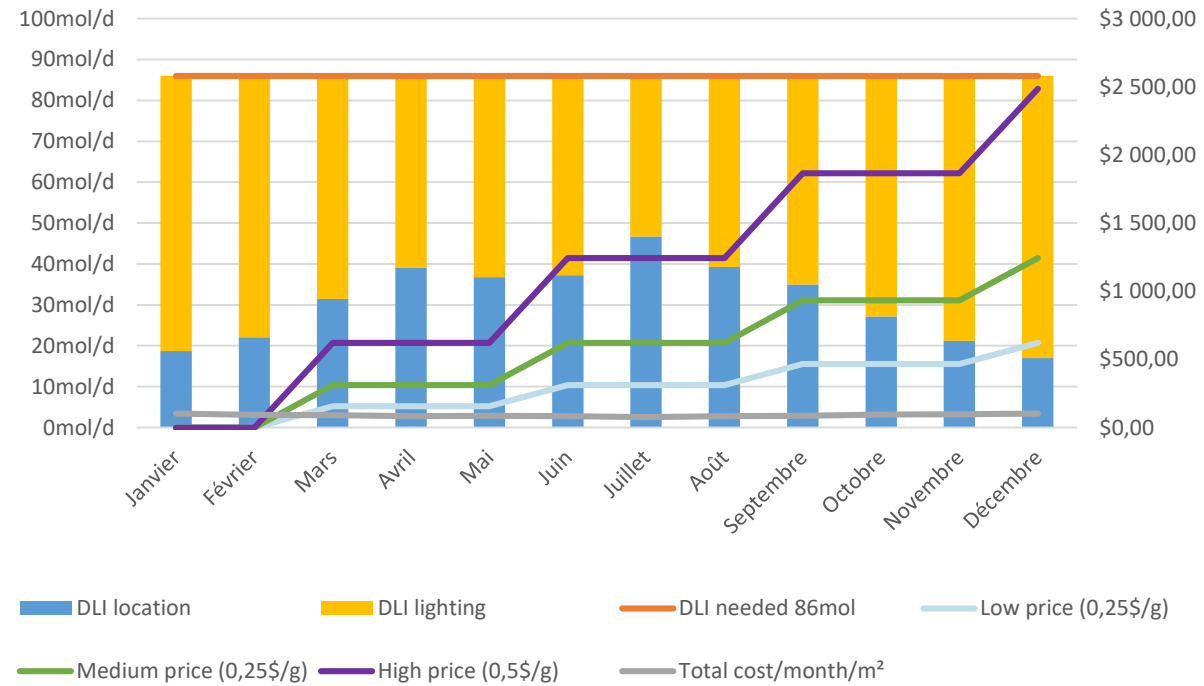
04 Estimate your profitability

VII. WHAT IF PRICES DECREASE?

Comparison of potential turnover for three price ranges cannabis yield and total lighting cost per square meter for a 69mol/day guideline



Comparison of potential turnover for three price ranges cannabis yield and total lighting cost per square meter for a 86mol/day guideline



04 Estimate your profitability

Profitability is always higher than costs

- Even when we anticipating worst case scenario
- Even when we studying non-relevant design (86mol/d)

