Deloitte Access Economics

Modelling the cost of Medicinal Cannabis

Department of Health – Office of Drug Control

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Deloitte.

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Glossary and key terms

CBD	Cannabidiol
CULTIVATION	The process of growing plants and harvesting
DAE	Deloitte Access Economics
DOH	Department of Health
GMP	Good Manufacturing Practice
IDMU	Independent Drug Monitoring Unit
MANUFACTURING	The process of extracting cannabis oil from the cultivated plant material
SQ FT	Square Feet
SQM	Square Metre
TGA	Therapeutic Goods Administration
THC	Tetrahydrocannabinol

Executive Summary

The Department of Health (DOH) through the Office of Drug Control has commissioned Deloitte Access Economics (DAE) to estimate the cost of cultivating and manufacturing medicinal cannabis. The purpose of this exercise is to cost the process from cultivation to manufacture using largely publicly available information and Deloitte internal subject matter experts.

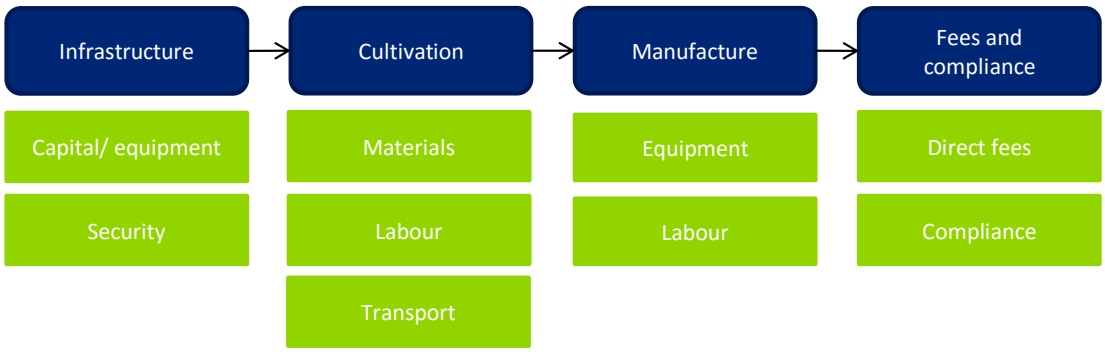
The analysis is broken up into costings for cultivation, and then for manufacturing. Three broad options for cultivation have been considered with each option based on ten individual growers. These options, and key specifications of each option, are as follows:

- Broadacre – outdoor cultivation using broadacre growing conditions, natural lighting and use of irrigation systems, located on a rural property 400-500km from manufacturer.
- Greenhouse – glass building providing protection for crops from adverse weather, natural lighting and climate control systems, located on a semi-rural property 100km from manufacturer.
- Indoor – cultivation in a building requiring artificial lighting and climate controls, either retro fit or new build in industrial area close to manufacturer.

Following cultivation, two supply chain options for the raw material (primary produce) have been considered. Firstly, the raw material of each option is transported to a domestic manufacturer, for extraction of cannabis oil. Alternatively, the raw material is exported, such that the manufacturing of cannabis oil from exported raw product is conducted internationally. The analysis looks at two export options, firstly where the dried cannabis flower is exported and secondly where the whole dried cannabis plant is exported.

Figure i provides an overview of the stages of production, under which a number of individual cost components were categorised. For example, cultivation includes activities such as planting, harvesting, materials, utility costs and transport. The cost for each component has been based on a literature review and desktop research, consultations and internal Deloitte expertise from similar processes.

Figure i: Overview of stages of production



Results

The establishment of a medicinal cannabis industry in Australia is likely to see a number of farms or growers enter the market. The number of growers who would establish operations is not known and would depend on factors such as total demand, licensing and regulations, expertise and appropriate facilities. Given the uncertainties around the number of growers, the analysis here focuses on costs as they would apply for ten growers meeting the national demand, as distinct from a single grower. Were cultivation to be conducted in a single facility meeting the same national demand, we would expect total cost to decrease due to gains in economies of scale and removing duplicated costs such as infrastructure, labour, security and regulatory costs. To illustrate the relationships between numbers of growers, size of operation and costs, a sensitivity analysis was conducted to investigate the impact on costs of varying the number of growers to 1, 5 and 20 growers.

Cultivation

The results of the cost analysis presented below assume a total annual demand in Australia of around 11 tonnes of dried cannabis flowers for the end use of 30,400 patients at maturity, based on one gram of plant product per day per patient. The level of demand is based on research by the University of Sydney Community Placement Program, in partnership with MGC Pharmaceuticals, investigated the potential demand of medicinal cannabis.[1] Based on this research, the expected number of patients using medicinal cannabis across medical conditions multiple sclerosis, HIV/AIDS, epilepsy and cancer is around 30,400 per annum at maturity.

The estimated cost of cultivation to meet the projected demand per annum is detailed below for each cultivation option. The results show that broadacre is the lowest cost option at $75 per square metre (sqm) or $888 per kg dried flower, and indoor the most expensive at $2,291 per sqm or $1,909 per kg dried flower. This translates to an annualised cost at maturity of $9.9 million per annum for broadacre, $17.1 million for greenhouse and $21.2 million for indoor cultivation.

The **annualised cost** accounts for operational expenses and a portion of the initial capital and infrastructure costs, that is, if equipment is expected to have a useful life of 10 years then 10% of the cost is accounted for each year. The **total estimated cost**, however, accounts for operational expenses and the full capital build and equipment expense required to establish the operation in year one to meet the expected demand for cannabis products. Total costs range from $10.6 million under broadacre to $41.8 million for indoor operations.

[1] MGC Pharma 2016, *Medicinal Cannabis in Australia: Science, Regulation & Industry*

Table ii: Annual cost of cultivation

Cultivation	$ per sqm	$ per kg dried flower	Annualised cost ($ million)	Total cost ($ million)
Broadacre	75	888	9.9	10.6
Greenhouse	1,108	1,539	17.1	20.5
Indoor	2,291	1,909	21.2	41.8

Source: Deloitte Access Economics

The significant difference between the costs of producing medicinal cannabis under different options relates predominantly to materials for cultivation and capital and infrastructure requirements. Because cultivation options using a greenhouse and indoor facilities would require large up-front investment in facilities, as well as high operational costs such as energy and fertiliser, these options necessarily come with higher costs. However, by cultivating under controlled conditions, they may give greater security of supply and, potentially, higher quality product[2]. Table iii shows the estimated cost for each stage of cultivation.

Across all cultivation options, the labour and materials for cultivation are the most significant costs. The total labour costs are similar across the options totalling around $7.7 million to $7.8 million. However, they account for a larger share of costs for broadacre at 78%, compared to 46% of greenhouse costs and 37% of indoor costs.

Materials for cultivation is the next highest cost component and also varies the most across the cultivation options. Material costs include expenses on seeds, electricity, insurance, pesticides, fertilisers and nutrients. The costs total $0.7 million for broadacre, $7.6 million for greenhouse and $10.7 million for indoor cultivation. The large variance is predominantly due to electricity consumption which is a minimal cost for broadacre but totals $8.9 million for indoor cultivation due to the lighting and climate control requirements for cannabis.

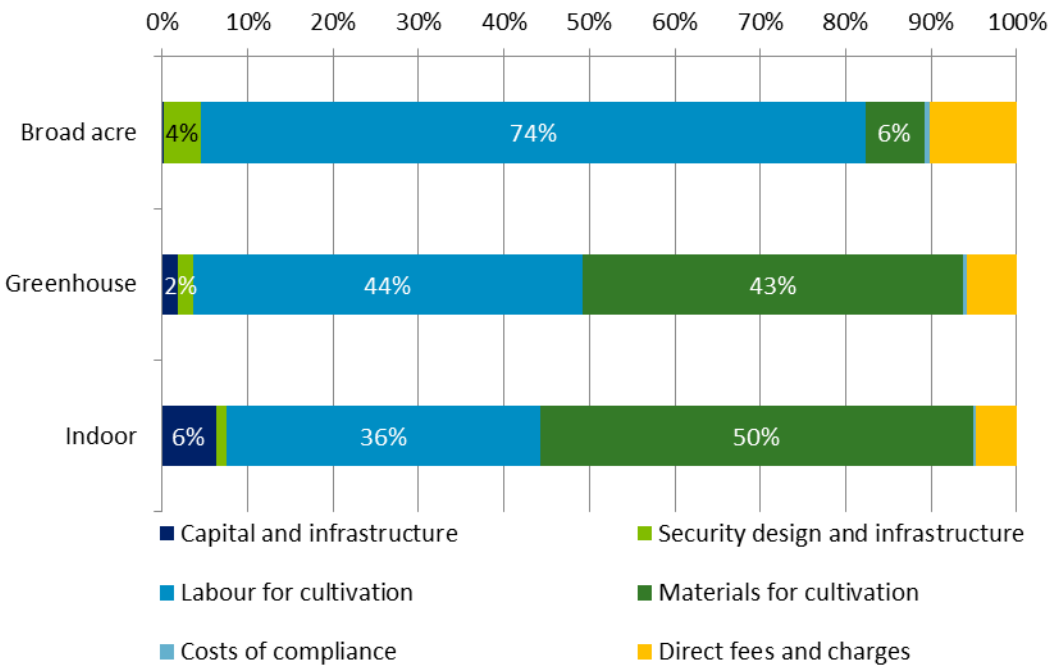
Table iii: Annualised costs by cultivation regime, $ million

Cost category	Broadacre	Greenhouse	Indoor
Capital, land and infrastructure	0.02	0.32	1.33
Security design and infrastructure	0.43	0.30	0.27
Labour for cultivation	7.67	7.79	7.79
Materials for cultivation	0.67	7.60	10.74
Costs of compliance	0.07	0.07	0.07
Direct fees and charges	1.00	1.00	1.00
Total	**9.86**	**17.08**	**21.20**

Source: Deloitte Access Economics

[2] Security and quality of production is out of scope for this project, which focusses on costs.

Chart i: Share of annualised costs



Source: Deloitte Access Economics

Where more than ten growers establish cultivation operations, for the same annual cannabis flower production, costs are estimated to increase largely due to higher infrastructure cost requirements given the increased boundary perimeter that needs securing and labour costs. Conversely, if fewer growers establish operations it is expected that costs will be lower. For an increase in the number of growers to 20, overall costs increased by 23% for broadacre, 14% for greenhouse and 11% for indoor cultivation. For a decrease in the number of growers to one, overall costs decreased by 21% for broadacre, 12% for greenhouse and 11% for indoor cultivation.

Manufacturing

Manufacturing costs have been assessed across four extraction methods — carrier oil extraction, solvent extraction, sub-critical CO_2 extraction and light hydrocarbon extraction. The costs for each extraction method relate to the processing of 11 tonnes of dried flower required to meet the demand for medicinal cannabis.

The results average around $40 per kg of plant product for the first three extraction methods, however, light hydrocarbon costs are around 40% lower at $25 per kg. Around half of the total manufacturing costs are for the extraction process which ranged from $2,010 per 100kg of plant material under carrier oil extraction, $2,585 for sub-critical CO_2 extraction, $2,626 for solvent extraction and $850 for light hydrocarbon.

Table iv: Cost of manufacturing

Cultivation	$ per kg dried flower	Annualised cost ($ million)	Total cost ($ million)
Carrier oil extraction	39.7	0.44	1.04
Solvent extraction	45.9	0.51	1.11
Super or sub-critical CO_2 extraction	43.3	0.48	0.85
Light hydrocarbon extraction	25.4	0.28	0.58

Source: Deloitte Access Economics.

Export of raw material

Table v details the estimated costs of exporting raw cannabis materials for manufacture internationally under two scenarios: export of dried cannabis flowers and export of the whole cannabis plant.

