Toxic Chemical Testing Example

(Adapted from: "*Influence Diagrams*", by Ronald A. Howard and James E. Matheson, Strategic Decisions Group, 1981)

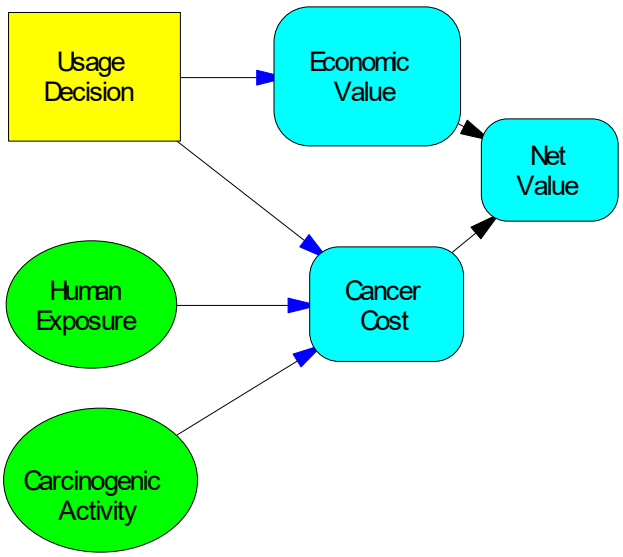
Summary of Decision Problem

A chemical having certain benefits may cause cancer to humans.
We wish to determine whether to
(a) ban its use,
(b) restrict its use, or
(c) permit its use
We must also determine whether to collect additional information about its
(d) cancer-producing activity, and/or
(e) its degree of exposure to humans

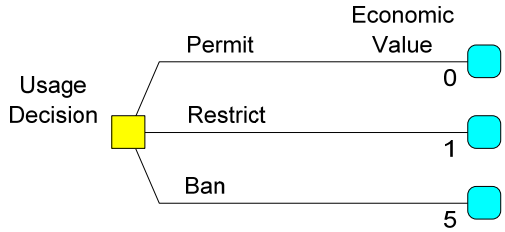
Notes about Influence Diagram:

- *Net value* depends only on *Economic Value* and *Cancer Cost.* It is independent of other variables.
- Also, the state variables *Human Exposure* and *Carcinogenic Activity* are independent.

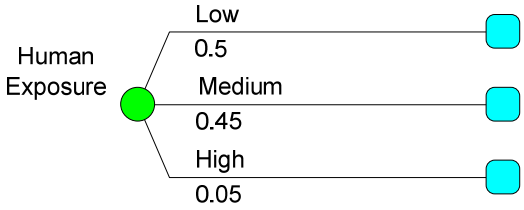
These facts are not obvious and require special knowledge about the particular problem at hand.



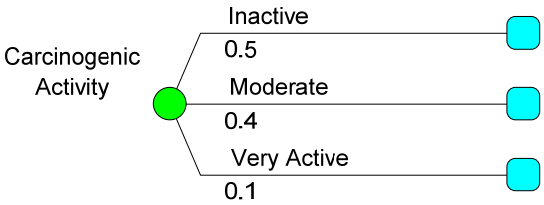
Influence Diagram for Primary Decision



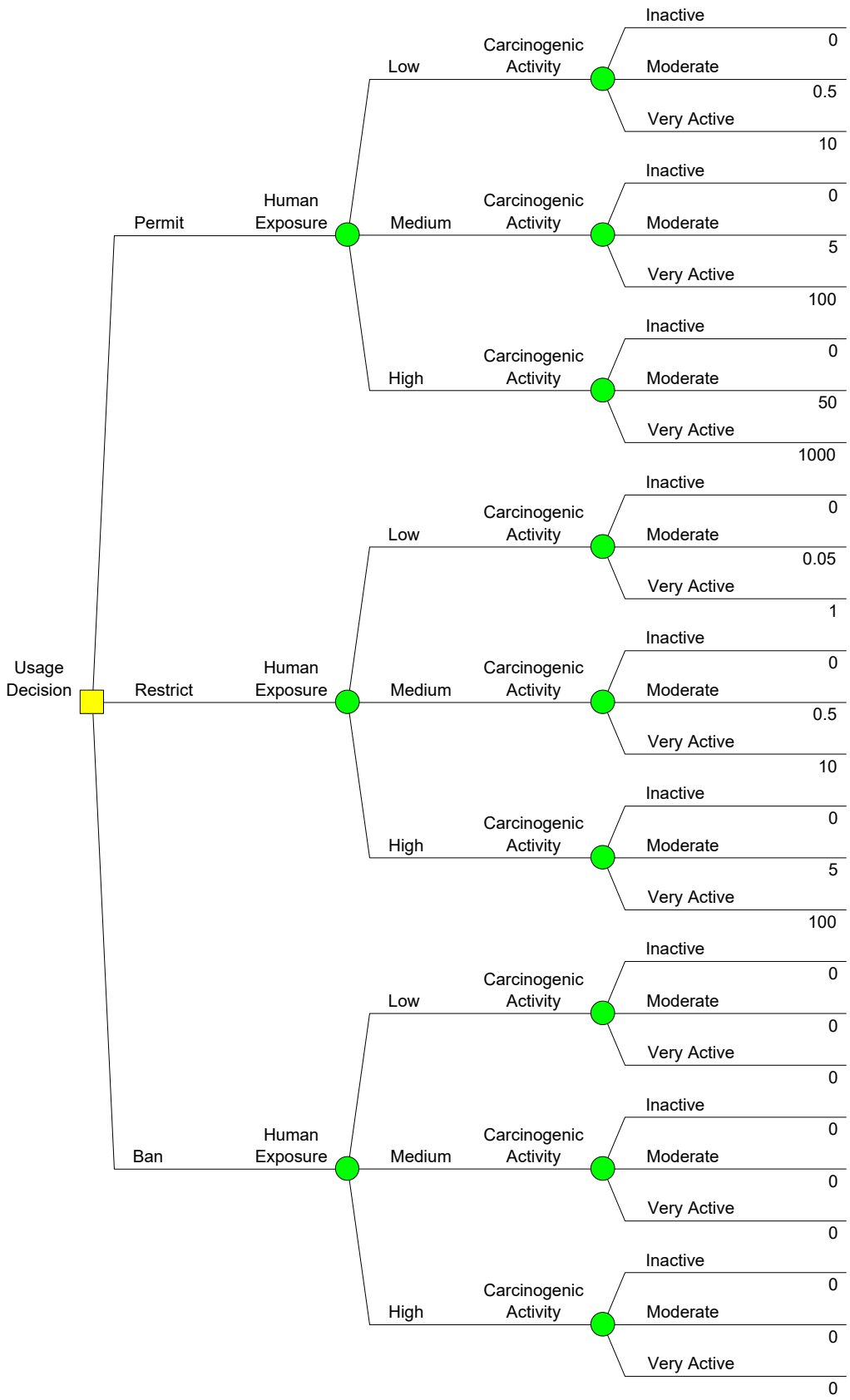
Usage Decision Alternatives and NPV of Economic Values (costs in $M)