Other costs have to be taken into account

- Temperature management
- Other equipments
- Workers



Thank you for your attention



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G R O U P

Cultivating trust

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Appendices

01 LATENT HEAT FLUX

$$LE = ET \cdot \lambda$$

LE Latent Heat

ET Evapotranspiration

λ Latent heat of water vaporization

$$\lambda = 10^3(2500 - 2,37T)$$

$$LE = \frac{mm}{s} \cdot \lambda \quad 1 \text{ mm} = 1l.m^{-2}$$



01 LATENT HEAT FLUX

Latent heat is the energy used to vaporize liquid water

This energy is not used for sensible heat

Evapotranspiration reduce the temperature rise by using energy to vaporize water



02 DLI TO PPFD

DLI = mol.d⁻¹

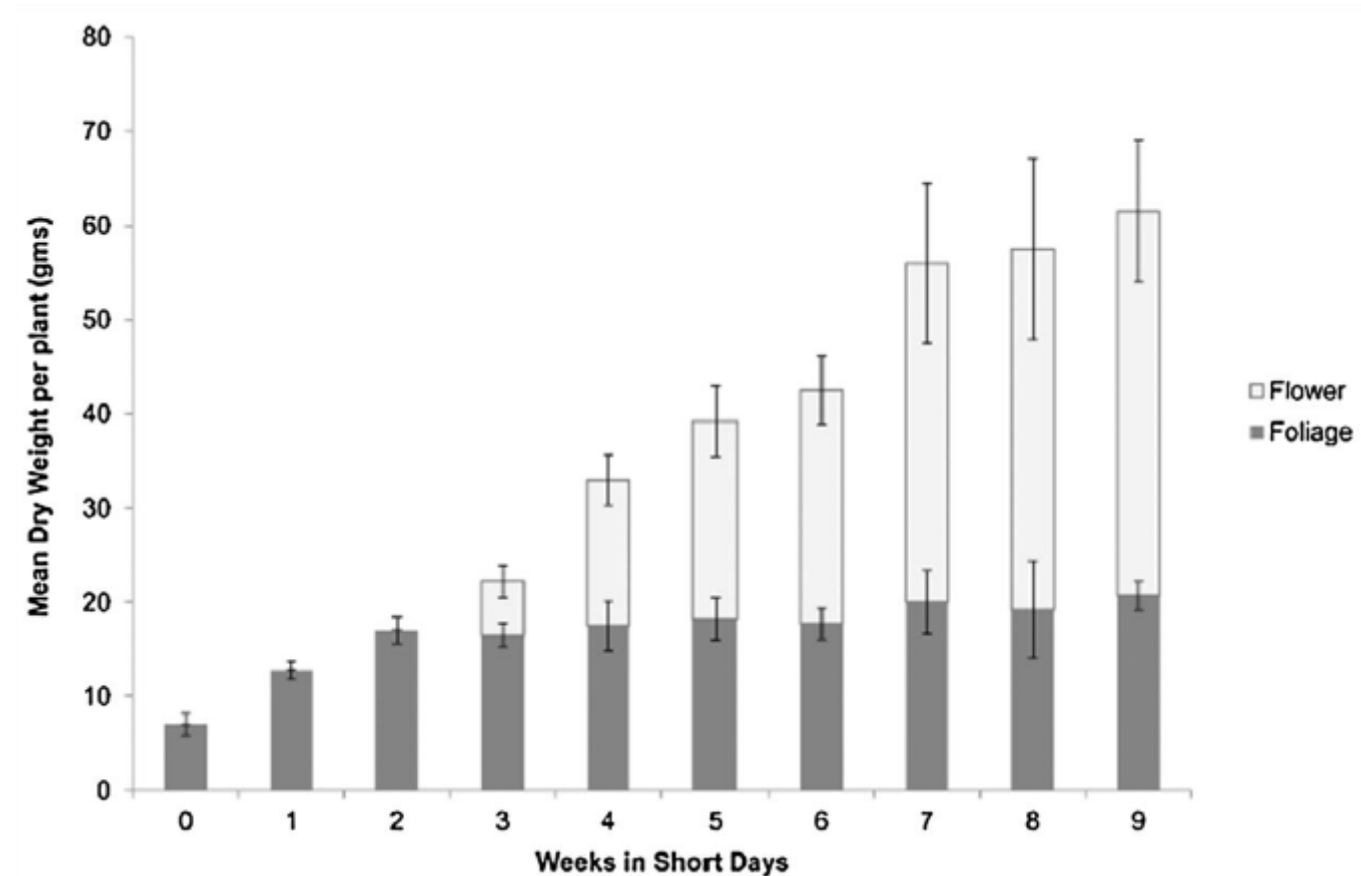
PPFD = μmol.m⁻².s⁻¹

Photoperiod = h

$$DLI = \frac{PPFD * (Photoperiod * 3600)}{1\ 000\ 000}$$

$$PPFD = \frac{DLI * 1\ 000\ 000}{(Photoperiod * 3600)}$$

03 Photosynthesis focused on flowering during short days



[5] POTTER, David J., 2014. A review of the cultivation and processing of cannabis (*Cannabis sativa* L.) for production of prescription medicines in the UK: Cultivation and processing of cannabis for production of prescription medicines. *Drug Testing and Analysis*. January 2014. Vol. 6, no. 1–2, p. 31–38. DOI 10.1002/dta.1531.

04 Photosynthesis focused on flowering

Table 2. Approximate^a conversion values for radiation of 400-700 nm from different sources. (Adapted from Thimijan and Heins, 1983.)

Radiation Source	Multiply by Indicated Value					
	Photons to Wm ⁻²	Wm ⁻² to Photons	Photons to lux ^b	Lux ^b to Photons	Wm ⁻² to lux ^b	lux ^b to Wm ⁻²
Sunlight	0.219	4.57	54	0.019	0.249	4.02
Cool white fluorescent	0.218	4.59	74	0.014	0.341	2.93
Plant growth fluorescent ^c	0.208	4.80	33	0.030	0.158	6.34
High-pressure sodium	0.201	4.98	82	0.012	0.408	2.45
High-pressure metal halide	0.218	4.59	71	0.014	0.328	3.05
Low-pressure sodium	0.203	4.92	106	0.009	0.521	1.92
Incandescent 100W tungsten halogen	0.200	5.00	50	0.020	0.251	3.99

^a Values vary depending on luminaire, lamp, ballast, and hours of use

^b Multiply lux times 93.02 to obtain foot candles

^c GTE Gro-Lux

05 CO₂ supply



Increasing ambient CO₂
increase internal CO₂
storage

Stomatal opening do not
have to be frequent
anymore