For the export of dried cannabis flowers scenario, broadacre is the cheapest cultivation method at $884 per kg dried flower, and indoor the most expensive at $1,901 per kg dried flower.

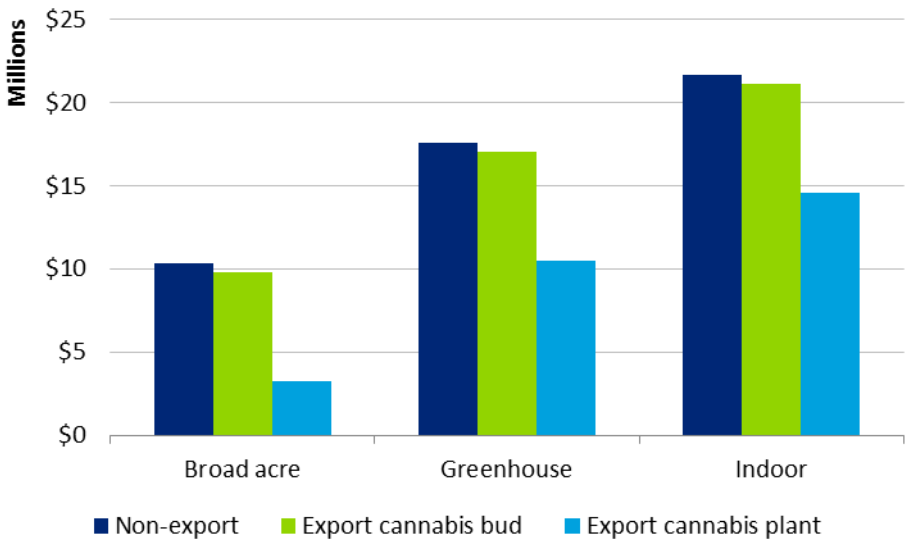
When the whole cannabis plant is exported, the total cost reduces significantly because the key labour cost of trimming the crop is not incurred. Excluding the trimming costs of around $5.8 million per annum, the cost for broadacre cultivation reduces to $3.3 million, $10.5 million for green house cultivation and $14.6 million for indoor cultivation. Manufacturing and plant destruction costs are also no longer incurred as these activities are conducted internationally.

Table v: Cost of cultivation – export of raw materials

Cultivation	$ per sqm	$ per kg dried flower	Annualised cost ($ million)
Export of dried cannabis flowers			
Broadacre	74	884	9.8
Greenhouse	1,102	1,531	17.0
Indoor	2,282	1,901	21.1
Export of cannabis plant			
Broadacre	25	295	3.3
Greenhouse	678	942	10.5
Indoor	1,575	1,313	14.6

Source: Deloitte Access Economics

Chart ii: Annualised cultivation cost – export versus non-export



Source: Deloitte Access Economics

Assumptions and limitations

Given the short timeframe required to complete the analysis, and that a medicinal cannabis industry in Australia is yet to be established, Deloitte Access Economics has had to make a number of assumptions around the demand, cultivation and manufacture of medicinal cannabis. The main assumptions and limitations have been as follows:

- The cost differentials for the three cultivation regimes reflect inputs from a range of different crops grown in a range of locations, both in Australia and abroad. Different locations throughout Australia will have different costs for the three regimes. As such, the costs are not directly transferable to any one location in Australia. Even though this high level analysis suggests broadacre cultivation is the cheapest, this would not necessarily be the case in some locations.
- Medicinal cannabis is not an active industry in Australia. Hence many of the costings have used international literature from established overseas cannabis industries as a guide, and we have assumed that international experience can be replicated in Australia.
    - International cost estimates were sourced on a square metre or square foot basis and converted to an Australian dollars per square metre basis.
    - We assume that equipment and electricity requirements (kilowatt hours – kWh) for indoor cannabis cultivation match that of international research based in the United States.
- Each cultivation option was based on *ten* facilities or farms, rather than a single facility or farm. If cultivation is conducted in a single facility, we would expect costs to decrease due to gains in economies of scale and removing duplicated infrastructure and labour costs.
- In the instances where suitable cannabis specific information was lacking or not replicable to Australian conditions, analogous crop types in Australia were used as an approximation to estimate cost components. Hemp, cherry tomatoes and hops were the

main crops referred to. These crops were selected specifically based on their similarity to cannabis crops, in terms of cultivation regimes used, cultivation difficulty, labour intensity and botanical classification (being closely related to cannabis). Calculations and figures which used these proxies have been documented.

- Individual legal cannabis manufacturing facilities which have been identified as part of the literature review produce on a smaller scale to what is needed for this analysis. International experience sourced through publicly available data was assumed to scale linearly. Where possible economies of scale were applied[3] but due to the limitations in available data and research, there was limited opportunity to apply these benefits. Therefore, the level of demand is less critical when assessing costs on a per square metre basis or per kg of dried cannabis flower basis.
- It is assumed that insurance for medicinal cannabis would be available in the Australian market, however it is unknown if this would be available, in what form and at what rate. Insurance costs have been included as an estimate based on insurance products for wheat in Northern New South Wales.
- It is assumed that the cannabis output from different types of cultivation is the same, and there are no differences in attributes such as quality or consistency of annual supply.
- Consultations were used where required to inform inputs to the modelling, however only limited consultations were conducted due to the time constraint. As such, there are several areas where the costings require more detailed investigation.

Deloitte Access Economics

[3] BOTEC Analysis Corporation, Economies of Scale in the Production of Cannabis, Angela Hawken, Ph.D. and James Prieger, Ph.D.

1 Introduction

1.1 Purpose of the report

The Department of Health through the Office of Drug Control commissioned Deloitte Access Economics to estimate the cost of cultivating and manufacturing medicinal cannabis.

The purpose of this exercise was to cost the process from cultivation to the manufacture of cannabis oil using publicly available information, Australian and international research, consultations and Deloitte internal subject matter experts.

1.2 Background

On 17 October 2015, the Commonwealth announced an intention to amend the Narcotic Drugs Act 1967 allowing the cultivation of cannabis for medical and scientific purposes. The amendments are intended to facilitate the production of cannabis products, in accordance with the Therapeutic Goods Act 1989, for specified patients under clinical care and for clinical trials.

It is widely recognised in epidemiological literature that access to medicinal cannabis or cannabis products may provide benefits for certain patients.[4] Those with terminal cancer, chronic pain, AIDS/HIV, and children with intractable forms of epilepsy can experience benefits such as pain relief, nausea control and increased appetite.

The NSW Government is investing in clinical trials aimed at exploring the use of cannabis and cannabis products to provide relief from a range of illnesses. The Victorian Government is planning on helping patients deemed to be in exceptional medical circumstances by making medicinal cannabis products available.

While there are systems in place within Australia under the Therapeutic Goods Act 1989 to license the manufacture and supply of cannabis-based products, there is no mechanism to allow the cultivation of cannabis plants in Australia. This leaves patients or their carers to turn to the black-market to obtain 'medicinal cannabis products'. As these black-market products are not regulated there is uncertainty as to their safety and quality. Also, because of the illegality associated with obtaining medicinal cannabis, decisions to use medicinal cannabis are often made without appropriate advice from a medical specialist.[5]

The amendments to the Narcotic Drugs Act 1967, allowing the cultivation of cannabis, will ensure the safety of medicinal cannabis products, as they will be subject to quality manufacturing requirements under the Therapeutic Goods Act 1989.

[4] Vaney, C.et al 2004 / Naftali, T. et al 2013 / Voth, E. & Schwartz, R. 1997

[5] Narcotic Drug Amendment Bill 2016, Public Information Paper. 10 February 2016

Medicinal cannabis in select countries

Canada, Israel, the Netherlands and the United States each to varying degrees have legalised production and distribution. As such, experiences in these countries provide useful insights into the progress Australia can expect to make should the amendment to the Narcotic Drugs Act 1967 become a reality. International examples also provide the best experience of cannabis cultivation that we have included as part of the research for this report.

Canada

In Canada, medical cannabis is governed by Health Canada. Until 2013, medical cannabis policy was set out under the Medical Access Regulations (MMAR). These regulations allowed permitted individuals to grow their own supply of cannabis, or use Health Canada's supply. Prairie Plant Systems was the sole supplier of cannabis to Health Canada for medical purposes. This monopoly system led to complaints of low quality products and limited variety of strains available to patients. Furthermore, there was concern that allowing patients to grow their own cannabis was difficult to regulate and increased supply into the black market.

MMAR was replaced by the Marijuana for Medical Purposes Regulations (MMPR) in 2013. Under these regulations, patients with approval from an authorised medical practitioner are able to choose from a number of licensed suppliers, which are strictly regulated. The highly regulated nature of the industry means that producers tend to be fairly large scale.

As of August 24, 2016, MMPR was superseded by the Access to Cannabis for Medical Purposes Regulations (ACMPR). This new development means that authorised Canadian patients will continue to have access to marijuana from one of 34 licensed producers. Canadians will also be permitted to cultivate a limited amount of cannabis for their own medical purposes, or have someone produce it on their behalf.[6]

Israel

In Israel, the Medical Cannabis Unit is an authorised unit of the Ministry of Health which issues permits for the use of medical cannabis. Patients must submit a referral from a specialist physician specifying the conditions under which the patient suffers and confirming that the patient should receive a permit. The Unit examines the recommendation and if satisfied that it meets the relevant criteria, grants a licence to the patient to use medical cannabis.

There are nine licensed suppliers of medical cannabis as of March 2016.[7] However, the Israeli Government has announced plans to move from a policy of permits to one of prescriptions[8]. Under this policy change, there will be no restriction on the number of producers, as long as they meet the required medical and food manufacturing standards. Pharmacies will be authorised to provide medical cannabis to any patient with a prescription.

[6] "Medical Use of Cannabis", Health Canada, 2016.

[7] "U.S. firms target investment in Israeli cannabis R&D", *Reuters*. Lubell, M. 2016

[8] "Availability of Medical Cannabis in Israel to Reach an All-time High", *Haaretz*. Efrati, I. 2016

Netherlands

In the Netherlands, the Office for Medicinal Cannabis (OMC) governs the production of cannabis for medical and scientific purposes. The Dutch government procures cannabis from a single authorised agricultural company. It is then provided to patients in its raw form via pharmacies for those with a valid doctor's prescription.

There is no limit to the amount of cannabis a doctor can prescribe. Physicians will usually start by recommending a small dose, then increasing the dosage as necessary. Patients are provided with six strains of cannabis developed by Bedrocan with standardised THC- and CBD-levels. Bedrocan is currently the only company in the world producing standardised, full-dried flower medicinal cannabis.[9]

United States of America

The availability of medicinal cannabis in America is determined at the state level. The nation, therefore, does not have a single approach to the issue. Under the federal controlled *Substances Act*, cannabis is still classified as a Schedule I drug (most restricted category), prohibiting almost any use or cultivation of the drug including for medical purposes. On 28 August 2016, the U.S. Drug Enforcement Administration (DEA) announced that cannabis will remain illegal for any purpose, but will relax the rules for cannabis research, making it easier for scientific study in the area.[10] Furthermore, the Food and Drug Administration does not approve the use of cannabis as a safe and effective drug.[11] Nevertheless, 25 states and Washington D.C. have legalised medicinal cannabis to varying degrees.

1.3 Approach to costings

To estimate the total cost of cultivating and manufacturing medicinal cannabis, Deloitte Access Economics relied largely on publicly available literature and research on medicinal cannabis industries in other countries.

Where data on the cultivation and manufacture of medicinal cannabis was not available, select consultations were conducted with various subject matter experts. In addition, other crop types which exhibit a similar cost structure or cultivation technique to cannabis were used as proxies such as cherry tomatoes, hops and hemp.

The approach was to identify the various stages from infrastructure setup to manufacturing of medicinal cannabis oil. The costs in each stage of production are presented as per unit costs, such as on a per square metre (sqm) basis, per employee, per metre or per kilogram basis.