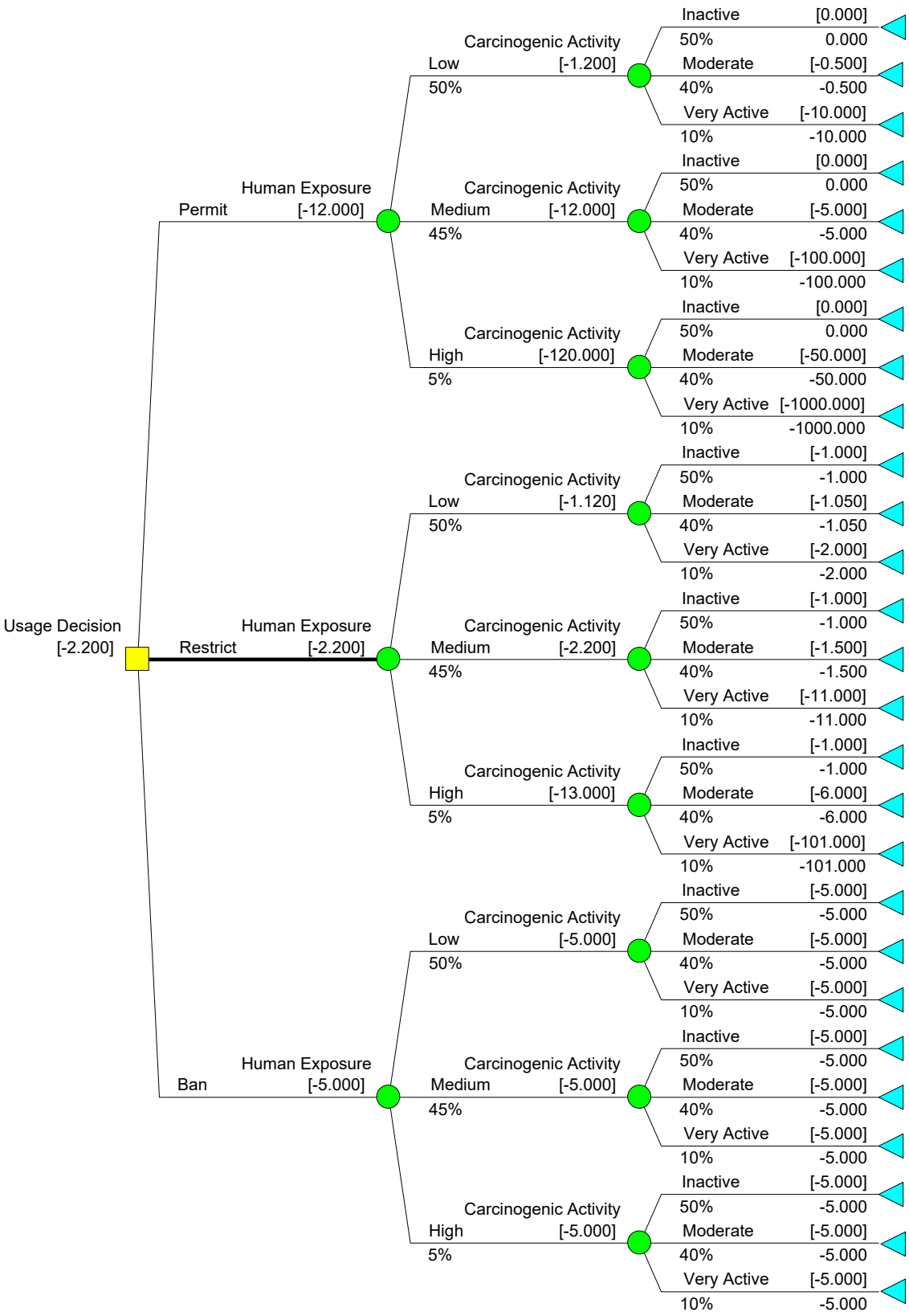
Initial Probability Assignments for Human Exposure



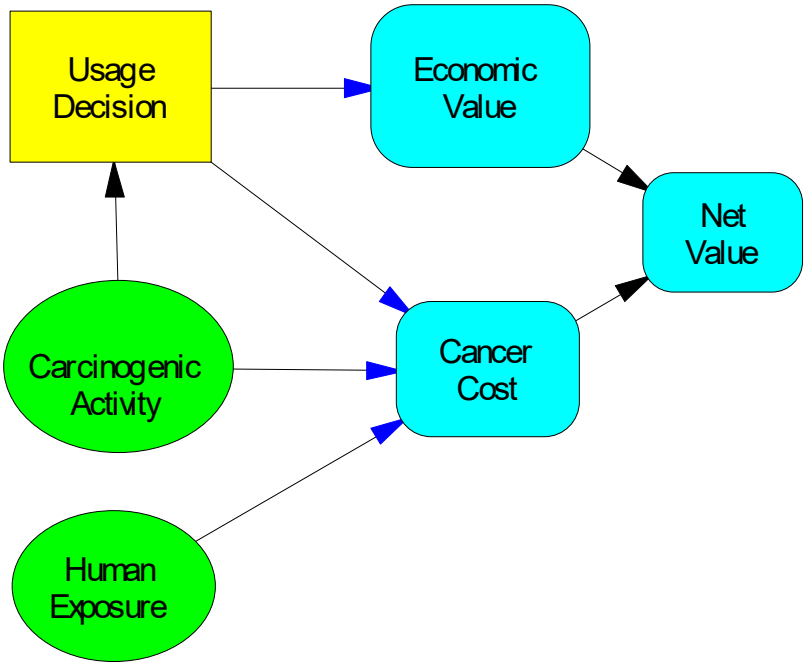
Initial Probability Assignments for Carcinogenic Activity



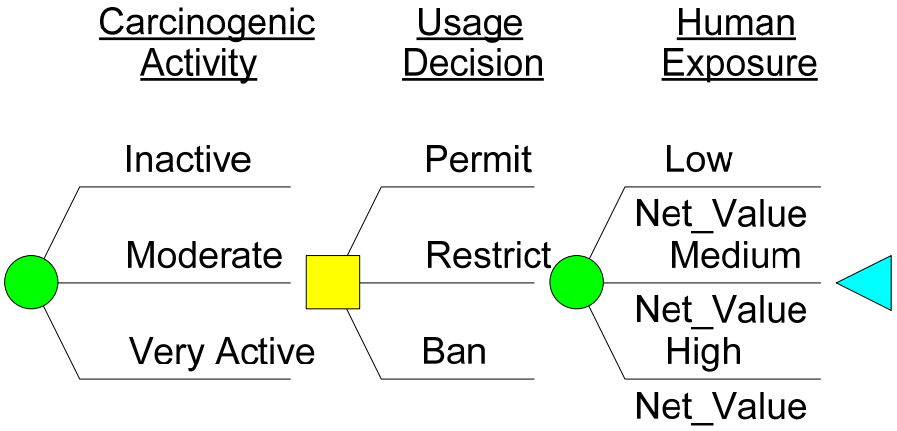
Estimated Cancer Costs given Usage, Human Exposure and Carcinogenic Activity ($ Millions)



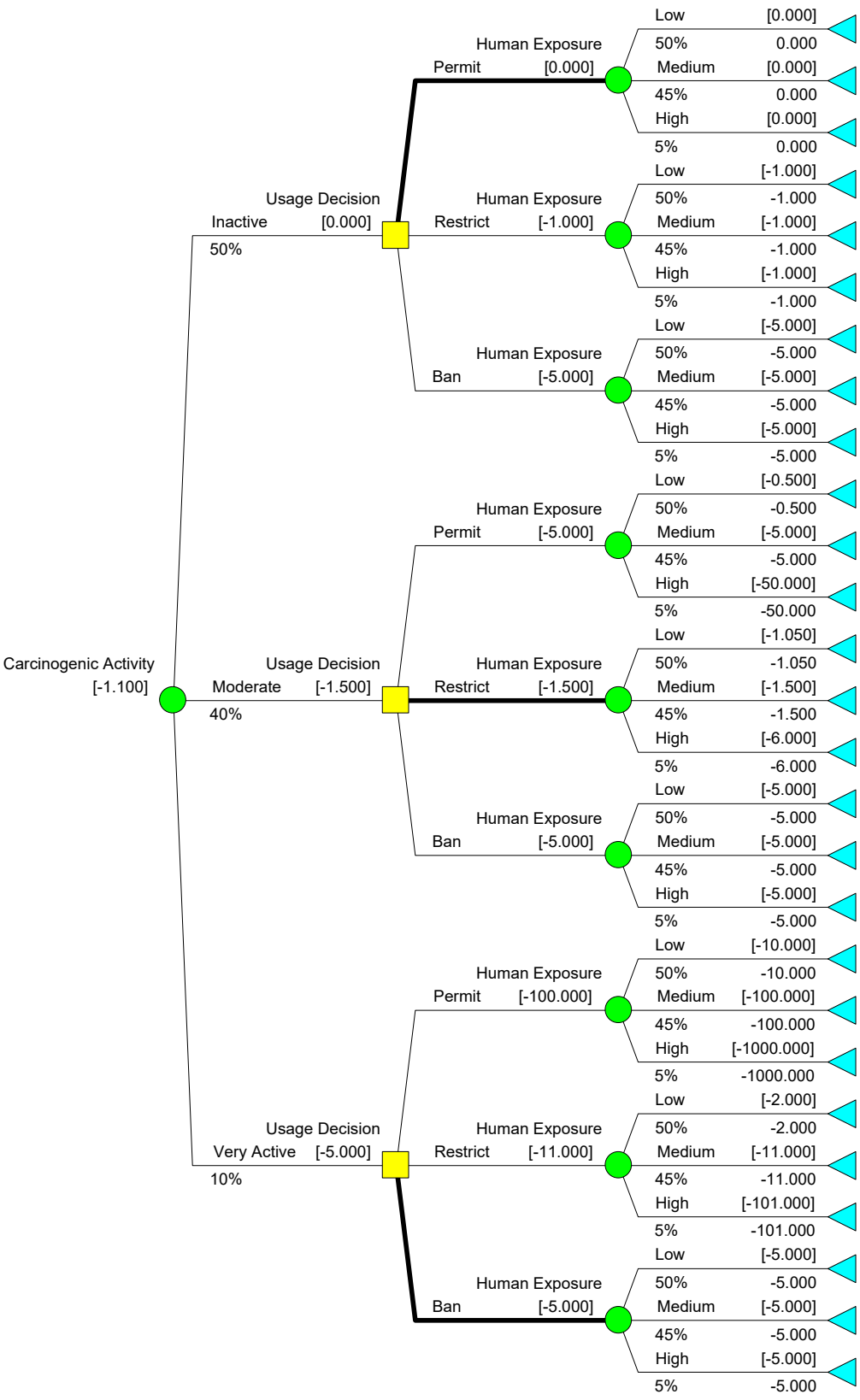
Toxic Chemical Testing Example—Decision Tree for Primary Decision—Restrict (-$2.2M)



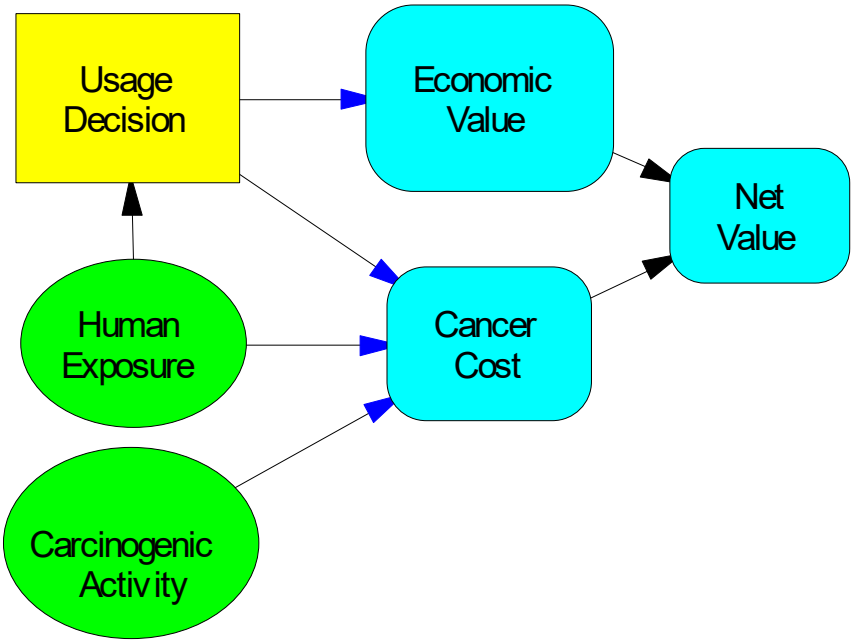
Influence Diagram for Perfect Information (Clairvoyance) on Carcinogenic Activity



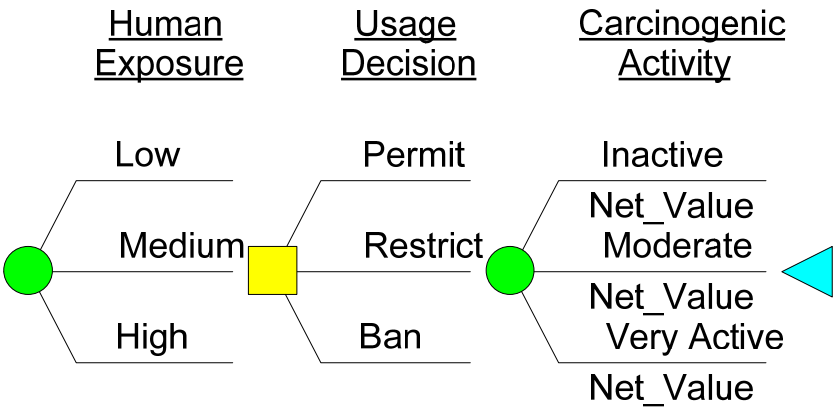
Generic Decision Tree for Perfect Information (Clairvoyance) on Carcinogenic Activity



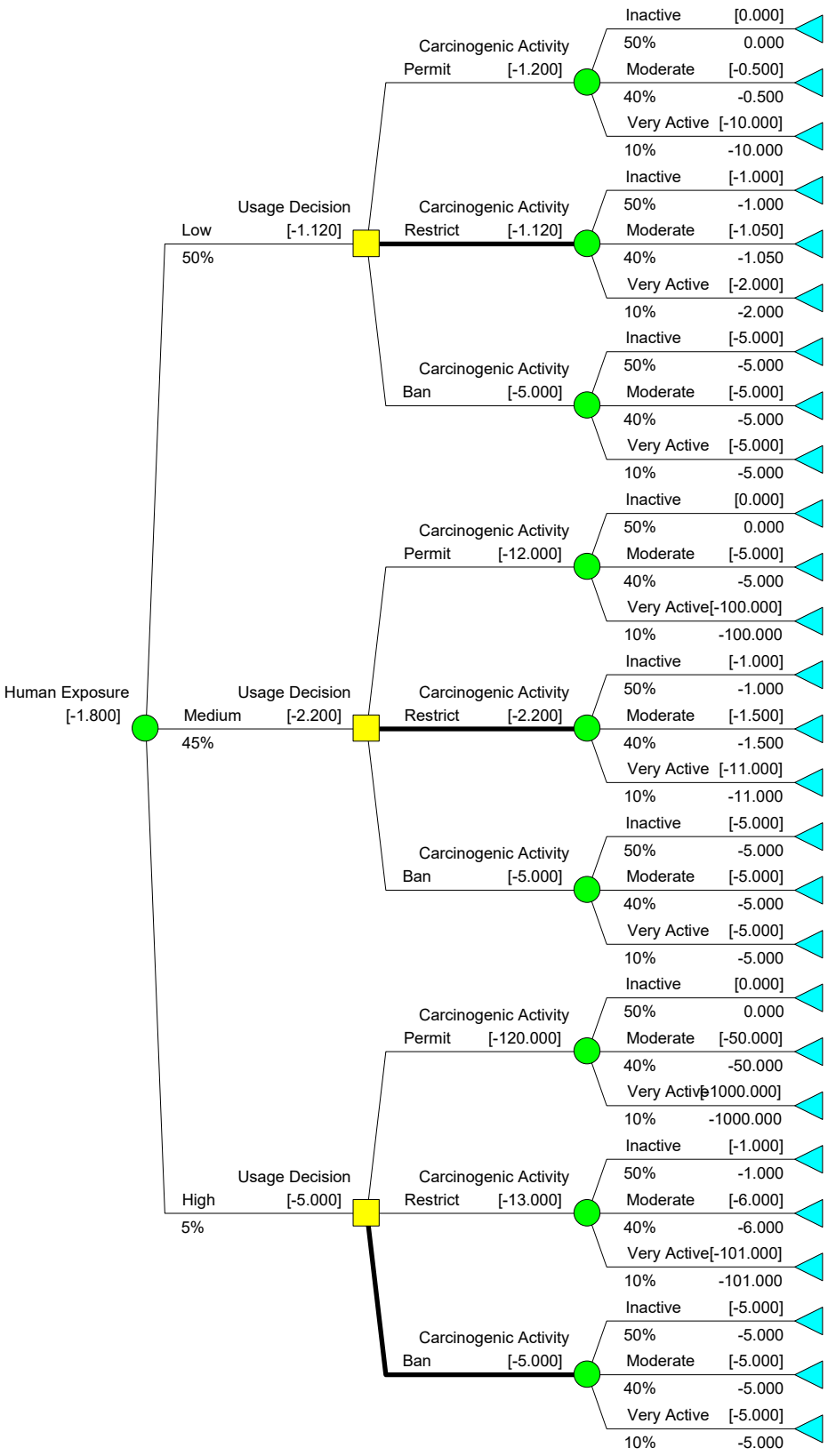
Expected Value of Perfect Info (EVPI) on Carcinogenic Activity = -1.1M + 2.2M = $1.1M



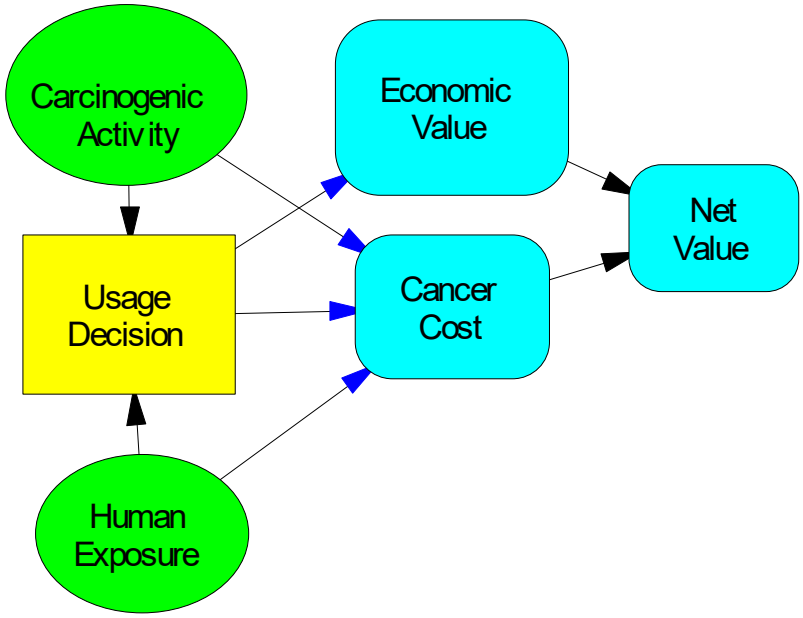
Influence Diagram for Perfect Information (Clairvoyance) on Human Exposure