[9] http://www.bedrocan.nl/

[10] "Marijuana to remain illegal under federal law, DEA says", USA Today, 11 Aug 2016

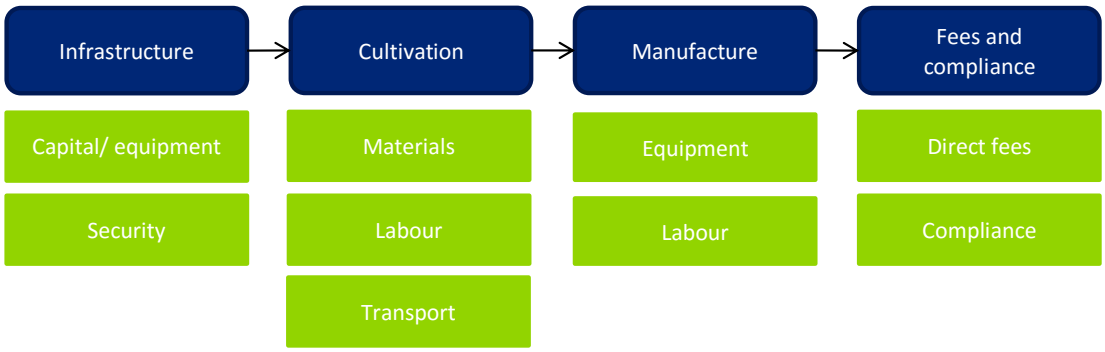
[11] "FDA and Marijuana", U.S. Food and Drug Administration. 2016

2 Scope

2.1 Stages of production

For each cultivation option, the stages that were costed include infrastructure, cultivation, manufacture and fees and compliance (Figure 2.1).

Figure 2.1: Overview of the stages of production



Source: Deloitte Access Economics

The main cost components for each category are listed below.

- Capital and infrastructure for cultivation, i.e. fixed up-front setup costs (Capex):
    - building construction and land;
    - capital and infrastructure for cultivation, for example, irrigation systems in a greenhouse or indoor setting; and
    - security elements, such as fencing and CCTV facilities, to secure cultivation sites.
- Ongoing cultivation costs (Opex):
    - employee suitability checks and training;
    - labour for planting and harvesting;
    - materials for cultivation including pest control, weed control, nutrients and fertilisers;
    - transport from farm gate to manufacturing facility; and
    - crop insurance.
- Manufacture of cannabis oil based on carrier oil extraction, solvent based extraction, super- or sub-critical carbon dioxide extraction and light hydrocarbon extraction. With cannabinoids being found within the resin glands (trichomes) of female flowers of plants, the manufacturing process is costed up to cannabis oil extraction rather than harvesting:
    - infrastructure set up costs; and
    - operating costs.
- Fees and compliance:
    - direct fees and charges relating to cultivation and manufacturing of narcotics and medicines;

- destruction of plant materials; and
- quality assurance testing.

2.2 Cultivation and manufacturing options

The objective of the project was to cost medicinal cannabis across a number of cultivation options. This involved costing three options for cultivation, and five options for cannabis oil manufacture, one of which focused on the export of raw material for manufacturing overseas.

The cultivation options are listed below, and examined in Section 3.2 and Section 3.3.

- Broadacre – outdoor cultivation using broadacre growing conditions, natural lighting and use of irrigation systems, located on a rural property 400-500km from manufacturer.
- Greenhouse – glass building providing protection for crops from adverse weather, natural lighting and climate control systems, located on a semi-rural property 100km from manufacturer.
- Indoor – cultivation in a building requiring artificial lighting and climate controls, either retro fit or new build in industrial area close to manufacturer.

Similarly, the options for manufacturing are listed below, and examined in Section 3.4:

- carrier based oil extraction;
- solvent based extraction;
- super- or sub-critical carbon dioxide extraction;
- light hydrocarbon extraction; or
- exporting raw material to overseas manufacturer.

3 Costings

This section contains a detailed review of the unit costs incurred in each cultivation and manufacturing combination. The individual costs are presented in the following units for ease of comparison:

- annualised cost per sqm;
- annualised cost per kg dried flower;
- total annualised cost; and
- total cost including initial setup costs for infrastructure and equipment in the first year.

The **annualised cost** is the annual cost of operating expenditure, plus a component of capital and equipment costs required to meet annual demand for cannabis products. For capital and equipment costs, the annualised cost accounts for useful life of the item, for example, if the equipment is expected to last for 10 years, then 10% of the equipment cost is accounted for each year. This cost shows the potential cost in each year of the operation.

The **total cost** refers to annual operating expenditure, plus the total capital and equipment costs required to establish an operation which can meet the annual demand for cannabis products. This cost shows the potential cost in year one of the operation.

In Chapter 4, the individual costs are aggregated for the various cultivation and manufacturing options.

3.1 Assumptions and limitations

Given the short timeframe required to complete the analysis, and that a medicinal cannabis industry in Australia is yet to be established, Deloitte Access Economics was required to make a number of assumptions around the demand, cultivation and manufacture of medicinal cannabis. The key assumptions are summarised here.

3.1.1 Expected level of demand

An important consideration in estimating total costs is the level of demand that needs to be met. This is because of non-linearity of costs in both cultivation and manufacturing whereby, for example, doubling the volume of production does not double the costs. Generally, because of economies of scale,[12] unit costs become lower as the volume of production becomes higher.

The likely level of demand was unknown. The University of Sydney Community Placement Program, in partnership with MGC Pharmaceuticals, investigated the potential demand and land required to grow a sufficient level of medicinal cannabis.[13] Based on this research, the expected number of patients using medicinal cannabis across three medical conditions is around 30,400 per annum. The breakdown of demand from this study is shown below in Table 3.1.

Table 3.1: Estimated demand for medicinal cannabis

Condition	Patients per annum
HIV/AIDS	10,588
Multiple Sclerosis	15,875
Epilepsy	3,957

Source: MGC Pharma 2016, Medicinal Cannabis in Australia: Science, Regulation & Industry

In addition to the demand detailed in Table 3.1, it was estimated there would be demand for 995,827 treatment sessions per annum for cancer patients. It is not known the number of cancer patients this number of treatments sessions corresponds to.

Using figures presented in the study, the average daily use reported across other countries, and through discussions with the Department, we assumed an average usage of one gram of dried cannabis flower product per patient per day (across all medical conditions). For 30,400 patients, this requires 11 tonnes of dried cannabis flower product annually.

[12] Economies of scale are the cost advantage that arises from an increase in the output of a product.

[13] MGC Pharma 2016, Medicinal Cannabis in Australia: Science, Regulation & Industry

3.1.2 Potency and yield

3.1.2.1 Cannabis potency

Cannabis '**potency**' is defined as the measure of the amount of the desired cannabinoid- THC or CBD present in a cannabis sample.[14] According to the United Nations Office on Drugs and Crime (UNODC), cannabis potency is affected by: the part of plant used to extract the oils; product type (herb, resin or oil); cultivation method; sampling reliability and stability of storage conditions.[15]

The impact of the cultivation method (indoor versus outdoor cultivation) on the potency of cannabis was examined to ascertain if indoor cultivation could produce more potent cannabis plants. While there is literature theorising that indoor cultivation produces higher concentrations of THC and CBD, our research found no robust statistical data proving this. This was highlighted in a recent Australian study[16] which showed that while there was a trend towards higher THC levels in indoor grown plants, neither cultivation method was clearly more capable of producing more potent plants.[17] According to the National Drug and Alcohol Research Centre, indoor cultivation "ensures uniform quality due to the practise of cloning"[18] cannabis plants known to produce high THC/CBD content, suggesting that specific seed types are more favoured for cannabis cultivation, and that this factor has greater influence on potency than the growing location.[19]

As there was insufficient evidence to support the claim that a particular cultivation option favours potency, we assumed a consistent potency across all three cultivation options.

3.1.2.2 Cannabis yield

The UK Independent Drug Monitoring Unit (IDMU) has defined cannabis **yield** as a measure of dried flowering tops produced per unit of crop area.[20] However, much of grey literature does not specify what is meant by their use of the term 'yield'. In some cases, the definition of 'yield' has included both dried flowers and leaves.[21]

The yield per plant reported across individual cultivators varies significantly. The IDMU reports that plants grown outdoors and in greenhouses in Denmark had median gross weights of 308g and 584g respectively, with a mean yield of 8.7% flowering tops after drying. GW Pharmaceuticals, who have a Home Office Licence to grow cannabis in the UK, report

[14] NCPIC, 2014. "Weeding out the differences between THC vs. CBD"

[15] UNODC, 2009. "Why does cannabis potency matter?"

[16] Swift W. et al. 2013, *Analysis of Cannabis Seizures in NSW, Australia: Cannabis Potency and Cannabinoid Profile*.

[17] NCPIC, 2014. "Cannabis potency"

[18] McLaren, J. et al. 2007. "Cannabis potency and contamination: a review of the literature"

[19] Swift, W. et al. 2013. "Analysis of Cannabis Seizures in NSW, Australia: Cannabis Potency and Cannabinoid Profile"

[20] IDMU, 2013. "Cannabis Plants – Cultivation & Yields"

[21] RAND, 2010. "Estimated Cost of Production for Legalized Cannabis"

gross yields of 157g to 188g per sqm in greenhouse conditions, 251g to 397g per sqm indoors under mercury lights, and 516g to 573g per sqm under HPS lighting.[22]

The two important factors in the estimate of the yield per plant are the total yield of the plant, leaves and dried flowers, and the share of yield which the dried flower comprises. Based on IDMU research, the average dried flower yield is 64% in indoor plants compared to 33% for outdoor plants.[23] The density of plants would also be a contributing factor, however, IDMU notes that 'where a large number of plants are packed into a small space the yield from each plant will be substantially reduced. Indeed, the overall yield from 50 plants may not be significantly different from the overall yield from 10 plants grown in the same space'.[24]

To estimate the potential yield of cannabis in Australia, we have taken the average yield across a number of sources where yield is reported, and applied the dried flower yield.

Table 3.2: Crop yields[25]

Cultivation method	Dried flowers per sqm	Range
Broadacre	84 grams	70 to 150 grams
Greenhouse	180 grams	40 to 384 grams
Indoor	300 grams	266 to 750 grams

Source: Deloitte Access Economics

The following briefly outlines the difficulties associated with using existing yield data.

- Outdoor per hectare productivity is subject to the impact of local conditions such as weather, pests, climate and whether crops are irrigated or dryland. These will vary depending on outdoor location. As such, they have not been factored in here.
- For both outdoor and indoor cultivation, yield is dependent on factors such as strain, artificial/natural light intensity, type and amount of fertiliser/nutrients. These specifics are rarely detailed in source documents.
- Plant spacing varies between individual cultivators, however, as noted above the yield per square metre is likely to be fairly consistent with more condensed planting resulting in a lower yield per plant.

Given the significant variance in yield reported across different studies, the impact of different yields is considered further in the sensitivity analysis.

[22] IDMU, 2013. "Cannabis Plants – Cultivation & Yields"

[23] IDMU, 2013. "Cannabis Plants – Cultivation & Yields"

[24] IDMU, 2013. "Cannabis Plants – Cultivation & Yields"

[25] Sources of yield estimates include: IDMU, 2013. "Cannabis Plants – Cultivation & Yields"; https://www.unodc.org/documents/data-and-analysis/bulletin/2006/Bulletin_on_Narcotics_2006_En.pdf; UNODC p13, Recommended methods for the identification and analysis of cannabis and cannabis products; Further insights into aspects of the illicit EU drugs market 2013; http://liq.wa.gov/publications/Marijuana/BOTEC%20reports/5a_Cannabis_Yields-Final.pdf

3.1.3 Land required for cultivation

To produce the 11 tonnes of dried cannabis flowers per annum, 13.2 hectares of broadacre, or 1.5 hectares of greenhouse or 0.9 hectares of indoor facility is required based on the yield assumptions detailed above. This also assumes that broadacre produces one harvest per annum, with greenhouse and indoor capable of four harvests per annum given the ability to control the climate, lighting, nutrients and water requirements of the crop. The impact on costs due to changes in the number of crops per annum is analysed further in the sensitivity analysis.