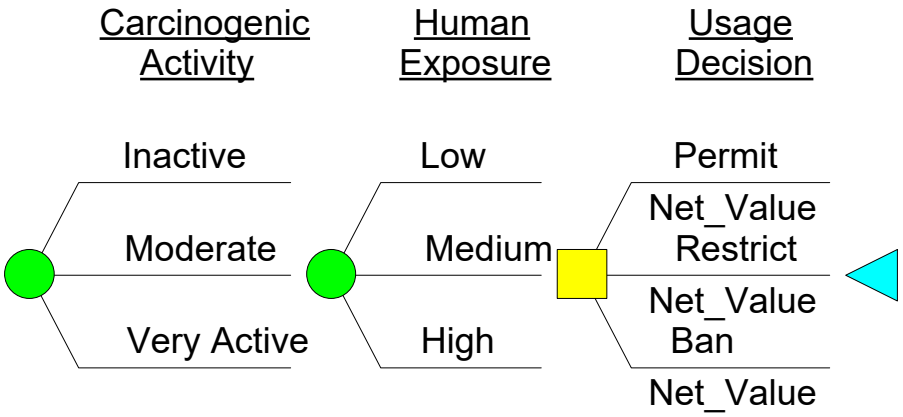
Generic Decision Tree for Perfect Information (Clairvoyance) on Human Exposure



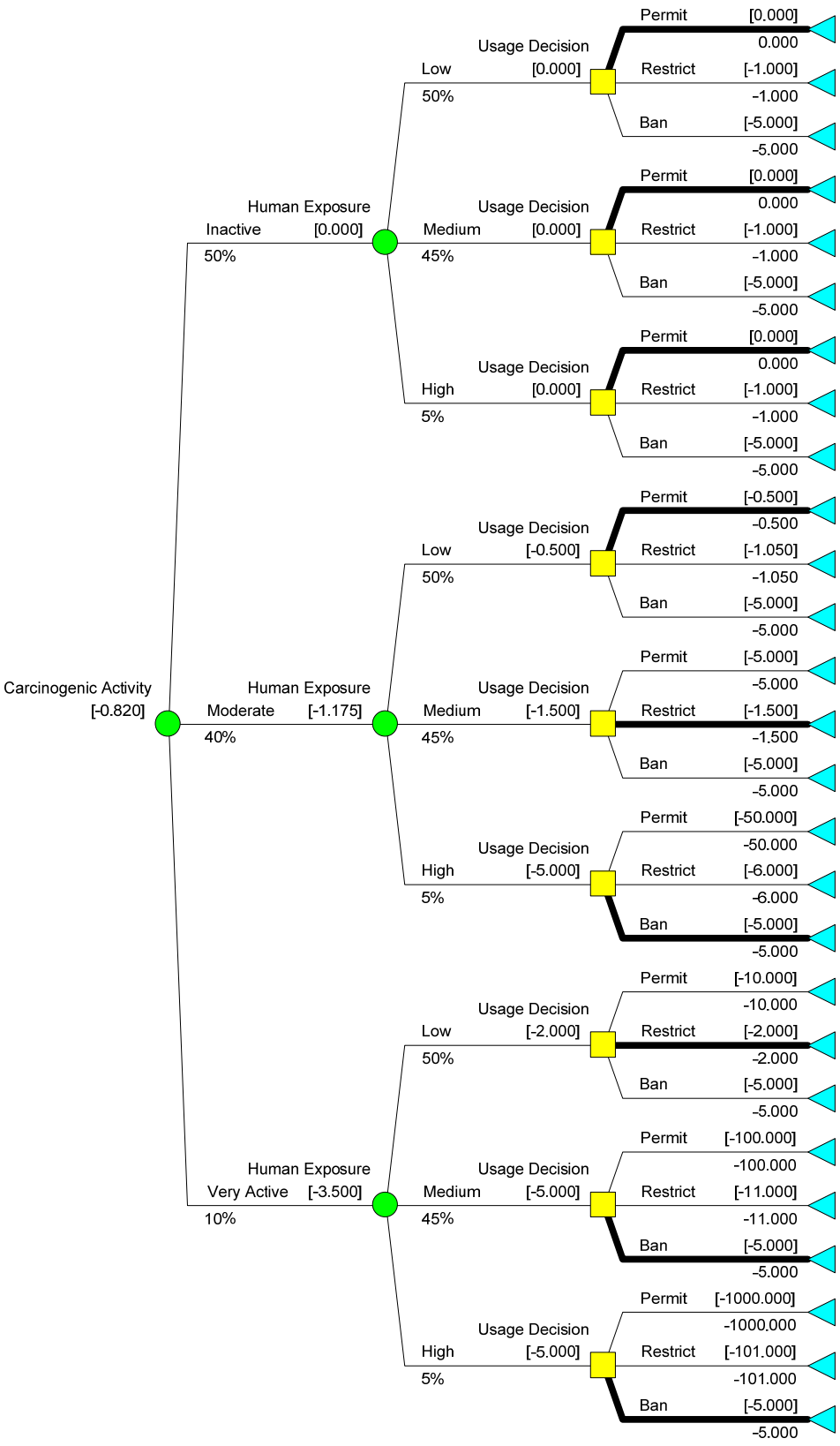
Expected Value of Perfect Information (EVPI) on Human Exposure = -1.8M + 2.2M = $0.4M



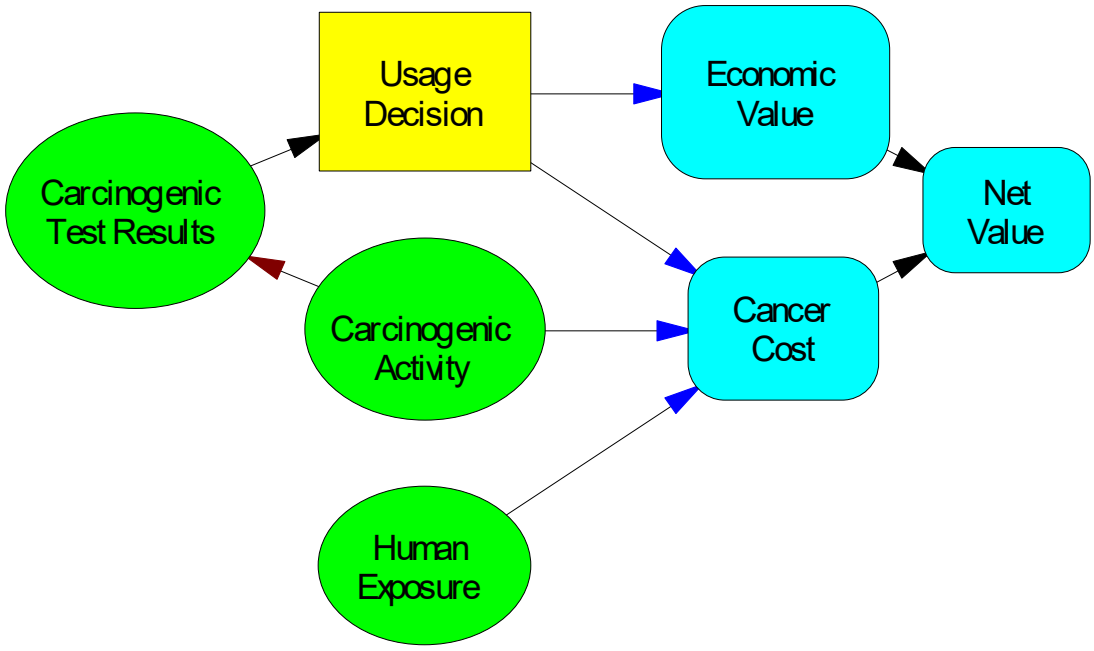
Influence Diagram for Perfect Information (Clairvoyance) on both Carcinogenic Activity and Human Exposure



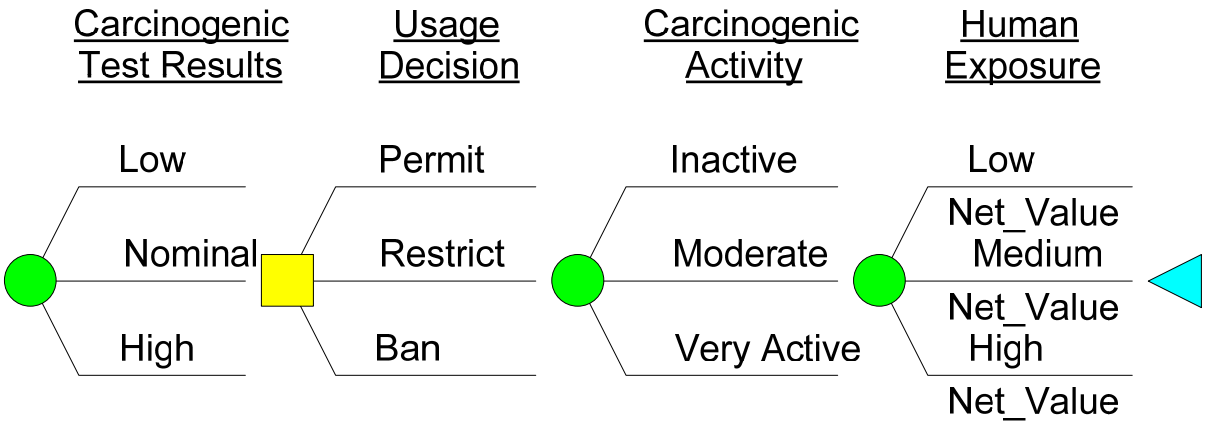
Generic Decision Tree for Perfect Information (Clairvoyance) on both Carcinogenic Activity and Human Exposure



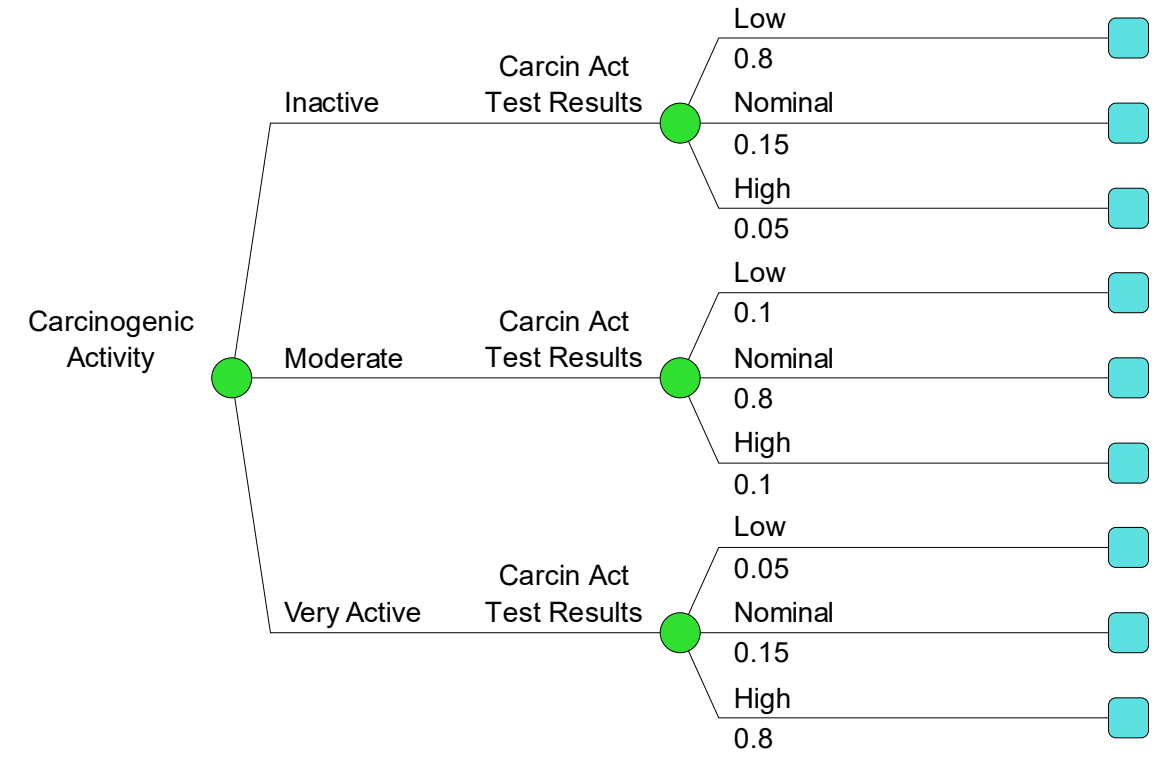
EVPI on both Carcinogenic Activity and Human Exposure = -0.82M + 2.2M = $1.38M



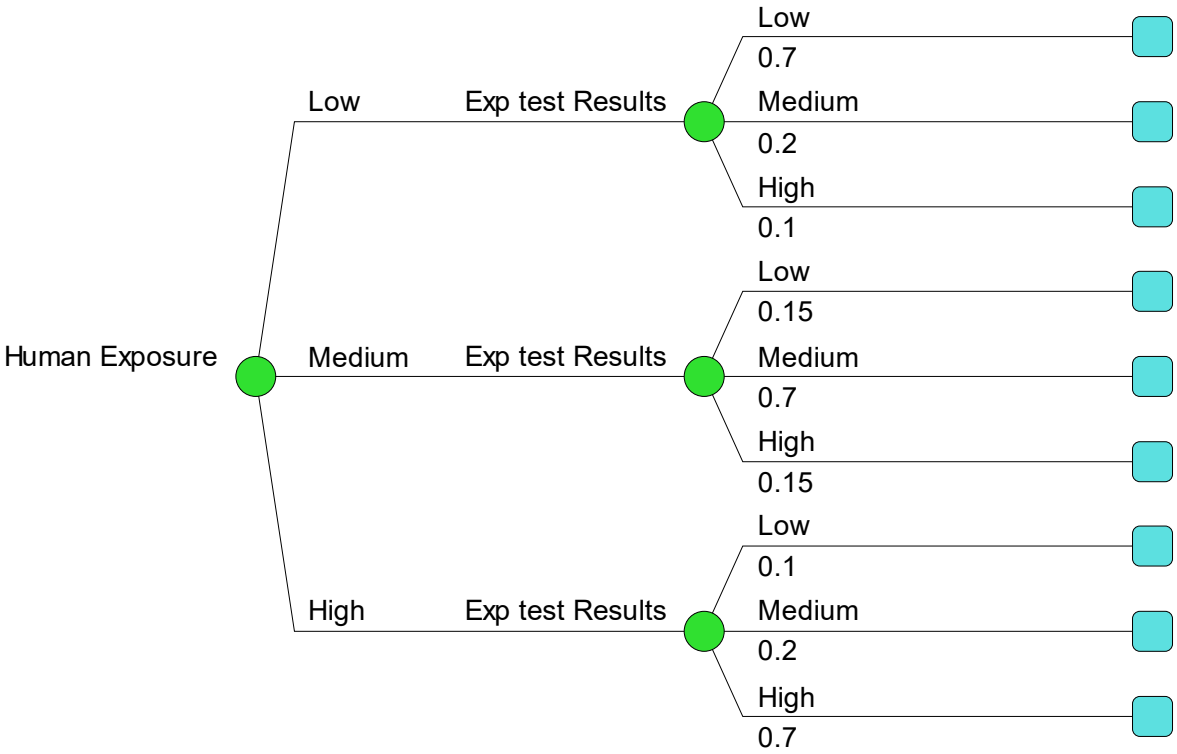
Influence Diagram for Expected Value of Sampled Information (EVSI)
of Test for Carcinogenic Activity



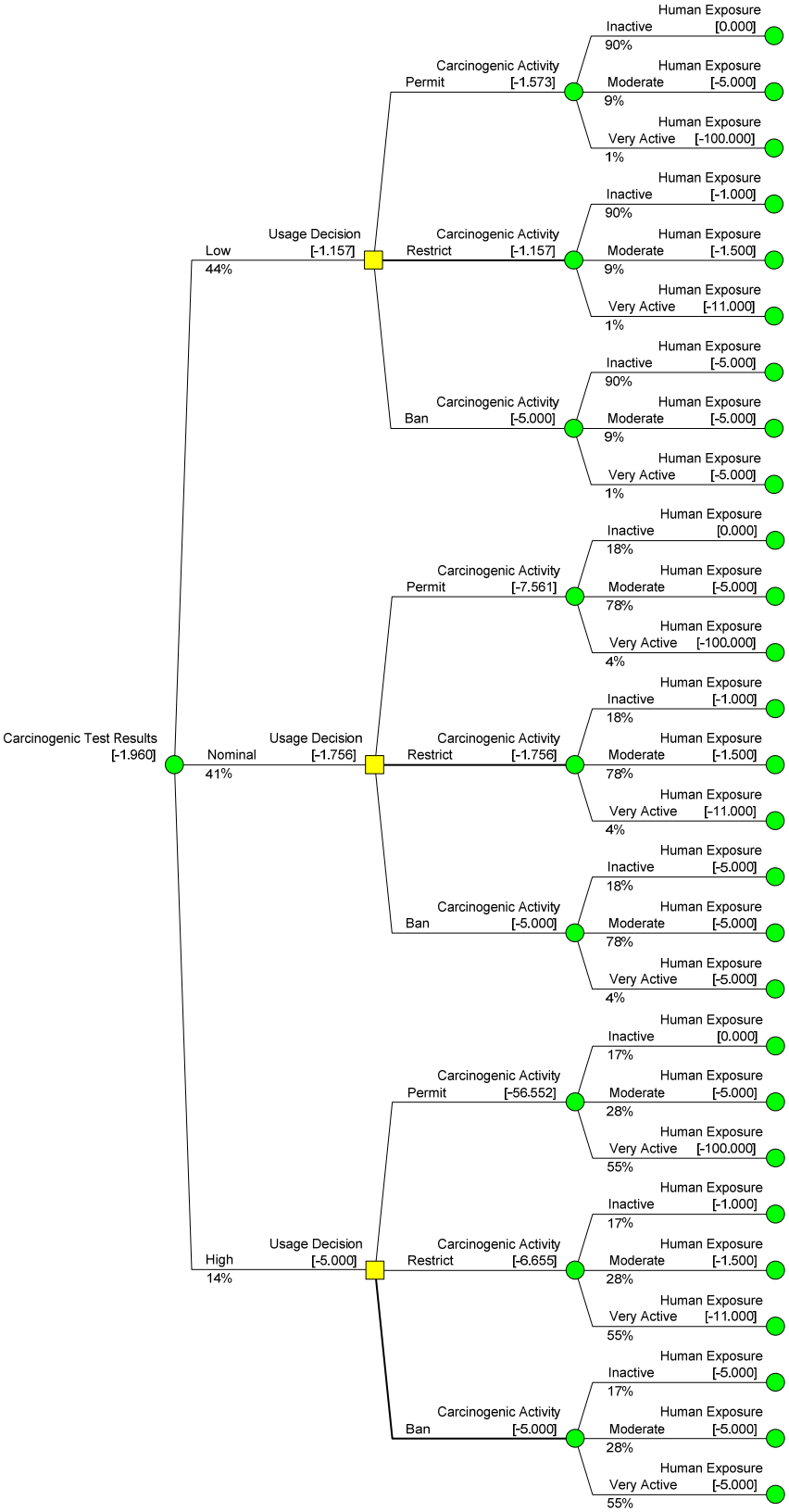
Generic Decision Tree for Expected Value of Sampled Information (EVSI)
of Test for Carcinogenic Activity
(Sequence of Chance Nodes, i.e., Carcinogenic Activity and Human Exposure, can be reversed.)