Table 3.3: Land required to meet demand

Cultivation	Crops per annum	Land
Broadacre	1[26]	13.2 hectares
Greenhouse	4[27]	1.5 hectares
Indoor	4[28]	0.9 hectares

Source: Deloitte Access Economics

3.1.4 Other main assumptions and limitations

- The establishment of a medicinal cannabis industry in Australia is likely to see a number of farms or growers enter the market. The number of growers who would establish operations is not known and would depend on factors such as total demand, licensing and regulations, expertise and appropriate facilities. Given the uncertainties around the number of growers, the analysis and results reported in Section 3 focuses on ten growers. Were cultivation to be conducted across a single farm or facility, we would expect total costs to decrease due to gains in economies of scale, and removing some duplicated costs such as infrastructure, labour, security and regulatory costs. The impact on the cost of cultivation from varying the number of growers to 1, 5 and 20 growers is included in the sensitivity analysis (see Section 5).
- Medicinal cannabis is not an active industry in Australia. Hence the costings have used international literature from established overseas cannabis industries as a guide and assumed that international experience can be replicated in Australia.
    - International cost estimates were sourced on a square metre or square foot basis and converted to an Australian dollars per square metre basis.
    - We assume that equipment and electricity requirements (kilowatt hours – kWh) for indoor cannabis cultivation match that of international research.
- The results reported in the analysis are for a single cost estimate, however, depending on the exact location of facilities the cost may differ. This is particularly the case for broadacre and greenhouses where some costs would differ to reflect the local climate. For example, a greenhouse in Queensland would likely have minimal heating costs compared to the same greenhouse in Tasmania. Similarly, broadacre production in an arid or semi-arid area will require irrigation water, incurring costs associated with

[26] In temperate climates, only one crop per year is possible. (United Nations Office on Drug and Crime, 2006)

[27] RAND Drug Policy Research Center, 2010. "Estimated Cost of Production for Legalized Cannabis"

[28] RAND Drug Policy Research Center, 2010. "Estimated Cost of Production for Legalized Cannabis"

irrigation, and production in areas of low soil fertility will require more fertiliser inputs than in naturally fertile areas.

- Costs for broadacre are based on a long term average yield. Given the variable and unpredictable nature of outdoor cultivation, there is likely to be a variable yield year-on-year, hence so too will the costs vary. Inputs such as irrigation water can minimise some of the vulnerability to seasonal conditions, but that involves costs that have not been factored in here. Furthermore, irrigation doesn't remove all of the threats to broad acre production. In reality in Australia, there would be significant changes in the per unit cost of broadacre cultivation year-to-year.
- In the instances where cannabis specific information was lacking, analogous crop types were used as an approximation to estimate cost components. These crops were selected specifically based on their similarity to cannabis crops, in terms of cultivation difficulty; labour intensity; botanical classification (being closely related to cannabis). Hemp, cherry tomatoes and hops were the main crops referred to. Calculations and figures which used these proxies have been clearly identified.
- Individual legal cannabis manufacturing facilities which were identified as part of the literature review produce on a smaller scale to what was expected to be needed in this analysis. International experience sourced through publicly available data was assumed to scale linearly. Where possible, economies of scale were applied but due to the limitations in available data and research there was limited opportunity to apply these benefits.
- It was assumed that insurance for medicinal cannabis would be available in the Australian market, however it was unknown if this would be available, in what form and at what rate.
- It was assumed that the cannabis output from different types of cultivation is the same, and there are no differences in attributes like quality or consistency of annual supply.
- Consultations were used where required to inform inputs to the modelling, however only limited consultations were conducted due to the time constraints.

For a complete list of parameters please refer to Appendix A.

3.2 Infrastructure

3.2.1 Capital and infrastructure for cultivation

Table 3.4 details the estimated capital and infrastructure costs required for each cultivation option. These are fixed and upfront costs, rather than ongoing. Indoor cultivation is expected to have the greatest capital requirements, due to both the building construction costs and equipment costs required to establish the facility.

Table 3.4: Capital and infrastructure costs

Cultivation method	$ per sqm	$ per kg dried flower	Annualised cost ($ million)	Total cost ($ million)
Broadacre	0.2	2.1	0.02	0.09
Greenhouse	20.8	28.9	0.32	3.60
Indoor	143.4	119.5	1.33	21.85

Source: Deloitte Access Economics

Basis for cost estimates

The following section summarises the rationale behind each cost estimate. The infrastructure costs include an estimate of the construction of premises required for cultivation, equipment required to grow cannabis crops and land cost.

Infrastructure costs – cost of construction of premises for cultivation

- Construction costs set at $47 per sqm for greenhouses and $580 per sqm for indoor facilities.
    - The size of facility required for greenhouse and indoor facilities accounts for the area used to grow cannabis plants versus the full size of the complex. 49%[29] of the total floor space was assumed to be used for cultivation purposes.
    - Annualised costs assume a useful life of 25 years for indoor buildings and 15 years for greenhouse premises.
    - The base construction costs reflect the construction of a single large facility. To allow for additional construction costs for ten smaller facilities, construction costs were increased by 10%.

Equipment costs

- Equipment costs relate to the set up cost of equipment required to cultivate such as irrigation, drainage systems, fans, lighting and heating systems.
- Previous research by BOTEC Analysis Corporation was used to estimate equipment costs for establishing indoor and greenhouse facilities. These figures were presented on a USD per square foot (sq ft) basis, which was converted to AUD per sqm and scaled up to the relevant size of facilities required.
    - Equipment costs were set at $122 per sqm for greenhouses and $700 for indoor facilities. The higher cost for indoor facilities is due to lighting and environmental control equipment.
    - Annualised costs assume a useful life of 10 years for equipment.
    - The base equipment costs reflect the construction of a single large facility. To allow for additional or duplicated equipment costs for ten smaller facilities, equipment costs were increased by 15%.[30]

[29] BOTEC Analysis Corporation, Economies of Scale in the Production of Cannabis, Angela Hawken, Ph.D. and James Prieger, Ph.D.

[30] The 10% scaling factor applied to infrastructure costs relates to the estimated increase in infrastructure costs per sqm of smaller scale facilities. Equipment costs were scaled by a 15% to account for duplicating various cost components that are needed at each facility, such as climate controllers..

- Capital costs for broadacre include tractor costs which were assumed to be $471[31] per hectare.

Land costs

- Land costs were based on the opportunity cost of the land, and annualised as an imputed rent by applying a rate of 4% of the estimated value of land.
- Land values for the cultivation options assumed a value of $6,000 per hectare for broadacre, $10,000 per hectare for greenhouse assuming a location closer to a major city than broadacre, and $3 million per hectare for indoor cultivation (based on outer south west and west Sydney industrial land values).
    - The value of land, particularly for indoor cultivation may vary significantly depending on the exact location of the facility. However, given we only account for 4% of the land cost each year as an annualised opportunity cost, it is not expected to have significant impact on results, especially given indoor cultivation is not a significant land user. For example, a land value of $3 million would result in an annual cost of $120,000 relative to $80,000 at a land value of $2 million for a property located further from the main industrial areas of Sydney, a minor cost relative to other cost components. In addition, any change in where the industrial area is located would have flow on impacts. For example, lower land values could be sought by having a more isolated facility, but that location is more likely associated with higher costs such as transport and security.
- It was assumed that no additional infrastructure is required to establish electricity connection to the premises, for example electricity poles.

The main components for capital and infrastructure costs are presented in Table 3.5.

Table 3.5: Distribution of infrastructure costs (annualised $ million)

Cultivation	Broadacre	Greenhouse	Indoor
Construction	0.000	0.113	0.50
Land	0.003	0.001	0.11
Equipment	0.020	0.207	0.71

Source: Deloitte Access Economics

3.2.2 Security for cultivation

Table 3.6 details the estimated security costs required under each cultivation option.

Broadacre shows the highest security cost at around twice that of greenhouse and indoor facilities. The main reason for this is that broadacre is assumed to require two layers of security fencing where greenhouses and indoor facilities have an initial layer of security which is the building itself, and as such only require one layer of fencing around the perimeter. However, even if only one layer of fencing was required it would have a higher cost due to broadacre also having a larger area to be secured by perimeter fencing than greenhouse and indoor options.

[31] NSW DPI, tractor cost per hectare

Table 3.6: Security costs

Cultivation method	$ per sqm	$ per kg dried flower	Annualised cost ($ million)	Total cost ($ million)
Broadacre	3.20	38.5	0.43	1.09
Greenhouse	19.3	26.8	0.30	0.41
Indoor	29.2	24.3	0.27	0.37

Source: Deloitte Access Economics

Basis for cost estimates

- Security fencing was based on three metre high security modular fencing which is used in locations such as indoor factories, airports, roads and bridges. The cost of fencing was set at $275 per linear metre, plus labour for installation.[32]
    - Greenhouse and indoor facilities were assumed to have a single fence with broadacre requiring two layers of fencing around the perimeter of land used for cultivation.
    - Labour costs for assembling the fencing was set at $187 per linear metre.
    - An allowance for a six metre perimeter around the premises was included which adds an additional 4.5% to the total length of fencing.
- CCTV costs for broadacre were calculated assuming the cameras are located on the perimeter of the property. For a 13.2 hectare land area, the perimeter was assumed to be square shaped. Calculations were based on each camera having up to 35 metres of range[33]. Using a 100%[34] markup on equipment costs to account for installation costs, the total security monitoring cost for broadacre over ten farms is $6,000. Network access, for example via 4G or satellite, for remote live viewing, recording and event logging was included in this system. For greenhouse and indoor facilities, costs were scaled based on size of the premises relative to broadacre cultivation.
- An alarm system for premises was estimated at $1,000 per site plus monitoring costs of $30 per month.
- The infrastructure for access control doors was estimated at up to $3,300 per door, inclusive of door hardware, software, key cards, and installation. The number of doors per facility is not known, but multiple access doors are needed to meet workplace safety requirements in areas such as fire escape, total costs are estimated at $52,000 across ten cultivation sites. Monthly fees also vary considerably and are reported as in the range of $15 to $130 per month. Assuming a high cost option gave a total annual cost of $1,560 per site.
- Patrolling of the facility can vary significantly from full time staff to scheduled visits per day. Given the range of potential options, for the analysis we assumed two patrols per day for one hour each visit. Under these parameters patrolling costs total $220,000 per annum across ten cultivation sites.
    - Although the security costs used in the analysis only provide an indicative cost at best, even doubling of security costs to $440,000 per annum would have a

[32] Estimate through consultations

[33] *Gold CCTV Package*, CCTV Camera Europe. 2013

[34] *Economies of Scale in the Production of Cannabis*. BOTEC Analysis Corporation, 2013

minimal impact on the overall cost per gram of cannabis product. In addition, broadacre may see higher patrolling costs given the size of the premises and the need for security personnel needing to travel further to reach the premises.

The main components for security costs are detailed below.

Table 3.7: Allocation of security costs (annualised $ million)

Security elements	Broadacre	Greenhouse	Indoor
CCTV	0.01	0.002	0.002
Fencing material	0.10	0.030	0.014
Fencing labour (one off cost)	1.78	0.303	0.235
Access control and patrolling	0.24	0.241	0.241

Source: Deloitte Access Economics

3.3 Cultivation

3.3.1 Labour

Table 3.8 details the estimated labour cost of planting, maintenance, harvesting and trimming for each cultivation method.