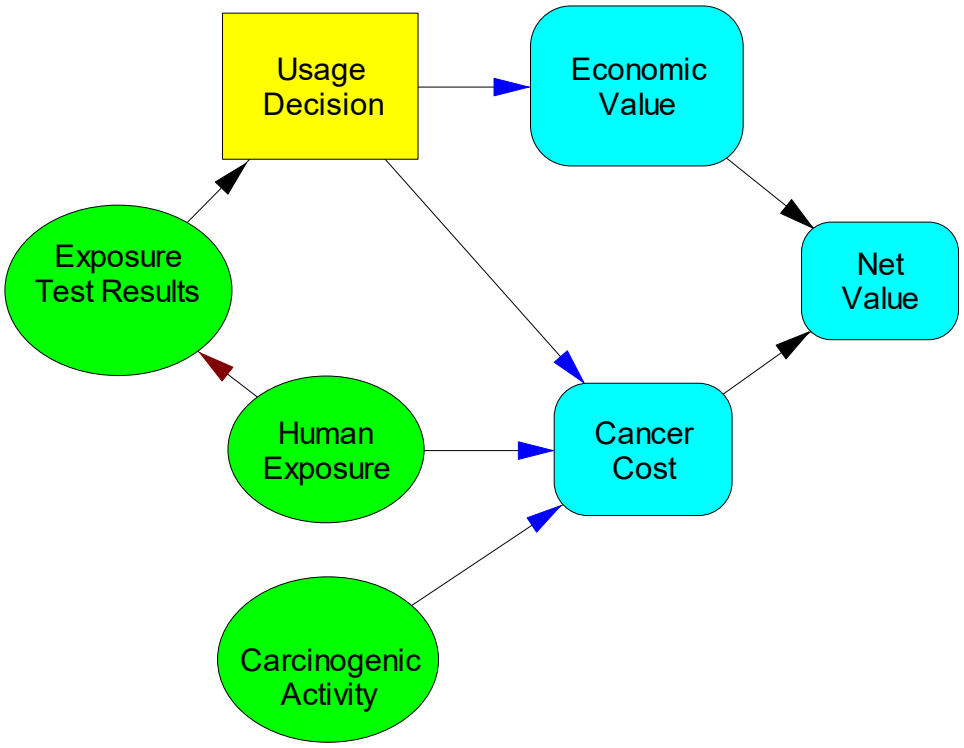
Reliability of Test on Carcinogenic Activity



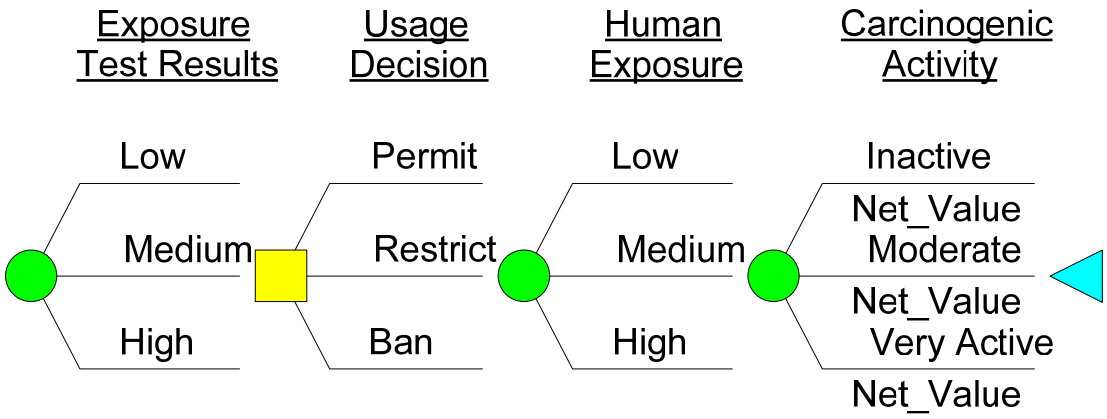
Reliability of Test on Human Exposure



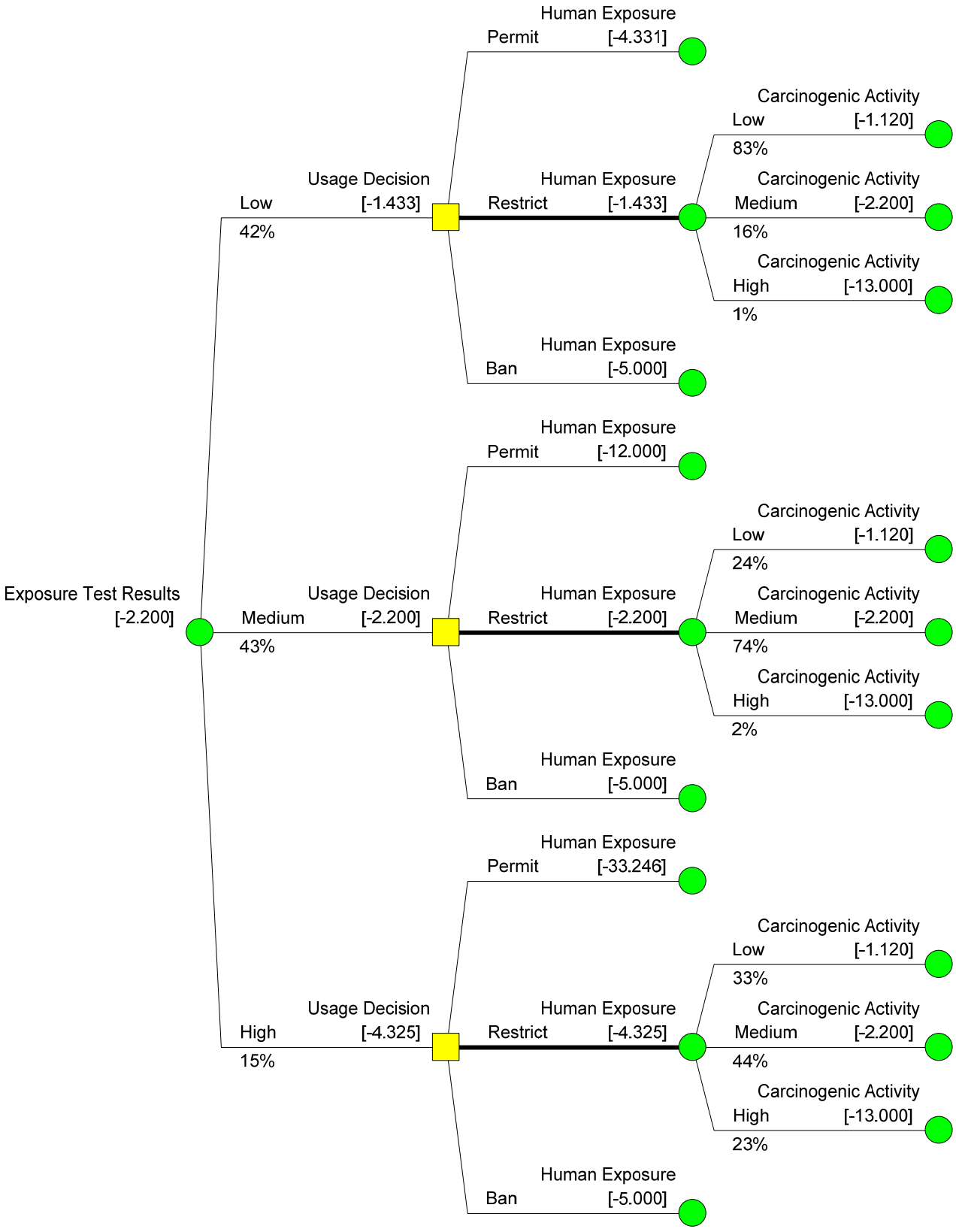
EVSI of Test on Carcinogenic Activity = -1.96M + 2.2M = $0.24M



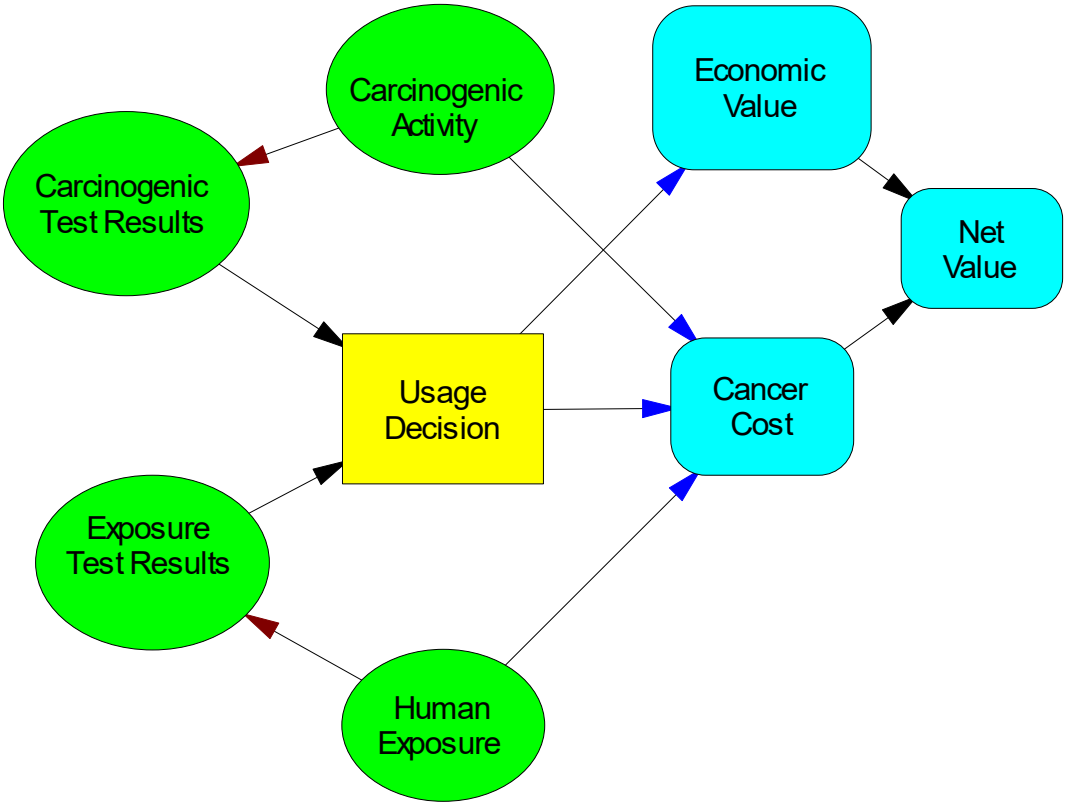
Influence Diagram for Expected Value of Sampled Information (EVSI)
of Test for Human Exposure



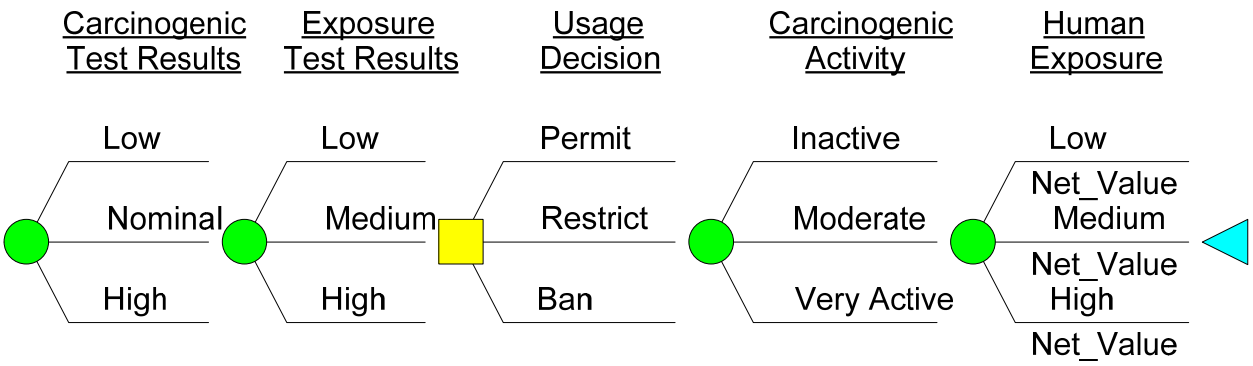
Generic Decision Tree for Expected Value of Sampled Information (EVSI)
of Test for Human Exposure
(Sequence of Chance Nodes, i.e., Human Exposure and Carcinogenic Activity, can be reversed.)



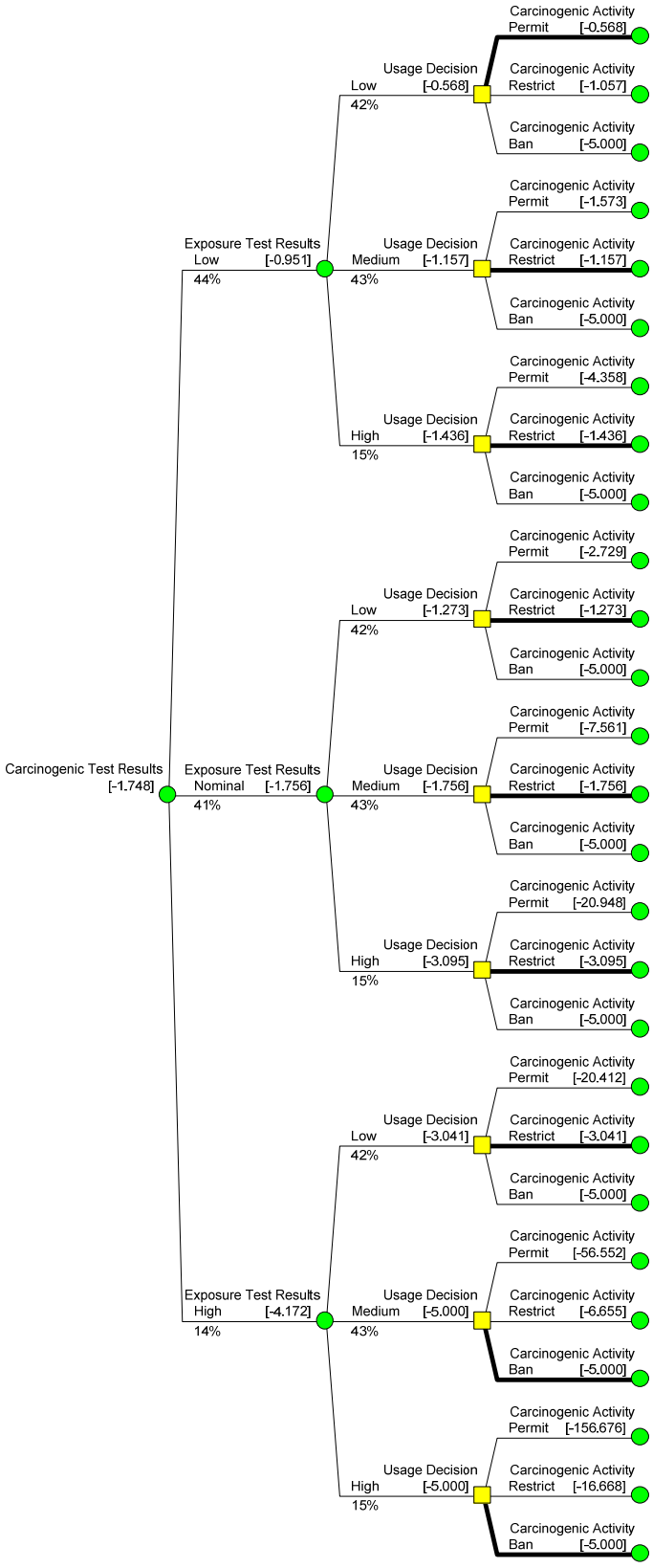
EVSI of Test on Human Exposure = -2.2M + 2.2M = $0M



Influence Diagram for Expected Value of Sampled Information (EVSI)
of both the Test for Carcinogenic Activity and the Test for Human Exposure