Labour costs across the cultivation options were quite similar. This is predominantly due to trimming costs which account for the majority of labour costs and are expected to be the same across all three methods.

Table 3.8: Labour costs

Cultivation method	$ per sqm	$ per kg dried flower	Annualised cost ($ million)	Total cost ($ million)
Broadacre	58.1	691.2	7.67	7.67
Greenhouse	505.1	701.5	7.79	7.79
Indoor	841.6	701.3	7.79	7.79

Source: Deloitte Access Economics

Basis for cost estimates

For all cultivation regimes, the main labour cost is associated with trimming. Based on a trimming rate of 42 grams per hour[35] and 11 tonnes of dried cannabis flowers per annum, the total trimming cost was estimated at $5.8 million per annum. The trimming rate is a key assumption for labour costs. Other sources indicated a trimming range from 38 grams per hour to 62 grams per hour, and using a high estimate of 62 grams per hour decreased trimming costs by around 30%.

[35] BOTEC Analysis Corporation, Economies of Scale in the Production of Cannabis, Angela Hawken, Ph.D. and James Prieger, Ph.D.

In addition to trimming, labour costs also include the following assumptions:

- The average wage rate was set at $25 per hour, reflecting a wage higher than a basic farm wage (Horticulture Award) to reflect a higher skill level required. The impact of changes in the wage rates is included in Section 5.
- Planting costs are assumed to take 46 hours of labour per hectare.[36]
- Agricultural workers included for 0.8 hours per sqm for greenhouse and 0.5 hours per sqm for indoor cultivation. Broadacre assumed additional agricultural labour of around $10,000, or 450 hours per hectare.
- Management costs at 0.1 per sqm, or around $95,000 per annum.
- One days training for each employee costed at one day's wages (8 hour work day).
- Employee suitability checks of $50 per employee (assume police background check).

The main components of labour costs are detailed below:

Table 3.9: Allocation of labour costs (annualised $ million)

Labour component	Broadacre	Greenhouse	Indoor
Planting	0.02	0.02	0.02
Harvesting and crop maintenance	7.61	7.73	7.73
Training	0.03	0.03	0.03
Employee suitability checks	0.01	0.01	0.01

Source: Deloitte Access Economics

3.3.2 Transport

Table 3.10 details the estimated transport costs of dried flower for each cultivation option. The "per kilogram per kilometre" cost was assumed to be the same for each cultivation option, the difference in costs is due to the distance each facility is from the local manufacturer.

Table 3.10: Transport costs (farm gate to manufacturer)

Cultivation method	$ per sqm	$ per kg dried flower	Annualised cost ($ million)	Total cost ($ million)
Broadacre	0.08	0.93	0.010	0.010
Greenhouse	0.20	0.28	0.003	0.003
Indoor	0.10	0.08	0.001	0.001

Source: Deloitte Access Economics

Basis for cost estimates

- Transport assumed delivery of product from the farm gate to the manufacturer via sensitive freight transport.
    - A cost of $0.87 per kg based on a transporting distance of 400km was used for broadacre and $0.22 per kg for greenhouse based on a transporting distance

[36] Gross Margin for Fresh Tomatoes, NSW Government: Industry & Investment, 2009

of 100km (from semi-rural NSW), and no transport requirements for indoor cultivation.[37]

- It was assumed that the transport of cannabis product would not require a police escort.
- For the export of raw material for manufacturing internationally, the dried cannabis flowers or whole cannabis plant, additional shipping expenses would be incurred. Based on the weight of material (under both export scenarios), shipping costs were estimated at $1,500 for transport of a 20 foot container and $520 for other port charges.[38]
    - Given it is not known where the raw material would be exported to, the costs were based on shipping the product from Sydney to Los Angeles. For comparison, shipping to Hamburg was estimated to cost around $1,200 inclusive of the container and other shipping charges.
    - For export, the transport of product from the farm gate to the port was assumed to be the same on a per kg per basis as the transport cost from the farm gate to manufacture. In practice, while cultivators may be able to plant so the farm and manufacturer are close together, or co-located particularly for greenhouse and indoor cultivation methods, the location of ports cannot be moved. Hence, it is more likely the farm will be further away from the port than the manufacturer.
    - Regardless of destination port, shipping expenses do not have a significant impact on the overall cost of cannabis cultivation.

3.3.3 Materials

Table 3.11 details the estimated material costs required for each cultivation option. Materials include seed for planting, utilities, insurance, pesticides, fungicides, nutrients, fertilisers and weed control. These are ongoing costs, incurred each year the cultivation occurs.

Utilities and materials are a key overall cost driver, particularly for greenhouse and indoor settings. The main source of information for these components was the BOTEC Analysis Corporation report on *Economies of Scale in the Production of Cannabis*. Material and utilities costs were included in the sensitivity analysis in Section 5.

Table 3.11: Material costs

Cultivation method	$ per sqm	$ per kg dried flower	Annualised cost ($ million)	Total cost ($ million)
Broadacre	5.1	60.5	0.7	0.7
Greenhouse	493	684.6	7.6	7.6
Indoor	1,161	967.6	10.7	10.7

Source: Deloitte Access Economics

Basis for cost estimates

- For broadacre we assumed a cost of $5.10 per sqm compared to $493 per sqm in greenhouses and $1161 per sqm in indoor facilities. Approximately 80% of costs per sqm

[37] Estimate through consultations

[38] http://www.fivestarshipping.com.au/

for greenhouse and indoor materials (excluding utilities) were for nutrients and the remainder for insecticides and pesticides.

- Utilities represented a major component of the costs for greenhouse and indoor facilities. To estimate the cost in an Australian setting, the total kWh used per sqm based on international experience was multiplied by a cost of $0.25 per kWh[39] to reflect Australian electricity prices, which are notably higher than the cost of electricity in the United States, provided in the study as USD$0.0596 per kWh.
    - While materials for broadacre are only minor at 6% of costs, for greenhouse and indoor cultivation, they account for around 45% of costs due to costs of lighting and temperature control. Greenhouses were estimated to incur a cost for utilities of $353 per sqm and for indoor facilities $966 per sqm.
- The cost of planting seed was sourced from various international distributors and averaged around $12 per seed, based on a packet of 10 seeds. However, given the significant number of seeds which would need to be purchased to meet demand in Australia, it is expected the average price would be discounted to reflect the increased demand, assuming supply can rapidly increase to meet this new level of demand.
    - Investigating commercial seed prices from Australian distributors indicated that prices per seed reduce by around 60% to 80% when a large parcel of seeds is purchased relative to a small packet seeds. This was fairly consistent across different seed categories. Therefore, a discount of 70% to the average seed price was applied to reflect the large scale purchasing requirements at maturity.
- Although it is likely that seeds may be the only initial propagation option when medicinal cannabis crops are first planted (seed costs account for around 5% of broadacre costs to 1% of indoor costs), as the industry matures other options for sourcing crop materials may potentially be adopted including vegetative reproduction methods, such as cuttings or grafting. These techniques ensure genetic consistency across generations as the derived plants have the same DNA as the 'mother' plant.
- There are costs and benefits from this alternative propagation that need to be considered:
    - It is likely that any cost savings made from reducing seed purchase would be offset by the additional labour (with appropriate technical skills) requirements of vegetative reproduction. We would expect costs for grafting to be higher than costs for cuttings.
    - The vegetative plantlets would require greenhouse space and incur variable production costs (such as growing medium, fertiliser and irrigation) that would not otherwise be required for a seed-based production system.
    - Vegetative reproduction may accelerate the overall crop cycle as cuttings and grafts can be collected earlier in the crop maturity cycle than seeds. This could then positively impact the efficiency of capital and potentially increase number of crops per annum.
    - Using the same genetic material may result in higher or more consistent yields and quality of products, and selection of genetic material that is especially suited to medicinal cannabis production in Australia.

[39] Energy Price Fact Sheets, EnergyAustralia, 2016

    - All of these factors interact, however, it is unclear on the net impact of the interactions, as such, a cost impact has not been included in the analysis.
- As crop insurance for broadacre cannabis does not currently exist, the cost was estimated using rates of insurance for multiple peril crop insurance for wheat. ABARES reports that for New South Wales the insurance premium for wheat of between 4.6% and 6.7% (averaging around 5%),[40] based on an insured value of 40% of the crop value. This value is a midpoint as insured value can range from 25% to 60% with premium rates ranging from 1.4% to 13% depending on the location within NSW.
    - Deloitte Access Economics adopted the average premium rate of 5% covering a 40% loss and applied this to the estimated annual cost of the crop. This resulted in a total insurance cost per annum of $160,000.
    - This cost can vary significantly. Adopting a 60% rate of coverage incurs a 10% premium resulting in a $4 million premium per annum.
    - For greenhouse and indoor facilities insurance estimates from the BOTEC analysis of $4.60 per sqm were adopted, resulting in a total crop insurance cost of $83,000 per annum.
    - There is no guarantee that crop insurance could be placed for medicinal cannabis, at this or any price.

The individual components for material and utilities costs are detailed below.

Table 3.12: Allocation of material costs (annualised $ million)

Materials & utilities components	Broadacre	Greenhouse	Indoor
Seeds/cultivars	0.48	0.22	0.13
Utilities	0.01	6.03	9.90
Insurance	0.16	0.07	0.04
Nutrients/pesticides	0.03	1.28	0.66

Source: Deloitte Access Economics

3.4 Manufacturing process

3.4.1 Process overview

Four main methods of cannabis oil extraction were explored in this analysis:

- Solvent extraction (using ethanol);
- Carrier oil extraction (using olive oil);
- Super- or sub-critical carbon dioxide extraction; and
- Light hydrocarbon extraction.

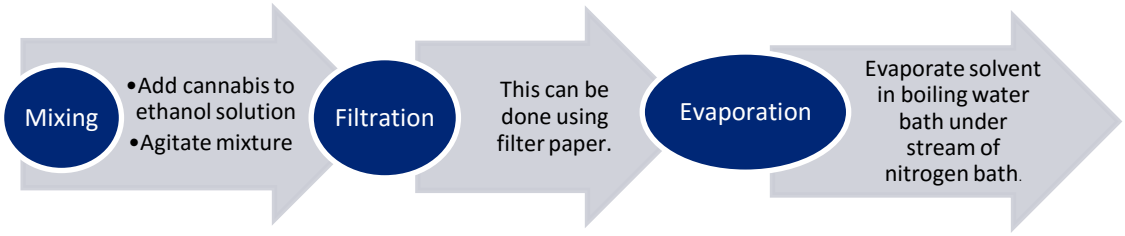
The following provides a brief explanation of each of these extraction methods

[40] National Rural Advisory Council, Feasibility of agricultural insurance products in Australia for weather-related production risks.

Solvent extraction: ethanol solvent

Solvent extraction is a basic technique performed in laboratories involving the separation of a substance (in this case medicinal cannabis oil) from a mixture (un-useful oils). This is achieved by preferentially dissolving that substance in a suitable solvent. The following steps outline basic procedure for solvent extraction in a laboratory context:

Figure 3.1: Solvent extraction process: Ethanol



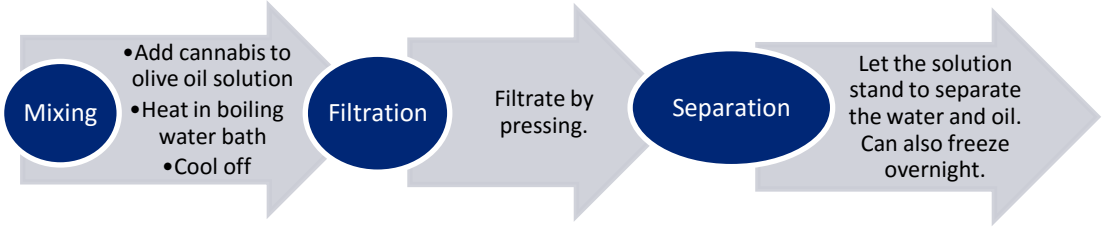
Source: University of Siena, Department of Pharmacy

This method is common for small scale and illegal production in home-grown cannabis operations. Popular solvents are petroleum-ether; naphtha and ethanol, however the concerns with using these chemicals are their flammability and toxicity. Since the cannabis oils are concentrated by evaporating the solvents that were used for extraction, this will leave behind residual solvent. Taking into account the risks involved, the recommended solvent for this method of extraction is ethanol.