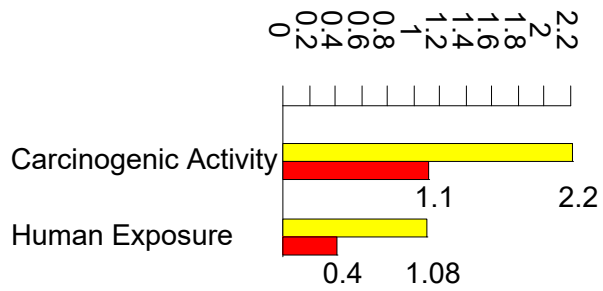
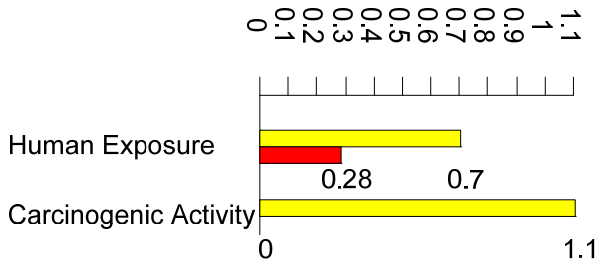
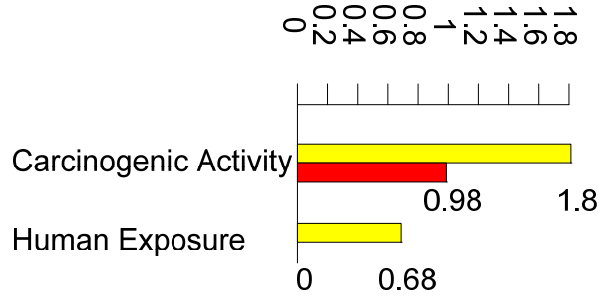


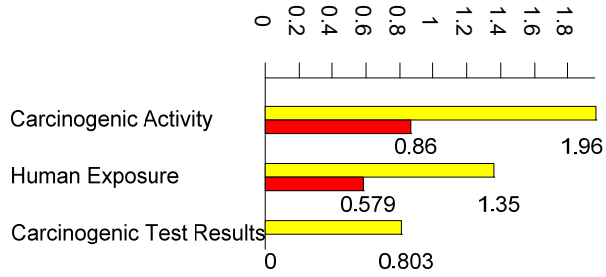
Generic Decision Tree for Expected Value of Sampled Information (EVSI)
of both the Test for Carcinogenic Activity and the Test for Human Exposure
(The order of Test Results can be reversed. The order of Chance Nodes can be reversed, too.)



EVSI of Tests on Carcinogenic Activity and Human Exposure = -1.748M + 2.2M = $0.452M

Value of Information/EVPI (red) and Control (yellow)
Calculated Automatically by DPL

 DPL EVPI: From Basic Decision Tree	EVPI about Carcinogenic Activity = \$1.1M EVPI about Human Exposure = \$0.4M These DPL_EVPI are the same as those calculated using dedicated decision trees (see above). Decision trees, however, also provide optimal policies for each of clairvoyant's predictions.
 DPL EVPI: From Decision Tree used to calculate the EVPI on Carcinogenic Activity (➔EVPI(C) = \$1.1M)	DPL EVPI on Carcinogenic Activity is 0 (Because in this decision tree the Usage Decision is made <u>after</u> the true outcome of Carcinogenic Activity is known.) EVPI on Human Exposure = \$0.28M<0.4M (Clairvoyance on Human Exposure is less valuable if we already have perfect information on Carcinogenic Activity.) ➔ EVPI for both Carcinogenic Activity and Human Exposure = 1.1M+0.28M = \$1.38M Matches the EVPI explicitly calculated using dedicated decision tree above.
 DPL EVPI: From Decision Tree used to calculate the EVPI on Human Exposure (➔EVPI(E) = \$0.4M)	DPL EVPI on Human Exposure is 0 (Because in this tree the Usage Decision is <u>after</u> the true Human Exposure is known.). EVPI on Carcinogenic Act/y = \$0.98M<1.1M (Clairvoyance on Carcinogenic Activity is less valuable if we already have perfect information on Human Exposure.) ➔ EVPI for both Carcinogenic Activity and Human Exposure = \$0.4M+0.98M = \$1.38M Matches the EVPI explicitly calculated using dedicated decision tree above.

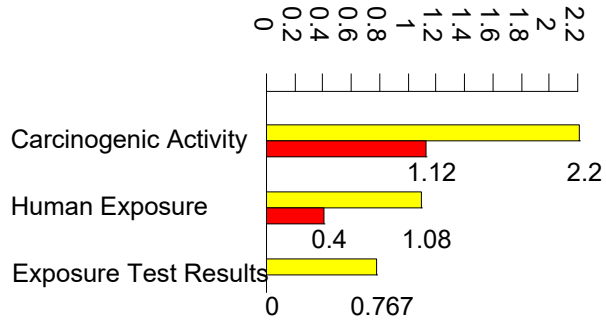


DPL EVPI: From Decision Tree for the EVSI about Carcinogenic Activity (EVSI = $0.24M)

Carcinogenic Activity Test Results reduce the EVPI about the true Carcinogenic Activity:
DPL_EVPI(C) = 0.86M < $1.1M

Info about Carcinogenic Activity
EVSI(C) + DPL_EVPI(C) =
$0.24M + 0.86M = $1.1M =Original EVPI(C)

EVPI about Human Exposure
EVPI(E) = $0.58M>0.4M!!
The information provided by the Carcinogenic Activity Test Results increases the value of perfect information (clairvoyance) on Human Exposure!
EVSI(C)+EVPI(E)=$0.24M+0.58M=$0.82M

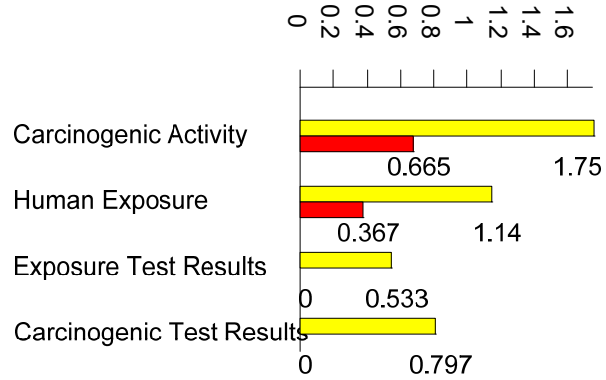


DPL EVPI: From Decision Tree for the EVSI about Human Exposure (EVSI = $0)

The Human Exposure Test Results have no value because the best decision alternative is the same for all possible test outcomes.

Info about Human Exposure
DPL_EVPI about Human Exposure = $0.4M
EVSI(E) + DPL_EVPI(E) =
$0 + 0.4M = $0.4M = Original EVPI(E)

EVPI about Carcinogenic Activity
DPL_EVPI(C) = $1.12M > 1.1M!!
Even though the Human Exposure Test has no value by itself, it does increase the EVPI about Carcinogenic Activity a little ($0.02M)!



DPL EVPI: From the Decision Tree for the EVSI on both Tests for Carcinogenic Activity and for Human Exposure (EVSI = $0.452)

EVSI of both tests > sum of individual EVSI's
$0.452 > $0.24M + $0

EVPI about Carcinogenic Activity
DPL_EVPI(C) = $0.665M
EVSI(B)+EVPI(C)=0.452M+0.665M=1.12M
Same as above.

EVPI about Human Exposure
DPL_EVPI(E) = $0.367M.
EVSI(B)+EVPI(E)=0.452M+0.367M=0.82M
Same as above.

PERFECT INFORMATION SUMMARY (EVPI)

Joint Perfect Information Value with = -0.82 Value of = +1.38 **Joint Decision Rule ↘**			Exposure Perfect Information Value with = -1.8 Value of = +0.40 *Decision Rule* ***Low***	***Medium***	***High***
			Restrict	*Restrict*	*Ban*
Carcinogenic Perfect Information Value with = -1.10 Value of = +1.10 *Decision Rule*	***Inactive***	*Permit*	**Permit**	**Permit**	**Permit**
	Moderately Active	*Restrict*	**Permit**	**Restrict**	**Ban**
	Very Active	*Ban*	**Restrict**	**Ban**	**Ban**

TEST (IMPERFECT) INFORMATION SUMMARY (EVSI)

Joint Test Information Value with = -1.748 Value of = +0.452 **Joint Decision Rule ↘**			Exposure Test Information Value with = -2.2 Value of = 0 *Decision Rule* ***Low***	***Medium***	***High***
			Restrict	*Restrict*	*Restrict*
Carcinogenic Test Information Value with = -1.96 Value of = +0.24 *Decision Rule*	***Low***	*Restrict*	**Permit**	**Restrict**	**Restrict**
	Nominal	*Restrict*	**Restrict**	**Restrict**	**Restrict**
	High	*Ban*	**Restrict**	**Ban**	**Ban**