Carrier oil extraction: olive oil

The extraction of cannabis oils by using olive oil is quite similar to using ethanol as a solvent, see Figure 3.2.

Figure 3.2: Carrier oil extraction process: Olive oil



Source: University of Siena, Department of Pharmacy

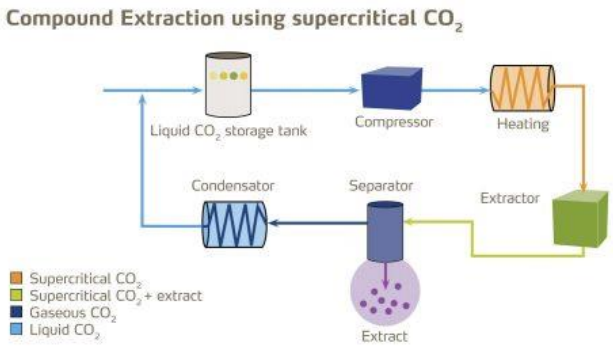
The most obvious difference in steps between olive oil and ethanol extraction is the final step. In olive oil extraction, the solution is allowed to set to allow the immiscible components of olive oil and cannabis oils to separate fully. The concern with using this method is the time required to perform this separation step, as best result require overnight freezing of the mixture.

As mentioned previously this method will leave behind traces of olive oil in the cannabis oil. While olive oil is non-toxic, it is perishable and will have to be stored in a cool, dark location and should not be kept for long periods. Noting this, it is a relatively inexpensive option for extraction and is preferred over using ethanol if extracting for medicinal uses.

Super- or sub-critical carbon dioxide extraction

This method is widely acknowledged as the way to achieve the highest concentration end product. Unlike regular solvent extraction, super-critical solvent extraction can produce a product with no solvent residues. Other benefits of using this method are its extraction properties can be widely and precisely manipulated with subtle changes in pressure and temperature, carbon dioxide is inexpensive and it is perfectly adapted in essential oils industries due to its low critical temperature of 31°C. The following flowchart illustrates the steps involved in super-critical carbon dioxide.

Figure 3.3: Supercritical carbon dioxide extraction



Source: Essential Oils | Plant Therapy

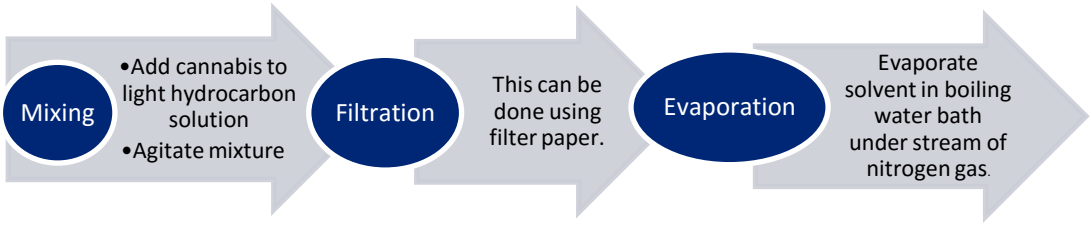
As seen in Figure 3.3, liquid CO_2 is compressed and heated to a super-critical phase. It is then pumped into an extractor, which freezes and compresses the fluid into a cold liquid state. The product is passed through the dried cannabis flowers in the separator, removing all the essential trichome oils out of the plant material and into collection receptacles. After the extraction process is complete, the CO_2 pressure is decreased, allowing it to either return to gaseous phase or stay in liquid phase[41]. In either form the carbon dioxide is captured and stored to be used again.

Light hydrocarbon extraction

Light hydrocarbons (namely propane and butane) are the most popular solvents used in cannabis extraction. This method is preferred due to the lower cost of extraction equipment, speed of extraction and ease of production. Chemically, light hydrocarbons easily dissolve cannibinoids into soluble form without dissolving other undesirable compounds, resulting in a high quality extract. The following diagram provides an overview of the extraction process.

[41] *CO2 extraction: Your Complete Guide to CO2 Cannabis Oil*, Anthony Franciosi. 2016

Figure 3.4: Solvent extraction process: Light hydrocarbons



Source: University of Siena, Department of Pharmacy

While using light hydrocarbons reduces capital and operating expenditure, the costs involved in installation safety apparatus is expected to offset much of the savings. Light hydrocarbons are inherently combustible, so the extraction lab must be set up in a controlled environment constructed to the relevant national safety standards[42]. For large-scale production, using light hydrocarbons has its drawbacks. A supercritical CO_2 system can be scaled to accommodate for higher demand pressures, however a light hydrocarbon system will likely be restricted by limits on flammable solvents.

3.4.2 Manufacturing costs

Manufacturing of medicinal cannabis oil can be done using various techniques. A search of international manufacturers in the United States and Canada showed that for those manufactures which provide details of their extraction method, there is no one approach which is favoured but that a variety of methods are adopted. The choice of method is likely based on the price, processing time, final product and the needs of customers.

Table 3.13 details the estimated cost of manufacturing cannabis oil based on four extraction methods. To supplement publicly available data, the extraction costs per 100 kg of plant material reported in this section were based on industry consultations. The manufacturing costs are stand-alone and independent of the cultivation method.

Table 3.13: Manufacturing costs

Cultivation method	$ per sqm	$ per kg dried flower	Annualised cost ($ million)	Total cost ($ million)
Olive oil extraction	3.3	39.7	0.44	1.04
Solvent extraction	3.9	45.9	0.51	1.11
Super- or sub-critical carbon dioxide extraction	3.6	43.3	0.48	0.85
Light hydrocarbon extraction	2.1	25.4	0.28	0.58

Source: Deloitte Access Economics

[42] Marijuana Venture, 2015. "An Education in Extraction"

Basis for cost estimates

- For each extraction method a number of tests are required for product analyses. Total costs were estimated at $800 for broadacre and $1,400 for indoor and greenhouse operations. The higher cost for indoor and greenhouse reflect four harvests to one for broadacre.
    - HPLC or GC analysis $50 per sample or batch, for qualification of THC and CBD;
    - Afflatoxin analysis: $100 per annum;
    - Herbicide/pesticide analysis $360 per annum;
    - Heavy metal analysis $65 per annum; and
    - Residual solvent analysis $50 per annum.

Olive oil solvent extraction

- Limited information was available on the cost of manufacturing equipment. Capital expenditure was estimated using groundnut oil extraction[43] as a proxy. The cost of a medium expeller oil extraction unit was priced at $600,000.
- Operating expenses took into account the market price of food grade extra virgin olive oil (estimated at $6.50/L); the cost of a filter ($60) and a labour component comprising of two laboratory technicians (assumed $75,000 annual salary per technician).
- 3 litres of olive oil is required to process 100 kg of cannabis plant material.
- The extraction process was estimated to cost $2,010 per 100 kg of plant material.

Ethanol solvent extraction

- Due to the similar nature of using ethanol and olive oil as solvents, this capital cost was also estimated using groundnut oil extraction as a proxy and set at $600,000.
- Operating expenses took into account the market price of ethanol (estimated at $8.22/L); the cost of a filter ($60); an activated charcoal filter ($100) and a labour component comprising of two laboratory technicians (assumed $75,000 annual salary per technician).
- 3 litres of ethanol is required to process 1 kg of cannabis plant material.
- The extraction process was estimated to cost $2,626 per 100 kg of plant material.

Super- or sub-critical carbon dioxide extraction

- The capital cost for super- or sub-critical carbon dioxide extraction was based on a price estimate for a high production system capable of processing approximately 45 kg of cannabis per day. At this production rate, the system can potentially process up to 16.5 tons of cannabis per year.
- Operating expenses took into account the market price of CO_2 (estimated at $4.87/L); the cost of a 20µm filter ($60), an activated charcoal filter ($100) and a labour component comprising of two laboratory technicians (assumed $75,000 annual salary per technician).
- Approximately 3 litres of CO_2 is required to process 100 kg of cannabis plant material.
- The extraction process was estimated to cost $2,525 per 100kg of plant material.

[43] Small Scale Oil Extraction from Groundnuts and Copra. Appropedia, 2011.

Light hydrocarbon extraction

- The capital cost for light hydrocarbon extraction was based on a price estimate for a production system capable of processing approximately 130 kg of cannabis product per day.
- Operating expenses took into account the market price of $147 per 45 kg and a labour component comprising of two laboratory technicians (assumed $75,000 annual salary per technician).
- The extraction process was estimated to cost $850 per 100kg of plant material.

Table 3.14: Allocation of manufacturing costs

Manufacturing method	CapEx ($)	OpEx ($ per annum)	Annualised cost ($)	Annualised cost ($ per kg dried flower)
Olive oil extraction	600,000	371,100	435,000	45
Solvent extraction	600,000	438,860	503,000	46
Super- or sub-critical carbon dioxide extraction	365,500	435,450	476,000	46
Light hydrocarbon extraction	295,000	244,717	274,217	25

Source: Deloitte Access Economics

3.5 Fees and compliance costs

Table 3.15 details the estimated fees and compliance costs for the cultivation and manufacture of a narcotic drug.

The major cost component of this category is the fees and charges, accounting for around 85% of fee and compliance costs.

Table 3.15: Fees and compliance costs

Cultivation	$ per sqm	$ per kg dried flower	Annualised cost ($ million)	Total cost ($ million)
Broadacre	8.1	95.9	1.07	1.06
Greenhouse	69.7	96.7	1.07	1.07
Indoor	115.9	96.6	1.07	1.07

Source: Deloitte Access Economics

Basis for cost estimates

- Licence and permit fees include:
  - Licence and permit fees for cultivation;
  - Licence and permit fees under the Therapeutic Goods Administration Good Manufacturing Practice (GMP);
  - Licence and permit fees for narcotic drugs manufacture; and
  - Costs in compliance with regulations and licence conditions under both narcotic drugs legislation and GMP.

- Other compliance costs include the destruction of plant materials which are not used in manufacturing and sampling of crops for quality assurance. Based on the cost of destroying hazardous waste in Australia[44], the total plant destruction costs are estimated at $37,000 for broadacre, $6,300 for greenhouse and $5,500 for industrial. The difference in plant destruction costs is due to the difference in cannabis flower per plant across the cultivation options and transport of materials.
- Quality assurance testing was also estimated at $27,000 for broadacre and $66,000 for greenhouse and indoor facilities. It should be noted that quality assurance costs would likely be borne regardless of compliance requirements. The costing assumed the tests below.
    - Soil nutrients – once off test before the crop is planted to establish initial fertiliser requirements, assume one test per five hectares assuming the soil type is consistent throughout. This only applies in the broadacre as planting medium for greenhouse and indoor scenarios is inert and sterile.
    - Seed purity and germination – once off before planting to establish what seeding rate should be used.
    - Pathogens – assumed six tests (two tests each for bacteria, fungus and virus) during the growing season. Per hectare for broadacre, or assumed 20 samples per test for greenhouse and indoor.
    - Tissue nutrients – assumed three tests during the growing season to establish what in-crop nutrients are required. Per hectare for broadacre, or for greenhouse and indoor assumed 20 samples per test.

The individual components for fees and compliance costs are detailed below.

Table 3.16: Allocation of fees and compliance costs (annual $ million)

Cultivation	Broadacre	Greenhouse	Indoor
Licence and permit fees	1.00	1.00	1.00
Plant disposal	0.04	0.01	0.01
Quality assurance testing	0.03	0.07	0.07

Source: Deloitte Access Economics.

3.6 Regulatory cost burden

The nature of cannabis and its use makes medicinal cannabis a highly regulated industry. Given the highly regulated nature of cannabis crops there are a number of additional costs which will be incurred by any potential industry participant which are not typical of most other crops cultivated in Australia. Of the costs which are detailed above in Section 3, the list below details the costs involved in meeting the expected regulatory and compliance requirements for cannabis.

It should be noted that the regulatory costs discussed in this section are a subset of the costs detailed in Sections 3.2 to 3.5 and are not additional.

[44] Department of the Environment, Estimate of the cost of hazardous waste in Australia, July 2014

The costs included in the regulatory burden were split into direct costs and compliance related costs, each listed below.

- Direct costs
    - Licence and permit fees for cultivation;
    - Licence and permit fees under the Therapeutic Goods Administration Good Manufacturing Practice (GMP);
    - Licence and permit fees for narcotic drugs manufacture; and
    - Costs in compliance with regulations and licence conditions under both narcotic drugs legislation and GMP.
- Compliance related costs
    - Plant material disposal;
    - Security requirements;
    - Employee suitability checks; and
    - Secure transport of cannabis product;

In total it was estimated that the regulatory burden for cannabis crops will range from $1.48 million for broadacre to $1.28 million per annum for indoor cultivation based on an annualised cost of infrastructure. This includes $1.0 million of direct fees and charges, and between $0.28 million to $0.48 million for compliance related costs. The difference in costs between the cultivation options is largely driven by higher security costs and plant disposal costs which are higher for broadacre given the dried flower yield makes up less of the total yield on average, hence more plants are required.

Table 3.17: Allocation of regulatory costs (annualised $ million)

Cultivation	Broadacre	Greenhouse	Indoor
Direct costs	1.00	1.00	1.00
Compliance related costs			
Plant disposal	0.04	0.01	0.01
Employee checks	0.01	0.01	0.01
Secure transport	0.01	0.00	0.00
Security infrastructure	0.43	0.30	0.27
Total	**1.48**	**1.31**	**1.28**

Source: Deloitte Access Economics. Note: regulatory costs are a subset of costs detailed in Sections 3.2 to 3.5.

4 Results

The establishment of a medicinal cannabis industry in Australia is likely to see a number of growers enter the market. The number of growers who would establish operations is not known and would depend on factors such as total demand, licensing and regulations, expertise and appropriate facilities. Given the uncertainties around the number of growers, the analysis and results reported below focus on ten growers. The impact on the cost of cultivation from varying the number of growers to 1, 5 and 20 growers is included in the sensitivity analysis (see Section 5).

4.1 Cultivation method

Table 4.1 below details the total cost of each cultivation option to produce 11 tonnes of dried cannabis flowers. The lowest cost option is broadacre cultivation at $9.9 million per annum, followed by greenhouse cultivation at $17.1 million, while indoor cultivation is the most costly at $21.2 million per annum. The key difference between the options is the materials for cultivation, and in particular the utilities expenses incurred in greenhouse and indoor facilities.

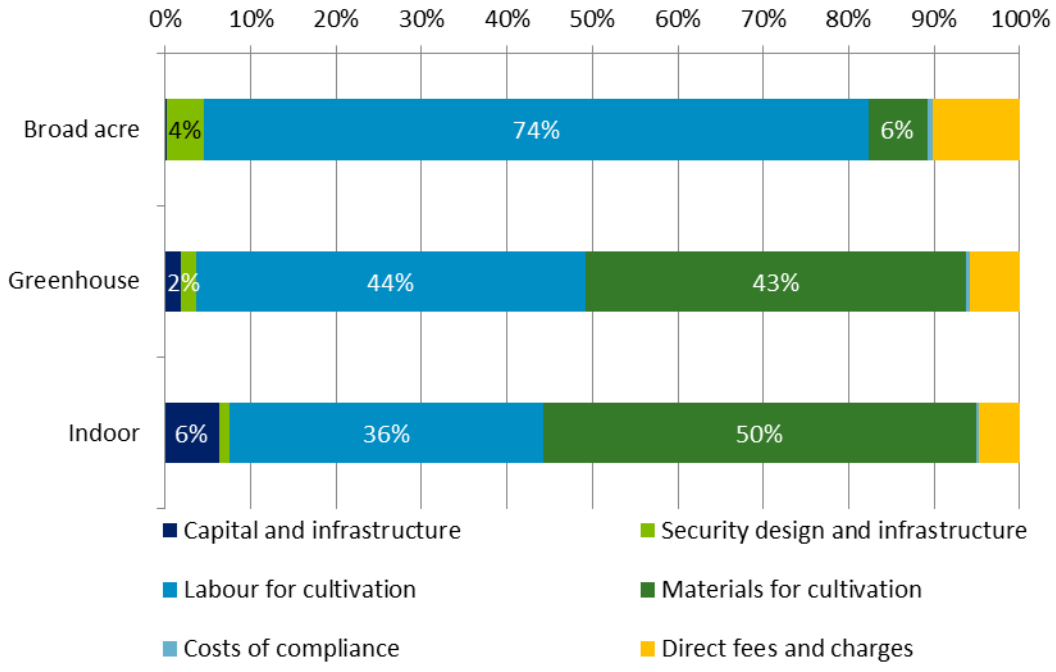
Table 4.1: Annualised costs by cultivation regime ($ million)

Cost category	Broadacre	Greenhouse	Indoor
Capital, land and infrastructure	0.02	0.32	1.33
Security design and infrastructure	0.43	0.30	0.27
Labour for cultivation	7.67	7.79	7.79
Materials for cultivation	0.67	7.60	10.74
Costs of compliance	0.07	0.07	0.07
Direct fees and charges	1.00	1.00	1.00
Total	**9.86**	**17.08**	**21.20**

Source: Deloitte Access Economics

Although each cultivation option had a similar labour cost due to trimming costs being the same across each option and being the most significant labour cost, labour accounted for a high of 74% of costs for broadacre to 36% for indoor cultivation costs (see Chart 4.1). For both greenhouse and indoor cannabis farming, materials (which include electricity costs) accounted for the greatest share of costs, accounting for 43% of total costs for greenhouse (equal to labour costs) and 50% for indoor facilities.

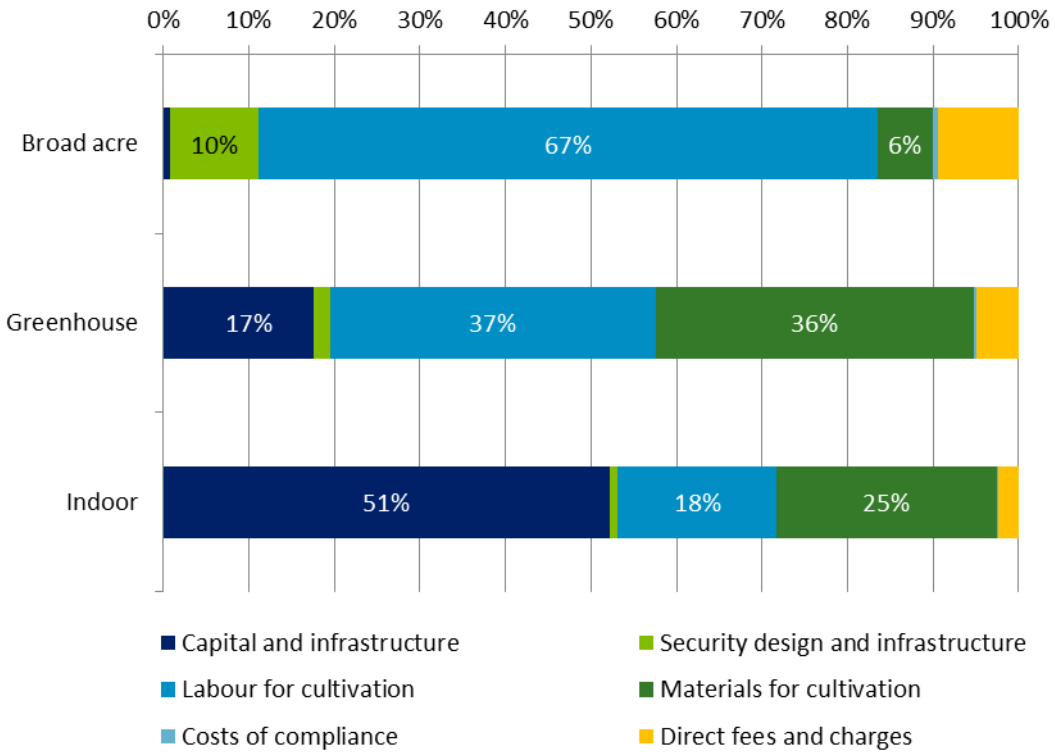
Chart 4.1: Share of costs by cultivation regime



Source: Deloitte Access Economics

Capital costs in relation to labour and equipment are relatively minor on an annual basis. This is due to only a portion of the initial capital costs being included each year. When looking at potential costs in year one, which include total setup costs, capital and infrastructure accounts for 17% of greenhouse costs and 51% of indoor costs. There is only a minor capital cost for broadacre which is largely due to security requirements.

Chart 4.2: Potential costs in year one including capital and cultivation



Source: Deloitte Access Economics

Table 4.2 below shows the annualised cost on a *per kg of dried flower* basis and shows the same results as total annualised cost where labour and materials are the key drivers of costs. The results represent the total costs divided by the tonnes of product produced.

Table 4.2: Estimated costs by cultivation regime ($ per kg dried flower)

Cost category	Broadacre	Greenhouse	Indoor
Capital, land and infrastructure	2	29	120
Security design and infrastructure	38	27	24
Labour for cultivation	691	702	701
Materials for cultivation	61	685	968
Costs of compliance	6	7	7
Direct fees and charges	90	90	90
Total	**888**	**1,539**	**1,909**

Source: Deloitte Access Economics

4.2 Capital and operational costs

The costs of cultivation can be classified as capital or operational expenses. These expenses are based on whether the costs are a fixed up-front cost (capital expenditure) or an ongoing cost which is incurred each year (operational expenditure). The allocation of costs is listed below.

- Capital and infrastructure for cultivation, i.e. fixed up-front setup costs:
    - building construction and land preparation;
    - capital and infrastructure for cultivation, for example, irrigation systems in a greenhouse or indoor setting; and
    - security elements, such as fencing and CCTV facilities, to secure cultivation sites.
- Ongoing cultivation costs:
    - employee suitability checks and training;
    - labour for planting and harvesting;
    - materials for cultivation including pest control, weed control, nutrients and fertilisers;
    - transport; and
    - crop insurance.

At maturity of the industry, capital expenditure is estimated to account for around $210,000 per annum for broadacre to $1.36 million for indoor cultivation. Although capital costs can be a significant cost in the first year to establish operations, annualising the costs across the useful life of the capital shows it accounts for a small portion of total costs each year. The share of capital costs accounted for annually are: 4% for land, 4% for building/premises (6.7% for greenhouse) and 10% for equipment.

Table 4.3: Estimated costs by cultivation regime

Cost category	Broadacre	Greenhouse	Indoor
Capital expenditure (annualised)	0.21	0.38	1.36
Operational expenditure	9.65	16.70	19.84
Total	9.86	17.08	21.20

Source: Deloitte Access Economics

4.3 Manufacturing and export

Manufacturing costs were assessed across four extraction methods — carrier oil extraction, solvent extraction, sub-critical CO_2 extraction and light hydrocarbon extraction. The results across each method were fairly similar averaging around $40 per kg of plant product for the first three extraction methods, however light hydrocarbon costs were around 40% lower at $25 per kg. Around half of the total manufacturing costs were for the extraction process which ranged from $2,010 per 100kg of plant material under carrier oil extraction, $2,585 for sub-critical CO_2 extraction, $2,626 for solvent extraction and $850 for light hydrocarbon.

Table 4.4: Cost of manufacturing

Cultivation	$ per kg dried flower	Annualised cost ($ million)	Total cost ($ million)
Carrier oil extraction	39.7	0.44	1.04
Solvent extraction	45.9	0.51	1.11
Sub-critical CO_2 extraction	43.3	0.48	0.85
Light hydrocarbon extraction	25.4	0.28	0.58

Source: Deloitte Access Economics

4.4 Export of raw material

A final option considered in the analysis was for the raw cannabis material to be shipped internationally for manufacturing. This section looks at the cost of two options for export; export of dried cannabis flowers and export of full plant material.

The costings assumed the same level of final plant product as the previous options for comparison purposes. Given the potential size of the international market, it is expected that the level of demand at maturity could be substantially higher.

4.4.1 Export of dried cannabis flowers

Where dried cannabis flowers are exported it was assumed that the costs are similar to those of the previous cultivation options discussed above. The differences relate to no manufacturing costs and minor changes to fees and charges.

Under this scenario the total cost fell by 5% for broadacre, 3% for greenhouse and 3% for indoor cultivation.

Table 4.5: Estimated costs for export of dried cannabis flower (annualised $ million)

Cost category	Broadacre	Greenhouse	Indoor
Capital, land and infrastructure	0.02	0.32	1.33
Security design and infrastructure	0.43	0.30	0.27
Labour for cultivation	7.67	7.79	7.79
Materials for cultivation	0.67	7.60	10.75
Costs of compliance	0.00	0.00	0.00
Direct fees and charges	1.00	1.00	1.00
Total	**9.81**	**16.99**	**21.11**

Source: Deloitte Access Economics

4.4.2 Export of full cannabis plant

Where the full plant is exported additional costs were excluded. The table below shows the total cost of exporting based on the exclusions listed below:

- no manufacturing costs;
- manufacturing fees and charges excluded;
- no plant destruction costs; and

- no trimming fees, labour costs assumed to only include planting, maintenance and harvesting.

Under this scenario the total cost fell by 68% for broadacre, 40% for greenhouse and 33% for indoor cultivation.

Table 4.6: Estimated costs for export of cannabis plant (annualised $ million)

Cost category	Broadacre	Greenhouse	Indoor
Capital, land and infrastructure	0.02	0.32	1.33
Security design and infrastructure	0.43	0.30	0.27
Labour for cultivation	1.14	1.25	1.25
Materials for cultivation	0.67	7.60	10.75
Costs of compliance	0.00	0.00	0.00
Direct fees and charges	1.00	1.00	1.00
Total	**3.28**	**10.46**	**14.57**

Source: Deloitte Access Economics

5 Sensitivity analysis

This section provides a sensitivity analysis on the key parameters used in the modelling. Parameters tested in the sensitivity analysis include the number of growers, materials cost, dried flower yield, harvest per annum, patient usage per day, number of patients and wage rate. Other parameters were also tested but did not have as significant impact as the parameters reported below.

The sensitivity analysis results for patient usage per day and number of patients per annum requires an increase in the annual amount of cannabis cultivated, however, all other results presented are based on the same level of annual production of 11 tonnes of cannabis flower.

The sensitivity analysis assesses the impact on costs of varying the number of growers to 1, 5 and 20, relative to the base case of 10 growers that has been the assumption in this report thus far.

With an increase in the **number of growers** to 20**,** costs increased due to the need to establish multiple facilities and duplication of various costs across all growers. Costs increased for construction and equipment, utilities, fees and permits, and labour. The basis for the cost increase for each component is detailed below.

- Construction and equipment costs;
    - expected increase in per sqm cost of construction by around 10% to 20% based on construction of smaller facilities. Midpoint of 15% used for the sensitivity analysis results.
    - security infrastructure - increase in the property perimeter due to multiple premises and requirement of multiple security systems.
- Utility costs — heating cost likely to increase when more greenhouses and indoor facilities are built as the perimeter is greater and hence more heat loss. It was unclear what the increase in heating costs would be. An increase in utilities costs of 10% was

used for the sensitivity analysis. For facilities with passive heating there would be no impact.

- Direct fees —fees and permit expenses paid by each grower; and
- Labour costs – operations manager required at each facility.
- For an increase in the number of growers to 20, overall costs increased relatively more for broadacre (23%) than greenhouse (14%) and indoor (11%). This was largely due to higher infrastructure cost requirements given the amount of land that needs securing and the operations manager costs.
- For a decrease in the number of growers to 1, overall costs for broadacre cultivation decreased by 21%, a relatively larger change than for greenhouse (-12%) and indoor (-11%). This was mainly due to eliminating duplicated costs such as capital and infrastructure, labour, security and regulatory costs.

Table 5.1: Sensitivity analysis (% change in annualised cost)

Parameter	Parameter value	Broad acre	Greenhouse	Industrial
Baseline (total $m)		10.4	17.0	20.7
Number of growers	**10**			
	1	-21%	-12%	-11%
	5	-12%	-7%	-6%
	20	23%	14%	11%
Materials per sqm				
	+50%	0.0%	16%	22%
	-50%	0.0%	-16%	-22%
Bud yield per sqm				
	+50%	-3%	-15%	-18%
	-50%	8%	45%	55%
# of harvests per annum	**4**			
	5		-9%	-11%
	3		14%	18%
	2	-2%	43%	54%
Usage (g per day)	**1**			
	1.5	38%	43%	44%
	0.5	-38%	-43%	-44%
Number of patients	**30420**			
	10000	-51%	-57%	-59%
	100000	173%	195%	201%
Wage rate per hour	**25**			
	30	13%	8%	6%
	20	-13%	-8%	-6%

Source: Deloitte Access Economics

An increase in **materials** cost by 50% led to an increase in total costs of 22% for indoor and 16% for greenhouse, however, has a limited impact on broadacre, reflecting the original share of total costs which materials costs accounts for (0.1%) in the base case.

Previous research has shown that dried flower yields and number of harvests per annum can vary significantly across individual growers. A decrease in the **dried flower yield** by 50% saw costs increase by 8% for broadacre and 55% for indoor. The difference in the increase in costs largely reflected the scale of the change, a 50% decrease in yield for broadacre represents a 40 gram per plant reduction compared to 150 grams for indoor.

An increase in the number of **harvests per annum** by one across each cultivation method would see a reduction in costs averaging 10% for greenhouse and indoor, and a fall of 2% for broadacre. Broadacre did not experience as large a reduction in costs because the majority of costs relate to cultivation and harvesting labour which was not expected to change significantly assuming the same level of production.

The percentage change in costs across all cultivation methods is similar for changes in average patient usage (grams per day) and number of patients. A 50% increase in **patient usage** to 1.5 grams per day per patient is expected to increase costs by around 40%. An increase in the number of **patients** to 100,000 resulted in costs approximately doubling.

Increasing **wages** for cannabis cultivation by 20% sees a greater change in broadacre (13%) relative to other cultivation options (6% to 8%). This is due to wages accounting for a higher share of costs in broadacre cultivation.

6 Further analysis required

Due to the desktop nature of this analysis, and limited ability to undertake consultations to fill information gaps, some of the assumptions and costings have a stronger basis than others. To provide further insight into a medicinal cannabis industry, particularly in the context of establishing the industry in Australia and differences that may eventuate relative to overseas experience, additional analysis would help to inform assumptions that are both significant in driving overall costs, and where confidence in existing estimates is low.

The list below outlines suggested areas for further research and consideration.

- Manufacturing – consult with manufacturers to establish the extraction methods which would be preferred and the specific extraction methodology they would utilise and potentially testing extraction techniques for efficiency and product quality. This analysis should focus on extraction methods which are currently used by commercial manufacturers in the United States. This includes extraction methods such as supercritical CO_2 extraction used by Bloom Farms[45] and the light hydrocarbon extraction process used by Neos.[46]
- Materials costs – consult with cultivators, principally with greenhouse and indoor operators to confirm the quantity of materials assumed, and in particular electricity requirements of cannabis crops.
- Automation – it is not clear what machinery could be used that may assists trimming or harvesting of cannabis crops, however any automation in trimming could see significant reductions in labour costs.

[45] http://getbloomfarms.com/mission/

[46] http://liveneos.com/aboutus.html

- Particularly for broadacre farming, the assumption of one plant per sqm may be different in Australian growing conditions, and will be dependent on the location of the farm. A test site could be established, or consultations held with farmers, to examine the optimal plant to sqm ratio. This could also be done for greenhouse and indoor cultivators to determine if a smaller plant to sqm ratio would still produce the same yield per plant.
- Similar to plants per sqm, the dried flower yield per cannabis plant and concentration of THC and CBD play a significant role in the number of cannabis plants which need to be cultivated. These factors could be further examined using different varieties of plant to determine the optimal yield for Australian conditions.
- Develop a better understanding of the relationship between the size of a facility or farm and the cost of cultivation.
- Risk and consequences of crop failure on supply of medicinal cannabis in Australia, particularly as it applies to broadacre farming.

Appendix A: List of parameters

The table below provides a list of key parameters used in the cost analysis and sources of information.

Table A.1: Summary of parameter values

Parameter	Value	Unit
General Assumptions for Modelling		
Spacing of plants	1	plant per sqm
Labour rate	$25	$ per hour
Cultivation		
Time required for planting	46	hours per ha
Time for training employees	1	days per worker
Employee suitability checks	$50	$ per worker
Transport		
Transport expenses: Broadacre	0.87	$ per kg
Greenhouse	0.22	$ per kg
Capital and Infrastructure		
Opportunity cost of land	4%	% per annum
Farming land preparation: Broadacre	$0.06	$ per sqm
Greenhouse construction	$47	$ per sqm
Indoor cultivation	$580	$ per sqm
Area of facility used for growing	49%	% of floor area
Security Design and Infrastructure		
CCTV: Broadacre	$19,000	$ per farm
Greenhouse	$6,500	$ per facility
Indoor	$5,000	$ per facility
Two layer intruder resistant perimeter	$352	$ per metre
Allowance for fencing around facilities	4.5%	%
Alarm system	$1000	$
Monitoring	$3600	$
Materials		
Cannabis seeds	$12	$ per seed
Price reduction for bulk buying	70%	%
Utilities: Broadacre	$0.12	$ per sqm
Greenhouse	$353	$ per sqm
Indoor	$966	$ per sqm
Electricity costs	$0.25	$ per kWh
Plant equipment: Broadacre	$471	$ per sqm
Greenhouse	$122	$ per sqm
Indoor	$700	$ per sqm
Insurance: Broadacre	5%	% farm value

Parameter	Value	Unit
Insured value of broadacre	40%	Crop value
Greenhouse	$4.60	$ per sqm
Indoor	$4.60	$ per sqm
Total supplements (pesticides etc): Broadacre	$0.19	$ per sqm
Greenhouse	$83	$ per sqm
Indoor	$72	$ per sqm
Annualised use of machinery	10	Life years
Direct Fees and Charges		
Licence and permit fees for cultivation	$65,000	$ per site per annum
Licence and permit fees under the TGA GMP	$22,960	$ per site per annum
Licence and permit fees for narcotic drugs manufacture	$12,000	$ per site per annum
Costs of Compliance		
Material disposal	$795	$ per tonne
Sampling and reporting for quality assurance		
Broadacre	$2,400	Total cost per farm
Greenhouse and indoor	$1,600	Total cost per facility
Manufacturing		
Carrier oil extraction	$600,000	Total cost
Solvent extraction	$600,000	Total cost
Sub-critical CO_2 extraction	$365,500	Total cost
Light hydrocarbon extraction	$295,000	Total cost
Annual salary of lab technician	$75,000	Total cost

Source: Deloitte Access Economics

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